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The significance of adding posterior decompression to spine stabilization in metastatic spinal surgery: a multicenter prospective study

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The usefulness of spine stabilization for treating metastatic spinal tumors with tumor-induced instability has been reported. However, no reports have prospectively evaluated the effectiveness of adding posterior decompression to stabilization surgery for improving symptoms. This multicenter prospective study aimed to determine whether adding posterior decompression to spine stabilization surgery for metastatic spinal tumors affects postoperative outcomes and complications. A total of 263 patients who underwent spine stabilization with (n = 189) or without (n = 74) decompression were analyzed. Patient demographics, the Spinal Instability Neoplastic Score (SINS), and the Epidural Spinal Cord Compression (ESCC) score were recorded. The outcomes were assessed preoperatively and at 1 and 6 months postoperatively in terms of neurological status, the Barthel Index, the EQ-5D-5 L, and the visual analog scale (VAS). Decompression was primarily performed in patients with severe neurological deficits and high-grade ESCC. Both groups showed postoperative improvement. Propensity score matching was applied to adjust for baseline differences. After matching, there were no significant differences in functional improvement between the decompression and nondecompression groups, and the complication rates were comparable. In matched patients presenting primarily with spinal instability and pain, the addition of decompression did not appear to confer a significant functional benefit within 6 months postoperatively.

Keywords Metastatic spinal tumors, Spine stabilization, Decompression, Propensity score matching, Multicenter prospective study, The epidural spinal cord compression (ESCC) score

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Metastatic lesions in the spine commonly develop in advanced-stage cancer and have a substantial impact on patient morbidity and mortality[1]. As metastatic spinal tumors become more prevalent in the aging population, managing these cases is increasingly complex and therefore calls for a multidisciplinary approach[2]. Owing to advancements in medical technology, surgical intervention has become increasingly viable[3,4].

The efficacy of nerve decompression and postoperative radiotherapy for patients with metastatic spinal tumors and neurological symptoms has been reported[5]. On the other hand, the usefulness of spinal stabilization surgery for pain and neurological symptoms caused by instability due to tumor invasion into the spine has also been reported[6–8]. Adding posterior decompression to spinal stabilization surgery may improve neurological symptoms[9]but if the tumor extends to the decompression site, it could lead to increased bleeding and prolonged surgery time. There have been no prospective studies comparing the postoperative results of spine stabilization surgery with and without decompression in patients with metastatic spinal tumors. This study aimed to prospectively investigate whether the addition of posterior decompression to spinal stabilization surgery for patients with metastatic spinal tumors affects postoperative outcomes and complications.

Results

Patient characteristics

The mean age was 66.6 years, with 170 males. A total of 111 patients were classified as Frankel A, B, or C, and 200 patients had grade 2 or 3 ESCC. Spine stabilization with decompression was performed on 189 patients, and no decompression was performed on 74 patients. When the spine stabilization with decompression group was compared with the spine stabilization without decompression group, the stabilization with decompression group presented significantly higher rates of severe neurological symptoms and severe dural compression by tumors (ESCC 2, 3: 167 cases, 88.4% vs. 33 cases, 44.6%, $P < 0.0001$; Frankel A, B, C: 100 cases, 52.9% vs. 11 cases, 14.9%, $P < 0.0001$; emergency surgery: 108 cases, 57.1% vs. 16 cases, 21.6%, $P < 0.0001$) (Table 1). The spine stabilization with decompression group had longer operation times (216.9 min vs. 163.8 min, $P < 0.0001$), and greater blood loss (416.3 g vs. 205.2 g, $P < 0.0001$).

Comparison of postoperative outcomes (before matching)

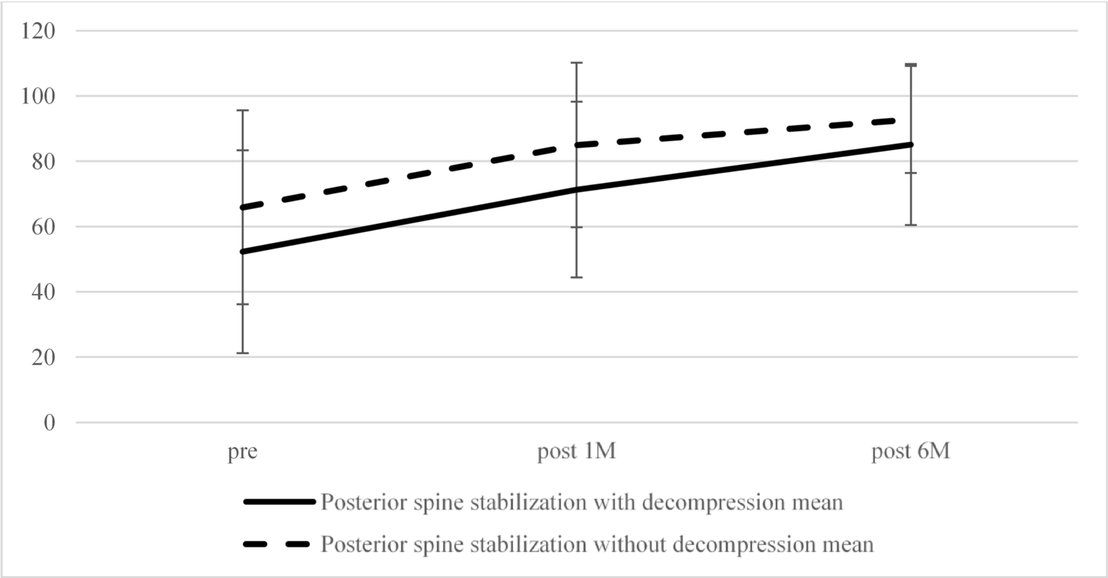
The preoperative Barthel index and EQ-5D-5 L score were lower in the decompression and stabilization group (52.3 vs. 65.9: $P < 0.005$, 0.31 vs. 0.40: $P < 0.05$) (Fig. 1). At one month postoperatively, the Barthel index differed

	Total, $N=263$	Posterior spine stabilization with decompression ($N=189$)	Posterior spine stabilization without decompression ($N=74$)	*P*
Age	66.6 (11.1)	67.1 (10.9)	65.3 (11.3)	0.26
Male n (%)	170 (64.6%)	124 (65.6%)	46 (62.2%)	0.67
Breast Ca n (%)	36 (13.7%)	26 (13.8%)	10 (13.5%)	0.99
Lung Ca n (%)	55 (20.9%)	39 (20.6%)	16 (21.6%)	0.87
Prostate Ca n (%)	30 (11.4%)	26 (13.8%)	4 (5.4%)	0.08
Kidney Ca n (%)	**31 (11.8%)**	**17 (9.0%)**	**14 (18.9%)**	**<0.05**
ESCC 0 n (%)	**11 (4.2%)**	**3 (1.6%)**	**8 (10.8%)**	**< 0.0001**
ESCC 1a-c n (%)	**52 (19.8%)**	**19 (10.1%)**	**33 (44.6%)**	
ESCC2 n (%)	**86 (32.7%)**	**63 (33.3%)**	**23 (31.1%)**	
ESCC3 n (%)	**114 (43.3%)**	**104 (55.0%)**	**10 (13.5%)**	
ESCC ≥ 2 n (%)	**200 (76.0%)**	**167 (88.4%)**	**33 (44.6%)**	
Height (cm)	161 (9.5)	161.3 (9.5)	161.4 (9.7)	0.87
Weight (kg)	57.7 (12.9)	57.7 (12.4)	57.7 (14.2)	0.81
Frankel A n (%)	**10 (3.8%)**	**8 (4.2%)**	**2 (2.7%)**	**< 0.0001**
Frankel B n (%)	**13 (4.9%)**	**11 (5.8%)**	**2 (2.7%)**	
Frankel C n (%)	**88 (33.5%)**	**81 (42.9%)**	**7 (9.5%)**	
Frankel D n (%)	**67 (25.5%)**	**51 (27.0%)**	**16 (21.6%)**	
Frankel E n (%)	**85 (32.3%)**	**38 (20.1%)**	**47 (63.5%)**	
PS 3,4 n (%)	159 (60.5%)	121 (64.0%)	38 (51.4%)	0.07
Pre chemotherapy n (%)	95 (36.1%)	65 (34.4%)	30 (40.5%)	0.39
Post chemotherapy n (%)	149 (56.7%)	112 (59.3%)	37 (50.0%)	0.21
Pre radiation n (%)	72 (27.4%)	46 (24.3%)	26 (35.1%)	0.09
Post radiation n (%)	124 (47.1%)	86 (45.5%)	38 (51.4%)	0.41
Pre Molecular Targeted Therapy n (%)	42 (16.0%)	31 (16.4%)	11 (14.9%)	0.85
Post Molecular Targeted Therapy n (%)	68 (25.9%)	43 (22.8%)	25 (33.8%)	0.08
Pre bone therapy n (%)	**62 (23.6%)**	**37 (19.6%)**	**25 (33.8%)**	**< 0.05**
Post bone therapy n (%)	146 (55.5%)	98 (51.9%)	48 (64.9%)	0.07
Pre opioid n (%)	**95 (36.1%)**	**61 (32.3%)**	**34 (46.0%)**	**< 0.05**
Post opioid n (%)	113 (43.0%)	75 (39.7%)	38 (51.4%)	0.10
Tomita score	5.6 (2.4)	5.6 (2.4)	5.7 (2.5)	0.67
Revised Tokuhashi score	7.9 (3.1)	7.7 (3.1)	8.4 (3.1)	0.12
SINS	10.5 (3.0)	10.3 (3.1)	11.1 (2.6)	0.08
Charlson's comorbidity index	6.6 (1.4)	6.7 (1.5)	6.4 (1.2)	0.09
Cervical n (%)	39 (14.8%)	23 (12.2%)	16 (21.6%)	0.08
CT/T n (%)	160 (60.8%)	**126 (66.7%)**	**34 (46.0%)**	**< 0.01**
TL/L/S n (%)	65 (24.7%)	41 (21.7%)	24 (32.4%)	0.08
Emergency n (%)	**124 (47.1%)**	**108 (57.1%)**	**16 (21.6%)**	**< 0.0001**
Operation time (min)	**202.0 (77.1)**	**216.9 (75.5)**	**163.8 (67.8)**	**< 0.0001**
Blood loss (g)	**357.3 (362.8)**	**416.3 (388.6)**	**205.2 (225.1)**	**< 0.0001**
Complications during surgery n (%)	**12 (4.6%)**	**12 (6.4%)**	**0 (0%)**	**< 0.05**
Perioperative Complications n (%)	43 (16.3%)	33 (17.6%)	10 (13.5%)	0.47
Reoperation n (%)	18 (6.9%)	14 (7.4%)	4 (5.6%)	0.79
Death n (%)	92 (35.0%)	63 (33.3%)	29 (39.2%)	0.39
survival days after operation (days)	292.6 (199.0)	294.9 (204.7)	286.6 (185.1)	0.87

Table 1. Demographic details ($N=263$). Mean (standard deviation) N (%). The bold values indicate statistically significant differences ($p<0.05$).

between the groups (71.3 vs. 85.0: $P<0.0001$), and there was a significant difference at six months (85.1 vs. 92.8, $P<0.05$). The trend of the Eq. 5D5L score was also similar to that of the Barthel index. Both indices significantly improved clinical symptoms postoperatively compared with preoperatively. A paired t test was performed on the Barthel index, Eq. 5D5L, VAS, and face scale, and significant improvements were observed in each parameter from before surgery to 1 month and 6 months after surgery (Supplementary Table 1). The degree of improvement, assessed by the change in the Barthel index, EQ-5D-5 L score, VAS score and face scale score from the preoperative value to the postoperative value (Δ), was not significantly different between the

a) Barthel Index



	Barthel index (pre)	Barthel index (1 M)	Barthel index (6 M)
Posterior spine stabilization with decompression	52.3 (31.1)	71.3 (26.9)	85.1 (24.7)
Posterior spine stabilization without decompression	65.9 (29.7)	85.0 (25.2)	92.8 (16.4)
P	<0.005	<0.0001	<0.05

Fig. 1. Changes in the Barthel index (**a**), Eq5D5L (**b**),visual analog scale (**c**), and face scale (**d**) scores of the participants before propensity score matching at baseline. Two-group (i.e., decompression and without decompression) comparisons were made via the Wilcoxon test. The EQ-5D-5 L score and Barthel index were significantly lower in the spinal stabilization with decompression group than in the preoperative period and at 1 month after surgery. (**a,b**) In addition, while the symptoms of pain and numbness were more severe in the spinal stabilization with decompression group at 1 month after surgery, there was no difference between the two groups at 6 months after surgery. (**c,d**) The data are the means (SDs).

groups at one month and six months postoperatively (Table 2). A subgroup analysis was performed to compare functional outcomes between patients with and without severe preoperative neurological symptoms (ESCC 2–3 and/or Frankel A–C). Although the severe group had a significantly lower preoperative functional status, both groups exhibited comparable degrees of improvement at 6 months postoperatively (Supplementary Table 2). Intraoperative complications were significantly more common in the decompression and stabilization group (12 patients, 6.4%) than in the stabilization-only group (0 patients, 0%), whereas perioperative complications occurred in 33 patients (17.6%) and 10 patients (13.5%), respectively, with no significant difference (Table 1).

Intraoperative and perioperative complications were categorized by type and Clavien–Dindo grade[10] (Supplementary Table 3). Most complications were low-grade and manageable, with no intraoperative events in the nondecompression group. There was no difference between the two groups in the amount of change in each parameter before and after surgery, but the Barthel index, EQ-5D-5 L score at baseline, was lower in the decompression group. The Kaplan–Meier survival curves revealed no significant difference in overall survival between the decompression and nondecompression groups (Log-rank test, $P = 0.41$) (Supplementary Fig. 1).

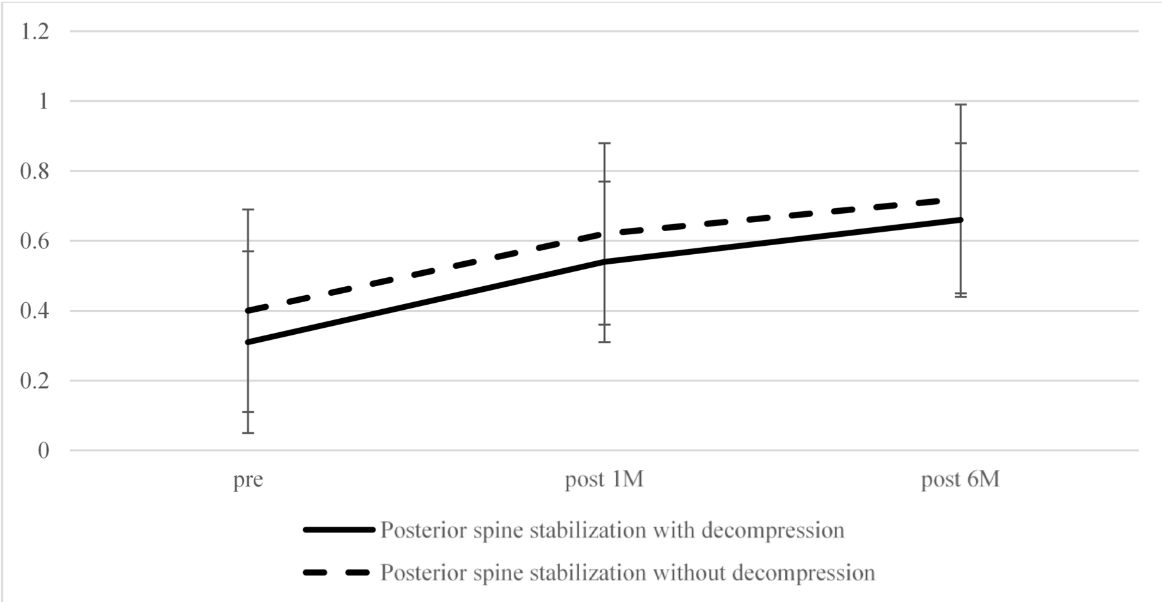
Factors that lead to the choice of spinal fusion with decompression

Multivariate logistic regression analyses revealed that the factors for selected spine stabilization with decompression were ESCC (odds ratio 2.9 $P < 0.0001$), Frankel A, B, and C (odds ratio 2.7 $P < 0.005$) (Table 3).

Comparison of postoperative outcomes (after matching)

Using propensity score matching, we divided the patients into two groups: 51 patients in the spinal decompression and fusion group and 51 patients in the spinal fusion group (Table 4).

b) EQ-5D-5L



	EQ5D5L (pre)	EQ5D5L (1 M)	EQ5D5L (6 M)
Posterior spine stabilization with decompression	0.31 (0.26)	0.54 (0.23)	0.66 (0.22)
Posterior spine stabilization without decompression	0.40 (0.29)	0.62 (0.26)	0.72 (0.27)
P	<0.05	<0.05	0.05

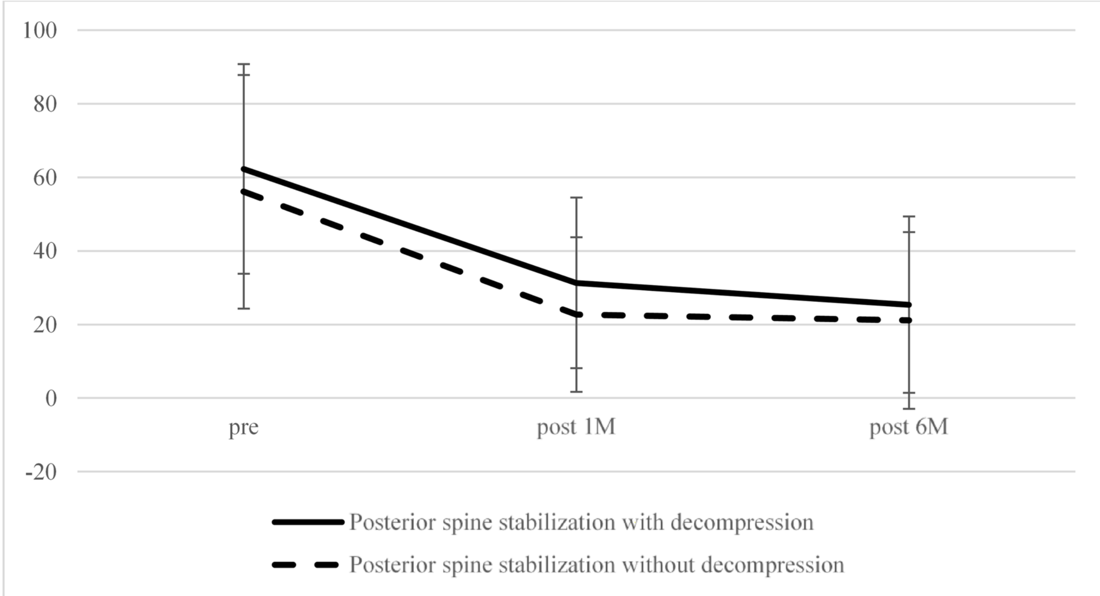
Fig. 1. (continued)

After matching, the spine stabilization with decompression group had longer operation times (229.8 min vs. 164.6 min, $P<0.0001$) and greater blood loss (453.8 g vs. 198.3 g, $P<0.0001$) (Table 4). The number of patients with intraoperative complications was 3 (5.9%) vs. 0 (0%), and the number of patients with perioperative complications was 9 (18.0%) vs. 5 (9.8%), with no significant difference between the groups (Table 4). When the postoperative results did not differ between the two groups in terms of the preoperative state, there were no significant differences in the Barthel index, EQ-5D-5 L score, or preoperative performance status at 1 and 6 months postoperatively (Fig. 2). The comparison between the two groups, with and without decompression, revealed the following mean changes from the preoperative period:

One month postoperatively, the mean change in the Barthel Index was 13.2 in the decompression group and 15.5 in the nondecompression group ($P=0.25$). The change in EQ-5D-5 L was 0.19 vs. 0.18 ($P=0.87$), that in VAS (visual analog scale) was 28.0 vs. 28.0 ($P=0.88$), and that in the face scale was 2.8 vs. 2.2 ($P=0.54$). At 6 months postsurgery, the mean change in the Barthel Index was 17.6 vs. 15.6 ($P=0.92$), that in the EQ-5D-5 L was 0.24 vs. 0.22 ($P=0.80$), that in the VAS was 45.4 vs. 32.8 ($P=0.33$), and that in the Face Scale was 3.5 vs. 3.0 ($P=0.86$).

These results indicate that there were no statistically significant differences in postoperative changes between the two groups at either 1 month or 6 months (Table 5).

c) VAS



	VAS (pre)	VAS (1 M)	VAS (6 M)
Posterior spine stabilization with decompression	62.3 (28.5)	31.3 (23.2)	25.4 (24.0)
Posterior spine stabilization without decompression	56.1 (31.8)	22.7 (21.0)	21.1 (24.0)
P	0.21	<0.01	0.24

Fig. 1. (continued)

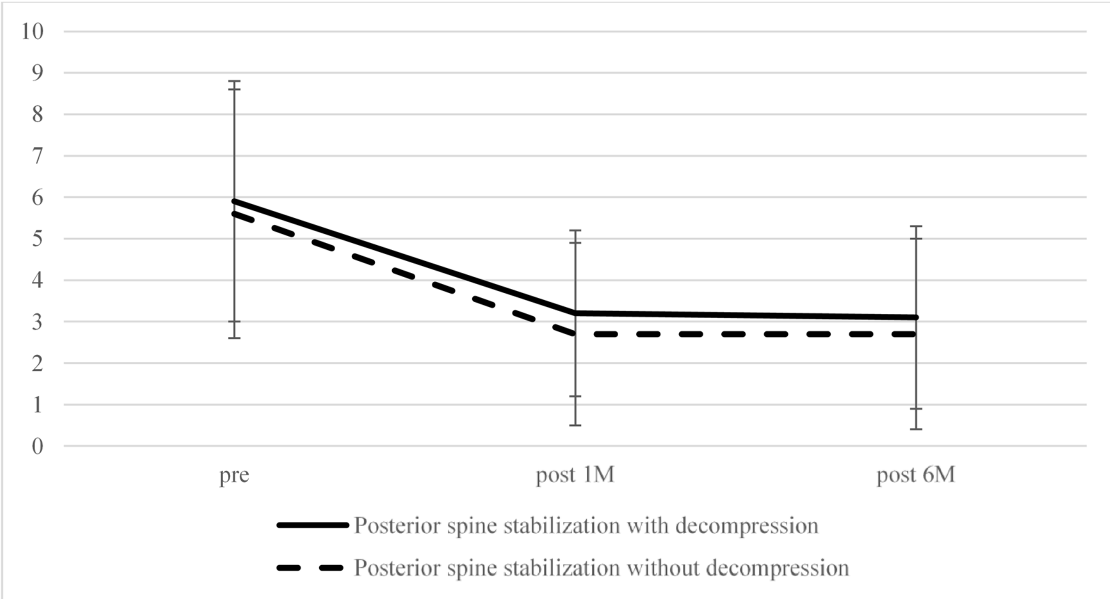
Discussion

It is unclear whether decompression should be added to spine stabilization surgery for the treatment of metastatic spinal tumors. This is the first report to be analyzed via a multicenter prospective study. Spinal decompression has been reported to be useful in the treatment of metastatic tumors[11]. On the other hand, spine stabilization surgery is a beneficial intervention for patients with metastatic spinal tumors and instability, offering significant pain relief, improved stability, and enhanced quality of life[12]. The Spinal Instability Neoplastic Score (SINS) is a method of evaluating spinal instability caused by metastatic or primary spinal tumors, and when a score of 7 indicates suspected instability, spinal fixation surgery is often considered[13].

Spinal instrumented fusion with decompression was effective in more severe cases of SINS[14]. In this study, the mean SINS score was 10.5 points, and many of the cases involved spinal instability. In cases where spinal instability is accompanied by a tumor that compresses the dural tube, spinal decompression and stabilization are often performed as effective treatments[9,15–20]. However, few reports have considered whether decompression should be added to spine stabilization surgery. While the study does not directly compare spine stabilization with and without decompression, it highlights the benefits of minimally invasive techniques over conventional open surgery in terms of complications, blood loss, and hospital stay for patients with spinal metastases[21]. MISt without decompression has been reported to be advantageous for patients with mild paralysis, but decompression is necessary for patients with severe paralysis[22].

The epidural spinal cord compression (ESCC) score is a scale that indicates the need for early treatment intervention in cases where there is spinal cord compression at scale 2 or 3 and paralysis is acutely worsening[23,24]. In this study, there was a tendency to add decompression in cases where the ESCC score was high. Both spine stabilization with decompression and without decompression surgery improved ADL, QOL, pain, and numbness more than before surgery did at 1 month and 6 months after surgery. Both procedures are helpful in patients with metastatic spinal tumors. There was no significant difference in postoperative improvement between spine

d) Face scale



	Face scale (pre)	Face scale (1 M)	Face scale (6 M)
Posterior spine stabilization with decompression	5.9 (2.9)	3.2 (2.0)	3.1 (2.2)
Posterior spine stabilization without decompression	5.6 (3.0)	2.7 (2.2)	2.7 (2.3)
P	0.43	0.08	0.2

Two-group comparisons were performed via the Wilcoxon test at three time points: preoperative, 1 month postoperative, and 6 months postoperative.

Mean (standard deviation)

Fig. 1. (continued)

	Total, *N* = 263	Posterior spine stabilization with decompression (*N* = 189)	Posterior spine stabilization without decompression (*N* = 74)	*P*
ΔBarthel Index	at 1month postoperatively	16.3 (23.8)	17.0 (25.5)	0.58
	at 6 months postoperatively	26.2 (30.7)	19.1 (26.0)	0.24
ΔEQ-5D-5 L	at 1month postoperatively	0.23 (0.23)	0.21 (0.26)	0.71
	at 6 months postoperatively	0.33 (0.26)	0.29 (0.33)	0.78
ΔVAS	at 1month postoperatively	31.0 (29.6)	31.0 (37.5)	0.79
	at 6 months postoperatively	38.0 (32.7)	36.4 (35.7)	0.95
ΔFace scale	at 1month postoperatively	2.7 (2.9)	2.4 (3.1)	0.65
	at 6 months postoperatively	3.2 (3.1)	3.1 (3.4)	0.96

Table 2. Comparison of preoperative-to-postoperative changes (Δ) between the two groups before propensity score matching. Mean (standard deviation). Two-group comparisons were made via the Wilcoxon test. No statistically significant differences were found for any of the scores.

Factor	Odds ratio	95%CI	*P*
ESCC	**2.9**	**2.0-4.5**	**< 0.0001**
Frankel A, B,C	**2.7**	**1.2–6.2**	**< 0.05**
Emergency	2.0	0.96–4.2	0.07
Age	1.0	0.98-1.0	0.85
Male	1.0	0.52–1.98	0.94

Table 3. Factors for which posterior decompression fixation is selected. The bold values indicate statistically significant differences ($p<0.05$).

stabilization with and without decompression. However, it is possible that in patients in whom the preoperative condition of patients with spinal decompression and stabilization was lower in terms of ADL and quality of life, the preoperative background was not consistent and the neurological symptoms were strong, so the addition of spinal decompression may not have made a difference in postoperative improvement.

Uei et al.[22] reported that there was no difference in outcome between spinal stabilization with and without decompression in patients with mild neurological symptoms, but this was a single-center retrospective study and did not match the preoperative background. Therefore, we performed propensity score matching on the basis of the ESCC scale at to match the preoperative background. A comparison of the two groups with matched preoperative data revealed that the Barthel index, Eq. 5D5L score, VAS score and face scale score were superior to the preoperative values. There was no significant difference in the degree of improvement between the two groups. There may be little significance in adding decompression to spinal fusion in patients with metastatic spinal tumors.

On the other hand, there are many postoperative complications, and the surgical indications need to be carefully determined according to the patient's general condition[25].

In this study, the operation time and amount of blood loss were greater for patients who underwent decompression and stabilization than for those who did not undergo decompression, but there was no significant difference in intraoperative or perioperative complications. These results were similar to those reported previously[23].

There are several limitations in this study. First, despite data being collected in a forward-looking manner, biases may persist due to incomplete records or missing information. Second, this was a multicenter study and not a randomized study. There are differences in the surgical indications between surgeons. Finally, in the postmatching review, many of the patients were Frankels D and E, and few patients had severe preoperative neurological conditions.

Despite these limitations, this sizeable prospective study allowed an assessment of the current surgical selection practices for spinal metastases in Japan, providing valuable insights and some guidance for managing these patients. On the basis of these results, in cases where tumor-rich blood vessels are expected to result in significant bleeding during resection[26,27]decompression may not be necessary if neurological symptoms are mild.

Conclusions

Spine stabilization with decompression was selected in patients with severe preoperative neurological symptoms and high ESCC. There was no significant difference in clinical symptoms before and after surgery between the two groups. There was no advantage of adding decompression in patients with spinal instability at least 6 months after surgery. Despite severe spinal canal stenosis, patients with only mild neurological symptoms may achieve improvement with stabilization alone, without the need for posterior decompression.

Methods

Study design and population

The Japan Association of Spine Surgeons with Ambition (JASA) conducted this multicenter prospective cohort study between October 2018 and March 2022. Patients scheduled for surgical treatment of metastatic spinal tumors, those aged ≥ 20 years, and those who provided consent to participate were included. Those aged < 20 years and those with difficulty completing the questionnaire were excluded. Patients who consented to this study and underwent surgical treatment for metastatic spinal tumors were included. A total of 413 patients from 35 facilities were registered, and 263 patients with complete data who underwent spinal stabilization with decompression and without decompression were analyzed. We compared the postoperative outcomes between the two groups. We also examined the factors that led to the selection of spinal fusion with decompression using multivariate logistic regression analysis. We again compared the postoperative outcomes between the two groups after the preoperative conditions were matched via propensity score matching.

Ethical considerations

This research protocol was approved by the ethics committee on clinical research of Kagoshima University (approval no. 180080). All participants provided written informed consent, and the study was conducted in accordance with the Declaration of Helsinki. The submitted manuscript does not contain any information about medical devices or drugs.

	Total, $N = 102$	Posterior spine stabilization with decompression ($N = 51$)	Posterior spine stabilization without decompression ($N = 51$)	*P*
Age	66.7 (11.0)	66.2 (10.9)	67.4 (9.0)	0.69
Male n (%)	70 (68.6%)	36 (70.6%)	34 (66.7%)	0.83
Breast Ca n (%)	9 (8.8%)	4 (7.8%)	5 (9.8%)	0.99
Lung Ca n (%)	26 (25.5%)	15 (29.4%)	11 (21.6%)	0.50
Prostate Ca n (%)	9 (8.8%)	6 (11.8%)	3 (5.9%)	0.49
Kidney Ca n (%)	17 (16.7%)	7 (13.7%)	10 (19.6%)	0.60
ESCC 0 n (%)	4 (3.9%)	2 (3.9%)	2 (3.9%)	0.86
ESCC 1a-c n (%)	33 (32.4%)	15 (29.4%)	18 (35.3%)	
ESCC2 n (%)	47 (46.1%)	26 (51.0%)	21 (41.2%)	
ESCC3 n (%)	18 (17.7%)	8 (15.7%)	10 (19.6%)	
Height (cm)	161.4 (9.5)	162.0 (8.8)	161.6 (9.5)	0.67
Weight (kg)	57.7 (13.0)	58.6 (14.3)	57.5 (15.2)	0.70
Frankel B n (%)	3 (2.9%)	1 (2.0%)	2 (3.9%)	0.54
Frankel C n (%)	15 (14.7%)	8 (15.7%)	7 (13.7%)	
Frankel D n (%)	28 (27.5%)	17 (33.3%)	11 (21.6%)	
Frankel E n (%)	56 (54.9%)	25 (49.0%)	31 (60.8%)	
PS 3,4 n (%)	54 (53.0%)	28 (54.9%)	26 (51.0%)	0.84
Pre chemotherapy n (%)	41 (40.2%)	19 (37.3%)	22 (43.1%)	0.69
Post chemotherapy n (%)	58 (56.9%)	33 (64.7%)	25 (49.0%)	0.16
Pre radiation n (%)	29 (28.4%)	12 (23.5%)	17 (33.3%)	0.38
Post radiation n (%)	51 (50.0%)	25 (49.0%)	26 (51.0%)	0.99
Pre Molecular Targeted Therapy n (%)	26 (25.5%)	17 (33.3%)	9 (17.7%)	0.11
Post Molecular Targeted Therapy n (%)	37 (36.3%)	19 (37.3%)	18 (35.3%)	0.99
Pre bone therapy n (%)	31 (30.4%)	14 (27.5%)	17 (33.3%)	0.66
Post bone therapy n (%)	67 (65.7%)	32 (62.8%)	35 (68.6%)	0.68
Pre opioid n (%)	43 (42.2%)	20 (39.2%)	23 (45.1%)	0.69
Post opioid n (%)	49 (48.0%)	24 (47.1%)	25 (49.0%)	0.99
Tomita score	5.6 (2.4)	5.9 (2.4)	5.8 (2.6)	0.94
Revised Tokuhashi score	7.9 (3.1)	8.0 (3.5)	8.2 (3.2)	0.70
SINS	10.5 (3.0)	10.1 (2.9)	10.6 (2.5)	0.51
CCS	6.6 (1.4)	6.7 (1.0)	6.4 (1.2)	0.88
Cervical n (%)	17 (16.7%)	9 (17.7%)	8 (15.7%)	0.99
CT/T n (%)	58 (56.9%)	30 (58.8%)	28 (54.9%)	0.84
TL/L/S n (%)	28 (27.5%)	13 (25.5%)	15 (29.4%)	0.82
Emergency n (%)	26 (25.5%)	14 (27.5%)	12 (23.5%)	0.82
Operation time (min)	**202.0 (76.9)**	**229.8 (85.4)**	**164.6 (72.6)**	**< 0.0001**
Blood loss (g)	**347.4 (318.4)**	**453.8 (374.0)**	**198.3 (211.6)**	**< 0.0001**
Complications during surgery n (%)	3 (2.9%)	3 (5.9%)	0 (0%)	0.24
Perioperative Complications n (%)	14 (13.9%)	9 (18.0%)	5 (9.8%)	0.26
Reoperation n (%)	4 (4.0%)	2 (3.9%)	2 (3.9%)	0.99
Death n (%)	39 (38.2%)	18 (35.3%)	21 (41.2%)	0.68
survival days after operation (days)	291.2 (199.7)	307.8 (160.3)	273.5 (186.2)	0.29

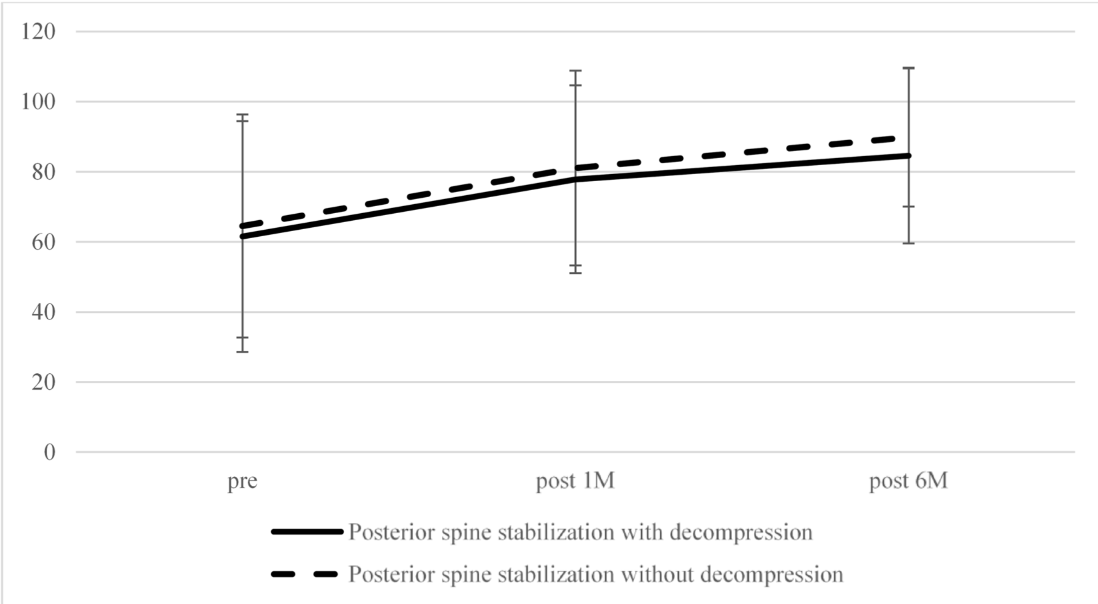
Table 4. Demographic details (propensity score matching; $N = 102$). Mean (standard deviation). The bold values indicate statistically significant differences ($p<0.05$).

Data collection

Data were extracted from the patients' medical records and entered into a standardized database.

Patient backgrounds, such as age, sex, underlying disease, cancer type, cancer treatment, chemotherapy, radiation therapy, molecular targeted therapy, bone modifying agent (BMA) use, and opioid use, were evaluated, along with paralysis and neurological symptoms at surgical intervention, duration from symptom onset, and the Frankel classification. Prognostic scores, e.g., the Tomita score[28]the revised Tokuhashi score[29]and the Spinal Instability Neoplastic score[13]were documented. The Spinal Instability Neoplastic Score (SINS)[13] was used to indicate spinal instability, and the Epidural Spinal Cord Compression (ESCC) score[30] was used to assess tumor compression. Surgical factors such as operation time, blood loss, and intraoperative and postoperative complications were investigated, and outcomes were assessed preoperatively and at one month and six months

a) Barthel Index



	Barthel index (pre)	Barthel index (1 M)	Barthel index (6 M)
Posterior spine stabilization with decompression	61.5 (32.9)	77.8 (26.8)	84.5 (25.0)
Posterior spine stabilization without decompression	64.5 (31.8)	81.0 (27.8)	89.8 (19.8)
P	0.66	0.56	0.22

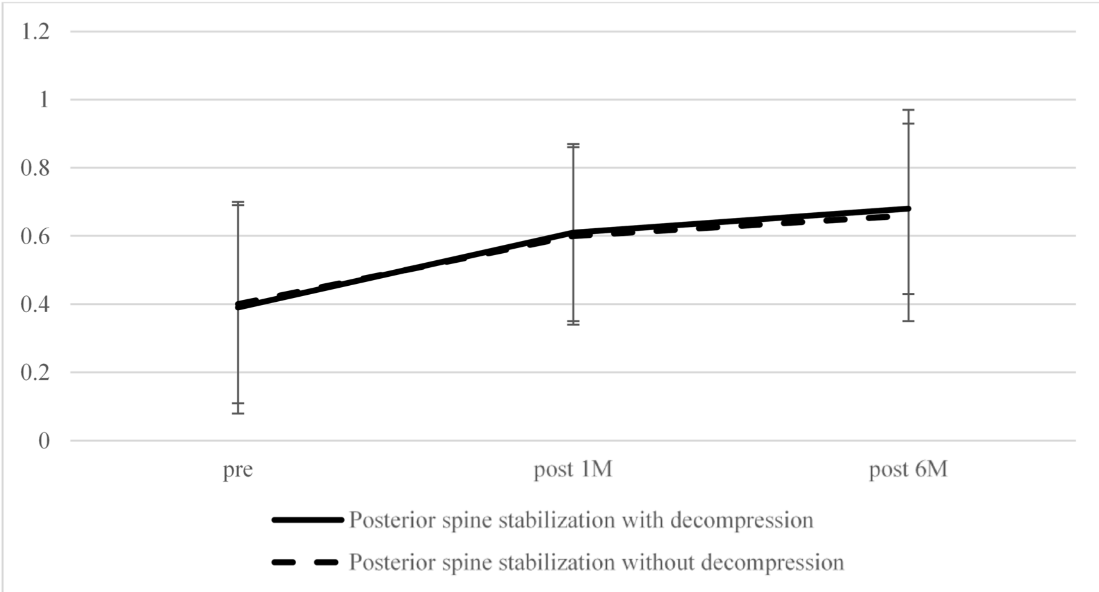
Fig. 2. Changes in the Barthel index **(a)**, Eq5D5L **(b)**, visual analog scale **(c)**, and face scale **(d)** scores of participants after propensity score matching at baseline. When the changes over time were compared, there was no statistically significant difference in the Eq5D5L score, Barthel index, VAS score, or facial scale score between the spine stabilization with decompression and spine stabilization without decompression groups. The data are the means (SDs).

postoperatively using neurological findings, performance status, the Barthel Index, EQ-5D-5 L score, VAS score, and vitality index.

Interventions
Comprehensive records of each intervention were meticulously maintained, capturing the surgical objectives, scheduling, timing of the initial consultation, length of paralysis, and all relevant surgical details, including procedure type, duration, blood loss, and complications.

Outcome measures
The parameters were compared between the two groups: the spine stabilization with decompression group and the spine stabilization without decompression group. The postoperative results were evaluated by assessing the change in each score over time, and the degree of improvement was evaluated by the difference in the score at each time point (e.g., the degree of improvement at 1 month postsurgery was Δ 1 month postsurgery score - presurgery score). After the factors that led to the choice of spine stabilization with decompression were evaluated via multivariate analysis, the preoperative conditions were matched using propensity score matching, and the postoperative results were evaluated again.

b) EQ-5D-5L



	EQ-5D-5L (pre)	EQ-5D-5L (1 M)	EQ-5D-5L (6 M)
Posterior spine stabilization with decompression	0.39 (0.31)	0.61 (0.26)	0.68 (0.25)
Posterior spine stabilization without decompression	0.40 (0.29)	0.60 (0.26)	0.66 (0.31)
P	0.77	0.85	0.82

Fig. 2. (continued)

Grouping and baseline matching

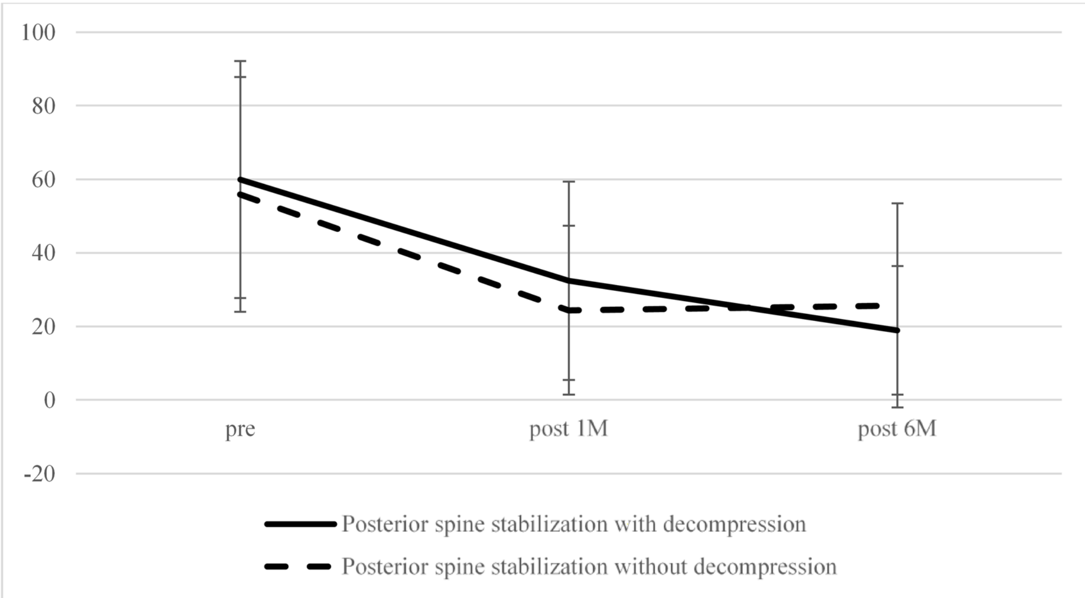
To minimize confounding and selection bias when comparing postoperative outcomes, a propensity score (PS) matching analysis was performed between patients with metastatic spinal tumors who underwent spine stabilization with decompression and those who underwent spine stabilization without decompression. First, logistic regression was employed to estimate each participant's PS for undergoing spine stabilization with decompression. Age, sex, ESCC scale score, Frankel classification, and emergency operation at baseline were included in calculating the PS. PS matching was performed at a 1:1 ratio using the optimal matching technique to minimize the average absolute distance across all matched pairs. A greedy nearest-neighbor matching algorithm with a caliper width of 0.2 standard deviations of the logit of the PS was used. After matching, covariate balance was evaluated via standardized mean differences (SMDs), which were calculated as the difference in means divided by the pooled standard deviation. An SMD of less than 0.1 was considered indicative of adequate balance (Supplementary Table 4).

Statistical analysis

The data were analyzed using Wilcoxon and Fisher's exact tests to compare the two groups.

Continuous variables are expressed as the mean (standard deviation). Categorical variables are expressed as the number of participants and proportions (percentages). To evaluate the postoperative results, we evaluated the parameters before surgery, one month after surgery, and six months after surgery using a paired t tests. Finally, we used multivariate logistic regression analysis to identify the factors that led to the choice of spinal fusion surgery. After the preoperative conditions were matched via propensity score matching, we compared the surgical outcomes between the two groups. P values less than 0.05 were considered to indicate statistical significance. Kaplan–Meier survival analysis was conducted to compare overall survival between the decompression and nondecompression groups. The log-rank test was used to assess statistical significance. JMP software was used for the statistical analyses (version 18, SAS Institute, Cary, NC, USA).

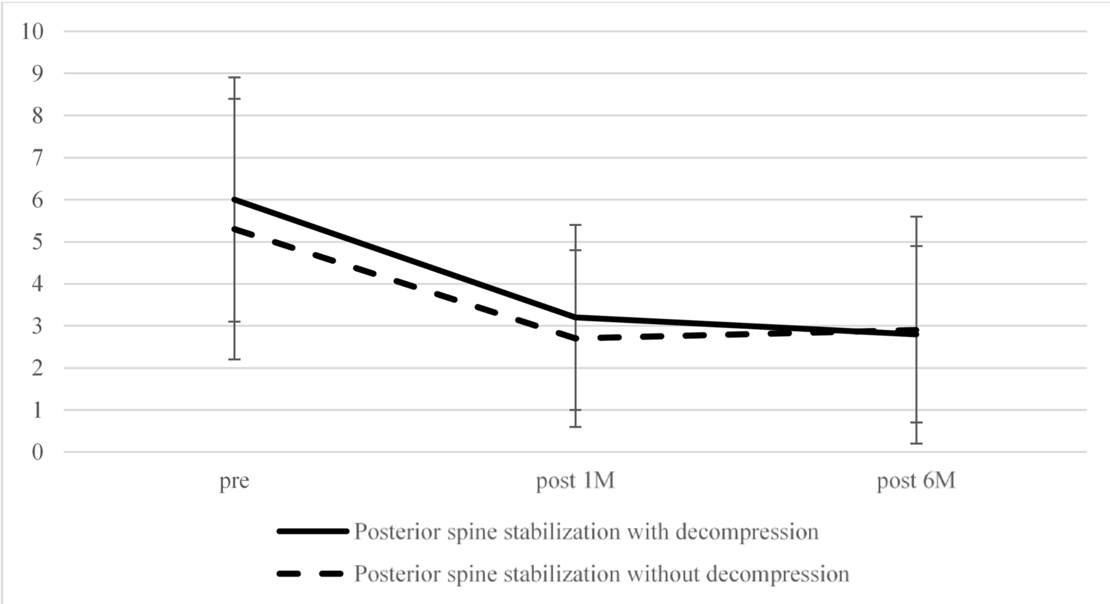
c) VAS



	VAS (pre)	VAS (1 M)	VAS (6 M)
Posterior spine stabilization with decompression	59.9 (32.2)	32.4 (27.0)	18.9 (17.5)
Posterior spine stabilization without decompression	55.9 (31.9)	24.4 (23.0)	25.7 (27.8)
P	0.52	0.15	0.75

Fig. 2. (continued)

d) Face scale



	Face scale (pre)	Face scale (1 M)	Face scale (6 M)
Posterior spine stabilization with decompression	6.0 (2.9)	3.2 (2.2)	2.8 (2.1)
Posterior spine stabilization without decompression	5.3 (3.1)	2.7 (2.1)	2.9 (2.7)
P	0.32	0.33	0.84

Two-group comparisons were performed via the Wilcoxon test at three time points: preoperative, 1 month postoperative, and 6 months postoperative.

Mean (standard deviation)

Fig. 2. (continued)

	Total, N = 102	Posterior spine stabilization with decompression (N = 51)	Posterior spine stabilization without decompression (N = 51)	P
ΔBarthel Index	At 1month postoperatively	13.2 (24.8)	15.5 (27.8)	0.25
	At 6 months postoperatively	17.6 (28.8)	15.6 (28.7)	0.92
ΔEQ-5D-5 L	At 1month postoperatively	0.19 (0.26)	0.18 (0.25)	0.87
	At 6 months postoperatively	0.24 (0.26)	0.22 (0.36)	0.80
ΔVAS	At 1month postoperatively	28.0 (29.5)	28.0 (38.6)	0.88
	At 6 months postoperatively	45.4 (27.2)	32.8 (37.2)	0.33
Δface scale	At 1month postoperatively	2.8 (3.3)	2.2 (3.1)	0.54
	At 6 months postoperatively	3.5 (2.9)	3.0 (3.6)	0.86

Table 5. Comparison of preoperative-to-postoperative changes (Δ) between the two groups after propensity score matching. Two-group comparisons were made via the Wilcoxon test. No statistically significant differences were found for any of the scores. Mean (standard deviation). Two-group comparisons were performed via the Wilcoxon test at three time points: preoperative, 1 month postoperative, and 6 months postoperative. Mean (standard deviation).

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Author contributions
H. T. and N. T. led the drafting of this manuscript in collaboration with other authors. H. T., I.K., H. S., and H. Sa. participated in the data analysis. Y.S., A.S., H.Ter., T.S., K.K., Y.K., M.I., M.P., Y.T., T.F., K.M., E.S., H.I., A.K., T.I., H.M., H.N., S.W., K.A., N.Ta., K.N., H.Saw., K.Ma., M.F., H.Su., H.F., T.O., T.Hi., B.O., K.Ko., K.U., H.M., S.T., K.H., C.I., D.Y., A.H., S.S., Y.G., M.M., K.W., T.N., T.K., H.Nak., N.N., S.K., S.I., K.Wat., G.I. and T.Fu. contributed to the collection of the clinical data. All the authors have read and approved the final manuscript.

Declarations

Competing interests
The authors declare no competing interests.

Additional information
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