

A new posterior stabilization technique in pediatric subaxial cervical vertebrae: Stabilization of spinous processes with the microplate/screw system: A radiological anatomy study

İlker Gulec, M.D., Feyza Karagoz Guzey, M.D., Burak Eren, M.D., Gunay Vahabova, M.D.

Department of Neurosurgery, Health Sciences University, Bağcılar Training and Research Hospital, İstanbul-Turkey

ABSTRACT

BACKGROUND: There are limited options for posterior stabilization techniques in cases of cervical subaxial instability in children. We designed this study to investigate whether the spinous process (SP) stabilization, which was previously used in adults, can also be used in children.

METHODS: Children aged 4–12 years who were admitted to our hospital between 2012 and 2020 and underwent 3D cervical computed tomography (CT) were retrospectively screened. Children without cervical spine fractures, tumors, deformities, or any abnormalities and motion artifacts on CT were included in the study. Eight hundred seventy children were identified. Then, 360 children randomly selected from the patient pool were divided into nine different age groups or 3 different age groups (4–6 years, 7–9 years, and 10–12 years). The length, height, thickness, and anomalies of subaxial SPs were studied on CT images of children. The suitability of the SPs for the microplate/screw stabilization system was investigated.

RESULTS: The suitability rate for screw insertion was 57.6% and the suitability rate for the stabilization in at least one segmental unit was 74.7%. The eligibility rate for stabilization involving C3, 4, 5, 6, and 7 vertebrae was 16.1%. There were nine different stabilization combinations and C6-7 segmental unit (71.9%) were the most common in those combinations. Bifidity prevented screw insertion in 21% of children. We found that the screw acceptance rate of SP started to increase statistically around 8 years of age and the number of segmental units that could be stabilized was at the age of 10–12 at most.

CONCLUSION: According to the results of this study, we believe that the SP stabilization method recommended for children can be used as a salvage method, to support anterior stabilization or alone in a small number of selected cases.

Keywords: Instability; pediatric; posterior; screw; subaxial; technique.

INTRODUCTION

Posterior surgical techniques (PST) are often used in childhood cervical instabilities.^[1–4] Depending on the type and weight of instability, the lateral mass (LM) screw stabilization system (LMSS),^[4,5] pedicle screw stabilization system (PSSS),^[4,6] lamina screw stabilization system (LSSS),^[7] sublaminar/interspinous wiring,^[4,8] or one of the other PST options^[9] are chosen. The small bone sizes of the cervical vertebrae in

children and the high anatomical variability significantly limit surgical options.^[4] Moreover, as the posterior stabilization systems in use are usually designed for adults, they are not often suitable for children.^[4,9]

Recently, new surgical approaches using spinous process stabilization (SPS) have been described in adults, such as S-Plate (SSS),^[10,11] Wavy-Rod (WRSS),^[12] or spinolaminar stabilization (SLSS)^[13] systems. In the first two methods, the

Cite this article as: Gulec İ, Karagoz Guzey F, Eren B, Vahabova G. A new posterior stabilization technique in pediatric subaxial cervical vertebrae: Stabilization of spinous processes with the microplate/screw system: A radiological anatomy study. *Ulus Travma Acil Cerrahi Derg* 2022;28:678-685.

Address for correspondence: İlker Gulec, M.D.

Sağlık Bilimleri Üniversitesi, Bağcılar Eğitim ve Araştırma Hastanesi, Beyin Cerrahi Kliniği, İstanbul, Turkey

Tel: +90 212 - 440 40 00 E-mail: ilkerulec@gmail.com

Ulus Travma Acil Cerrahi Derg 2022;28(5):678-685 DOI: 10.14744/tjtes.2021.24657 Submitted: 16.10.2020 Accepted: 16.02.2021

Copyright 2022 Turkish Association of Trauma and Emergency Surgery



spinous processes (SPs) are stabilized by bilateral plate/screw systems, and in the third by screw/rod systems. The surgical techniques mentioned above have been suggested for use as primary treatment options^[10] or salvage techniques.^[11] The advantages of SPS methods are easy to be implanted, low expected complication rates,^[10,11] and applicability without fluoroscopy. In addition, these methods proved to be highly biomechanically stable constructs.^[12,13]

In the current study, we hypothesized that the SPS technique can be used alone in the traumatic instability of pediatric subaxial vertebrae depending on the severity of the injury, or it can be used as a support for anterior stabilization systems. We investigated for the first time in the literature whether the microplate/screw stabilization system (MSS) is suitable for use in children by making SP measurements on 3D computed tomography (CT) images.

MATERIALS AND METHODS

The study was approved by the local ethics committee (decision no: 2020.06.2.05.08). Between 2012 and 2020, records of 4–12 years old patients who were admitted to our hospital for trauma and neck pain and who underwent cervical 3D CT examination were screened. All CT images were acquired using a high-resolution CT scanner (256-slice CT scanner, Philips, Netherlands). We accepted that images with a slice thickness of 1.5 mm or less were sufficient. Exclusion criteria: Children under 4 and over 12 years old, cases with fracture, tumor, deformity, or any abnormality in the cervical spine, and movement artifact on CT were not included in the study.

The children were divided into nine groups or three groups (4–6, 7–9, and 10–12 years old group) according to their age. The numbers of boys and girls were equal in each group. We pooled 870 children who met the inclusion criteria. Then, 360 children were randomly selected from the patient pool to the groups, and 1800 SP of 360 children were studied.

Measurements

Measurements were made on axial, sagittal, and 3D reconstruction of CT in subaxial vertebrae by two expert authors and averaged (Fig. 1):

1. SP length in the sagittal section: A virtual 3.7 mm line was placed on the SP, starting from the adjacent spinal canal toward the posterior. That line represents the diameter of the area needed for the screw application. The shortest length of the SP was measured in the midsagittal sections
2. SP height in the sagittal section: The bicortical shortest distance of the SP extending from superior to inferior was measured vertically on that virtual line
3. SP thickness in the axial section: The same virtual line was placed in the axial plane. The shortest distance between

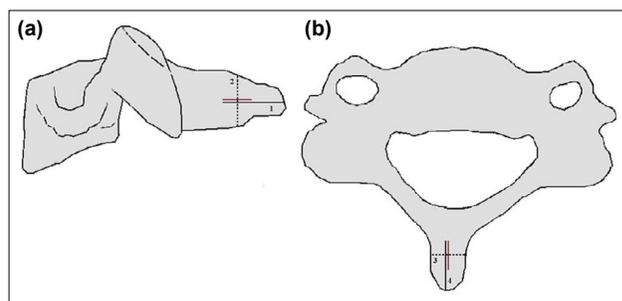


Figure 1. Measurement methods are illustrated on a C5 vertebra. **(a)** Sagittal length (1) and height (2) of spinous process (SP); **(b)** axial thickness (3) and antero-posterior length of SP (4) (red line: Representing the diameter of the area needed for the screw application).

- both outer cortices was measured horizontally, perpendicular to the virtual line
4. SP length in axial section: The anterior-posterior shortest length of the SP was measured.

Finally, bifidity preventing the insertion of spinous the screw was recorded in children.

Definition of the Recommended Stabilization System

The recommended MSS is currently used for the stabilization of bone structures in mandible and sternum surgery. This stabilization system has screws of different lengths and plate options of different lengths and angles. Frequent holes in the plates provide ease of application and have self-locking screws. We chose to use a 6 mm wide plate with a profile thickness of 1.6 mm and a 2.7 mm screw to stabilize the subaxial SPs. For a 2.7 mm screw application, a 0.5 mm (total 1 mm) safety zone was chosen. Finally, we decided that the plate should be used bilaterally to increase the stability of the system.

Eligibility Criteria for Screw Insertion and Stabilization in SP

1. In four measurements, if the values were 3.7 mm and above, the SP was considered to be suitable for screw insertion
2. The suitability of at least two sequential of SP for screw insertion was accepted as the eligibility criterion for stabilization.

Statistical Analysis

Percentages for nominal data, median values for sequential data, and mean and standard deviations for numerical data are given. Comparison between groups was made with Chi-square and Fisher's exact test according to the number of group subjects for nominal data, Kruskal-Wallis, and Mann-Whitney U for sequential data, variance analysis, and t-test for numerical data. Bonferroni correction test was used when variance analysis was applied. If $p < 0.05$, it was considered sta-

tistically significant. Professional support was received for statistical calculations.

RESULTS

The mean age was 8 ± 2.73 years old (range, 4–12 years old). The measurement results according to age groups, gender, and vertebral levels are presented in Tables 1 and 2. Results By gender: In boys, there were statistically significant differences in thicknesses of SPs at C3, 4, 5 ($p<0.001$), and C6 ($p=0.012$), and in height at C5 ($p=0.005$) compared to girls. There were statistically significant differences in height of SPs at C3 ($p=0.005$) and C5 ($p=0.041$) and sagittal length at C6 ($p=0.006$) and C7 ($p<0.001$) in girls compared to boys.

Comparison of 4–6 and 7–9 years old groups: Statistically significant differences were found between the groups in all subaxial SPs in terms of sagittal length ($p<0.001$) and heights in all ($p<0.001$). In axial length measurements, SPs at C3 ($p=0.006$), C4 ($p=0.016$), C5 ($p=0.004$), C6 ($p<0.001$), and C7 ($p<0.001$), and in thickness measurements, C7 ($p=0.015$) only showed statistically significant difference.

Comparison of 4–6 and 10–12 years old groups: There were

statistically significant differences between groups in sagittal length in all ($p<0.001$) and heights in all ($p<0.001$). There were statistically significant differences between SPs at C7 for axial thickness ($p<0.001$), and SPs at C3,4 ($p<0.001$), C5 ($p=0.006$), and C7 ($p<0.001$) for axial length. Comparison of 7–9 and 10–12 years old groups: Statistically significant differences were determined between all subaxial SPs in sagittal length ($p<0.001$) and heights in all ($p<0.001$). The axial length revealed a statistically significant difference only at C7 ($p<0.001$). In axial thicknesses, there was no difference between at C3, 4, 5, 6, and 7.

We determined that the SP length gradually increased from C3 to C7, and the most pronounced increase was in the C6 and C7 vertebrae. Among all age groups, the shortest SP dimension was in the C4 vertebrae in 4-year-old children and the highest in the C7 vertebrae. We also found that sagittal length and height, axial length increased significantly with age in children, and the thickness of SP increased by less than the other three parameters measured. We determined that the SP length gradually increased from C3 to C7, and the most pronounced increase was in the C6 and C7 vertebrae. Among all age groups, the shortest SP dimension was in the C4 verte-

Table 1. Spinous process measurements in genders

Measurement		Male	Female	All subjects	p*
		mm, mean \pm SD	mm, mean \pm SD	mm, mean \pm SD	
C3	SL	7.9 \pm 1.8	7.9 \pm 1.8	7.9 \pm 1.8	0.711
	SH	4.2 \pm 1	4.5 \pm 1	4.4 \pm 1	0.005
	AT	9 \pm 1.9	8.1 \pm 1.8	8.5 \pm 1.9	0.000
	AL	5.4 \pm 1.8	5.3 \pm 1.7	5.3 \pm 1.8	0.595
C4	SL	8.1 \pm 2	8.2 \pm 2.2	8.2 \pm 2.1	0.539
	SH	4 \pm 0.8	4.2 \pm 0.9	4.1 \pm 0.9	0.044
	AT	9.3 \pm 1.8	8.4 \pm 2.1	8.9 \pm 2.1	0.000
	AL	4.9 \pm 1.8	5 \pm 1.9	4.9 \pm 1.9	0.438
C5	SL	8.8 \pm 1.9	9.2 \pm 2.1	9 \pm 2	0.059
	SH	3.8 \pm 0.8	3.9 \pm 0.9	3.8 \pm 0.9	0.041
	AT	8.9 \pm 1.9	7.9 \pm 1.8	8.4 \pm 1.9	0.000
	AL	5.4 \pm 2.3	5.3 \pm 2.5	5.4 \pm 2.4	0.648
C6	SL	10.9 \pm 2.5	11.7 \pm 2.8	11.3 \pm 2.7	0.006
	SH	4.4 \pm 0.9	4.65 \pm 1	4.5 \pm 1	0.163
	AT	7.8 \pm 1.8	7.3 \pm 1.8	7.5 \pm 1.8	0.012
	AL	8.6 \pm 3.3	8.7 \pm 3.6	8.6 \pm 3.6	0.734
C7	SL	14.1 \pm 2.9	15.4 \pm 3.4	14.7 \pm 3.2	0.000
	SH	5.6 \pm 1	5.8 \pm 1.2	5.7 \pm 1.1	0.165
	AT	9.8 \pm 1.7	9.6 \pm 1.7	9.7 \pm 1.7	0.160
	AL	12.3 \pm 2.8	12.7 \pm 3.3	12.5 \pm 3.1	0.220

*Significant p values found in Student's t test marked as bold characters. AL: Axial length; AT: Axial thickness; SH: Sagittal height; SL: Sagittal length; SD: Standard deviation.

brae and the highest in the C7 vertebrae. We also found that sagittal length and height and axial length increased significantly with age in children, and increase of thickness of SP by age was not distinctive as to be other three parameters measured.

Results by Gender

The measurements of SPs are given in Table 1. In general, SPs of the upper levels (C3, C4, and C5) were thicker in boys, but their sagittal heights were longer in girls. There was no significant difference in their lengths. Contrary, lengths of the lower levels (C6 and C7) were significantly longer in girls.

Comparisons Between Age Groups

The measurements of SPs according to the age groups are given in Table 2. Sagittal lengths and heights, and axial lengths for all levels and axial thickness for C7 were significantly different between groups. All measurements and p values are given in Table. In comparisons between binary groups, the differences of sagittal lengths and heights in all levels and axial lengths in C7 between all groups, and axial lengths in C3, C4, C5, and C6 between 4–6 and 10–12 age groups were significant. Axial thickness was significantly different in only C7 level between 4–6 and 10–12 age groups.

Suitability of SPs for Screw Insertion

In 360 patients, 1037 of 1800 SP levels (57.6%) were found to be suitable for screw insertion and 763 SP levels (42.4%) were not (Table 3). There was no statistical difference between boys and girls for suitability. Screw acceptance rates were lowest in C4 (34.7%) and highest in C7 (96.6%) and then C6 (73%). The screw acceptance rate of SPs increased with increasing age, it was determined that suitability started to be more pronounced around the age of 8 (65%).

In the comparison of 4–6 and 7–9 years old groups, there were statistically significant differences in all levels (p=0.036 for C3 and p<0.001 for other levels). In the comparison of 4–6 and 10–12 years old groups, there were significant differences in all levels again (p=0.01 for C7, and p<0.001 for other levels). In the comparison of 7–9 and 10–12 years old groups, there were significant differences in only C4 (p=0.018) and C6 (p=0.041) levels.

Suitability for the SPS: Suitability of SPs for Screw Insertion

In 360 patients, 1037 of 1800 SP segments (57.6%) were found

Table 2. Spinous process measurements in age groups

Measurement		4–6 age group	7–9 age group	10–12 age group	p*
		mm, mean±SD	mm, mean±SD	mm, mean±SD	
C3	SL	6.8±1.3	7.8±1.4	9.1±1.9	0.000
	SH	3.8±1	4.3±0.8	5±1	0.000
	AT	8.7±1.9	8.5±1.7	8.4±2.1	0.571
	AL	4.8±1.5	5.4±1.6	5.8±1.9	0.000
C4	SL	7±1.5	7.9±1.6	9.5±2.2	0.000
	SH	3.5±0.7	4±0.7	4.6±0.8	0.000
	AT	8.9±2.1	8.9±1.9	8.8±2.1	0.772
	AL	4.5±1.6	5±1.8	5.3±2.1	0.002
C5	SL	8.1±1.7	8.9±1.4	10±2.3	0.000
	SH	3.3±0.7	3.8±0.7	4.4±0.8	0.000
	AT	8.7±1.9	8.3±1.9	8.3±1.8	0.262
	AL	4.8±2.1	5.6±2.1	5.7±2.86	0.007
C6	SL	9.8±1.9	11.2±1.9	12.9±3	0.000
	SH	4±0.8	4.5±0.8	5±1	0.000
	AT	7.6±1.7	7.7±1.9	7.4±1.9	0.518
	AL	7.4±2.7	8.8±2.9	9.9±4.1	0.000
C7	SL	12.9±2.4	14±2.6	17.3±2.9	0.000
	SH	5.1±0.9	5.7±1	6.3±1.1	0.000
	AT	9.4±1,3	9.3±1,7	10.1±2	0.001
	AL	9.3±1.5	9.8±1.6	14.8±3	0.000

*Significant p values found in variance analysis marked as bold character. AL: Axial length; AT: Axial thickness; SH: Sagittal height; SL: Sagittal length; SD: Standard deviation.

Table 3. Distribution of suitable spinous process levels for the screw by gender and age groups

		Levels (rate of suitable level number/group number)					All patients (rate and per cent)
		C3	C4	C5	C6	C7	
Gender	Male	87/180	55/180	64/180	133/180	174/180	513/900 (57.0%)
	Female	86/180	70/180	64/180	130/180	174/180	524/900 (58.2%)
Age groups	4–6	42/120	27/120	21/120	65/120	110/120	265/600 (44.1%)
	7–9	59/120	40/120	48/120	93/120	119/120	359/600 (59.8%)
	10–12	72/120	58/120	59/120	105/120	119/120	413/600 (68.8%)
All levels		173/360 (48%)	125/360 (34.7%)	128/360 (35.5%)	263/360 (73%)	348/360 (96.6%)	1037/1800 (57.6%)

Table 4. Distribution of the segments that can be stabilized with miniplate screw stabilization system

		C3-4 n/%	C4-5 n/%	C5-6 n/%	C6-7 n/%	C3-4-5 n/%	C5-6-7 n/%	C4-5-6-7 n/%	C3-4-6-7 n/%	C3-4-5-6-7 n/%	All n/%
Gender	Male	1/0.5	1/0.5	0/0	61/33.8	1/0.5	24/13.3	10/5.5	11/6.1	26/14.4	135/75
	Female	4/2.2	1/0.5	1/0.5	54/30	1/0.5	18/10	9/5	14/7.7	32/17.7	134/74.4
Age groups	4–6	3/2.5	0/0	0/0	36	1/0.8	8/6.6	3	9	6/5	66/55
	7–9	1/0.8	1/0.8	1/0.8	38	1/0.8	20/16.6	11	9	14/11.6	96/81.6
	10–12	1/0.8	1/0.8	0/0	41	0/0	14/11.6	5	7	38/31.6	107/89.1
All		5/1.3	2/0.5	1/0.2	115/31.9	2/0.5	42/11.6	19/5.2	25/6.9	58/16.1	269/74.7

to be suitable for screw insertion and 763 SP segments (42.4%) were not (Table 3). There was no statistical difference between boys and girls. In the comparison of 4–6 and 7–9 years old groups, there were statistically significant differences at C3 ($p=0.036$), and C5, 6, and 7 ($p<0.001$). In the comparison of 4–6 and 10–12 years old groups, there were statistically significant differences at C3, 4, 5, and 6 ($p<0.001$), and C7 ($p=0.01$).

Screw acceptance rates were at least in C4 SPs (34.7%) and highest in C7 (96.6%) and C6 (73%). The screw acceptance rate of SPs increased with increasing age, it was determined that suitability started to be more pronounced around the age of 8 (65%).

Suitability for the SPS

The suitability rate for MSS in at least one segmental unit was 74.7% (269/360) (Table 4). The suitability rate for MSS that includes all of the C3, 4, 5, 6, and 7th vertebral segments was found to be 16.1% (58/360). The most common segmental unit involved in stabilization combinations is C6-7 (71.9%). The highest number of segments involved in stabilization was found in children aged 11–12. A representative drawing showing the application of the recommended MSS in pediatric cervical vertebrae is presented in Figure 2.

A representative drawing showing the application of this system in pediatric cervical vertebrae is presented in Figure

2. The eligibility rate for miniplate screw system in at least one segmental unit of the subjects was 74.7% (269/360) (Table 4). The most common segmental unit involved in stabilization combinations was C6-7 (71.9%). The suitability rate for a system including all subaxial levels (C3 to C7) was found to be 16.1% (58/360). The highest number of levels involved in stabilization was found in children aged 11–12.

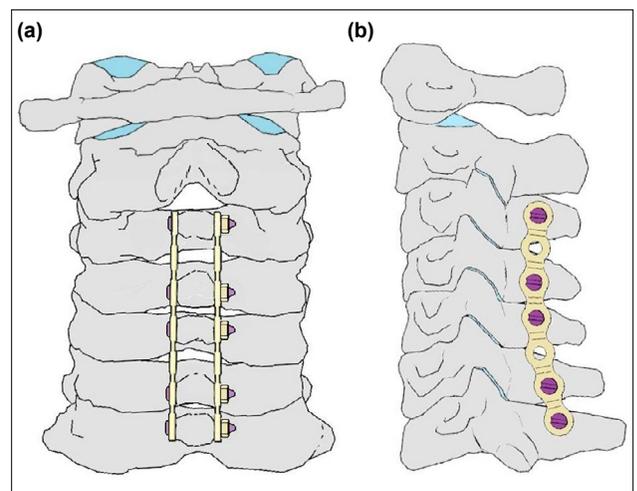


Figure 2. Representative drawing of the recommended microplate/screw stabilization system in a 9-year-old child: (a) Posterior view, (b) sagittal view.

Results for Bifidity

In cases with bifidity, no statistical difference was found in terms of age and gender. Bifidity rates in SPs were found to be 24%, 43.3%, 59.4%, 33.6%, and 5.2% in C3, 4, 5, 6, and 7th vertebrae, respectively. Bifidity was detected in 596 of 1800 SP segments (33.1%), 379 of which were not suitable for screw insertion. All cases with bifidity at C7 were found to be suitable for screw insertion. Bifidity was detected in 596 of 1800 SP levels (33.1%), 379 of which were not suitable for screw insertion. However, all cases with bifidity at C7 were found to be suitable for screw insertion. Bifidity rates in SPs were found to be 24%, 43.3%, 59.4%, 33.6%, and 5.2% in C3, C4, C5, C6, and C7 levels, respectively. In cases with bifidity, no statistical difference was found in terms of age and gender.

DISCUSSION

In the present study, we radiologically simulated the suitability of pediatric subaxial cervical SPs for MSS. The results of our study are as follows: (1) The suitability of subaxial SP of children between the ages of 4–12 for screws was 43.5% at age 4 and 70% at age 12, that ratio tended to increase with age; (2) bifidity was detected in 33.1% of the cases, 63.5% of them were not suitable for screw insertion in SP; and (3) 74.7% of the children were suitable for MSS system. Our study revealed that the children's subaxial vertebrae are partially suitable for the MSS system. We are of the opinion that it is easy to decide whether SPs are suitable for MSS on preoperative three-dimensional CT. We hope that it might be used as the only stabilization method in cases of mild instability such as facet fracture, non-overt anteriorly displacement of cervical spine due to anterior column damage or as a second surgical technique to support anterior stabilization.

In cases of cervical subaxial instability, non-rigid surgical techniques such as tying with featured sutures,^[8,9] wiring of sublaminar^[1,14] or interspinous,^[3,15] or rigid surgical techniques such as LMSS,^[4,5,15] PSSS,^[6] and LSSS^[7] are used.

Although there seem to be many PSTs for stabilization in children, those are actually limited in number. The simplest non-rigid method is the tying of lamina or SPs with vicryl sutures or polyester sutures, which is only possible in young childhood.^[8,9] The wiring technique (WT), which is the oldest method used,^[3,4] is currently recommended to use WT as a short segment or salvage method when rigid stabilization techniques are not suitable.^[4] The situation is no different for LSSS, which is popular in adults in recent years because children's laminae do not have sufficient dimensions for that method.^[16] Two PSTs routinely used in practice are LMSS and PSSS. The most preferred PST is LMSS. It has been reported that LMSS can be used at all subaxial levels in the majority of cases over the age of 4.^[17] Hedequist et al.^[5] reported that they applied LMSS without complications in 30 patients with a mean age of 10 years. The second one is PSSS, which is usually used for subaxial lower vertebral levels. Rajasekaran

et al.^[6] successfully treated 28 patients with a mean age of 9.7 years with PSSS. However, PSSS is a method avoided due to its possible risks and technical difficulties.^[5,18,19]

Recently, SPS with WRSS,^[12] SSS,^[10,11] and spinolaminar screws^[13] were described for use in adult degenerative or trauma cases. Those systems were used to support failed anterior construct^[11] or as primary treatment.^[10] Hirabayashi et al.^[10] and Neo et al.^[11] reported that SSS can be implanted more easily than other PST methods. SPS techniques have several advantages such as rapid access to the surgical field, less muscle damage, short operation time, being away from critical anatomical structures, and no need for intraoperative imaging support of low intraoperative bleeding.^[10–13] Inspired by the SPS methods in adults, we focused on the suitability of the MSS for use in cases of pediatric cervical instability.

In PST studies, surgery is simulated with 3.0 mm^[6,20] or 3.5 mm^[4,13,16,17] screws that are currently in commercial use. Small vertebral dimensions, large screw diameter, or both in children reduce the application rates of stabilization systems.^[16] Al-Shamy et al.^[17] reported that subaxial LMs were highly suitable for inserting 3.5 mm diameter screws in children with a mean age of 4.93, only 9% of the cases were unsuitable, all under 4 years old. Kanna et al.^[20] found that 82.5% of the cervical pedicles of pediatric patients with a mean age of 6.7 years were suitable for the insertion of screws with a diameter of 3 mm. Chern et al.^[16] demonstrated that the screw acceptance rate of the C3-6 laminae for bilateral LS implantation was 1.4% and 13% for the C7 lamina in children aged 1.5–16 years. The results revealed that LS can rarely be used. In our study, we used 2.7 mm diameter screws. We found that 57.6% of 1800 SP is suitable for screw insertion and stabilization can be made in nine different combinations. The eligibility rate for stabilization in at least one segmental unit was 74.7%. The C6-7 segmental unit was the segment with the highest stabilization rate at 31.9%, and this segment was also in another stabilization combination at 40%. The eligibility rate for stabilization including C3, 4, 5, 6, and 7 vertebrae was 16.1%. The percentage of possible application of our recommended MSS on the patient is quite high, and the use of the screw with a thinner diameter makes a significant contribution to that.

One of the criticisms about MSS maybe its biomechanical resistance. MSS can be compared with WT, PSSS, and LMSS. PSSS is the most stable structure that can stabilize all columns of the cervical vertebra.^[21] In LMSS, the motion limitation resistances required to correct the instability are sufficiently met.^[12] Mihara et al.^[12] compared WRSS to two types of WT and LMSS. WRSS was found to be the most restrictive method in flexion and extension, and effective limitation on axial rotation and lateral bending. Neo et al.^[11] argued that although SSS does not have biomechanical tests, SPSS has a better compressive force on SPs than WRSS. Jenkins et al.^[13] found that biomechanical test results of SLSS at C3-6 levels were similar to LMSS. They showed that adequate construc-

tion stiffness was achieved with unilateral SLSS, but that stiffness was further increased in bilateral application. In the MSS, the width of the plates, the thickness of the profile, and the smaller diameter of the screws compared to the SPS systems used in adults may raise doubts about the reliability of the system. We believe that the use of bilateral plates and self-locking screws will reduce potential problems. However, the use of bilateral plates and to tighten the screws with nuts may reduce this potential problem. Of course, biomechanical tests of the system must be required before clinical application.

The recommended MSS technique also has theoretical disadvantages. To use SPS methods, posterior cervical elements must be intact. On the other hand, the presence of laminas and SP fractures does not restrict the use of LMSS and PSSS, and posterior decompression does not affect the resistance of these stabilization systems.^[15] In addition, the osteoporotic bone structure of SPs may restrict the use of this system.^[12] Therefore, the aforementioned deficiency should be considered before the use of the MSS.

The frequency and severity of complications are an important factor in the selection of the surgical technique to be applied.^[4] In WT, pseudoarthrosis, resorption or displacement of the bone graft, cerebrospinal fistula and spinal cord injury occur more frequently than those in the rigid method.^[1,4] On the other hand, the risk of neurovascular injury is higher in LMSS and PSSS.^[4,5,18,19,22] With the use of intraoperative imaging support, screw malposition can be reduced by 35.1–82.1%.^[19] Screw loosening is a common problem of all rigid systems, but that is less common in PSSS.^[18,22] It has been reported that it is important to insert the screw in one attempt due to smaller LMs in young children, otherwise the LMs may be broken.^[5] Most of the complications mentioned above are not encountered in SPS methods. Neo et al.^[11] reported that limited kyphosis developed in only one case as a result of loosening of the C3 screw due to osteoporosis. However, since SPS methods are rarely used, we do not have much idea about the type of complications and their incidence.

The sizes and anatomical features of cervical SPs are different from each other. In studies conducted with adults, it was reported that the SP length gradually increased from C3 to C7, with the highest increase in C6 and C7 vertebrae,^[23,24] which was confirmed in our study. We noticed that the group with the shortest SP dimension was at C4 vertebra in 4-year-old children and the highest was at the C7 vertebra in all age groups. In addition, we found that SP thickness increased slightly in children compared to the other 3 parameters measured.

Bifidity is one of the most common developmental anomalies in the cervical spine. Bifidity was detected in subaxial vertebrae in 29.2% of Caucasian race and 19.6% of the Black race.^[25] In those studies, bifidity was most common in C5 and C4 SPs and least in C7 SPs. In our study, bifidity was found to be 33.1%, which was almost the same incidence as in Caucasian race,

and the frequencies of bifidity locations were consistent with previous studies. We examined bifidity in terms of whether it prevents stabilization application rather than its subtypes. We found that bifidity prevented screw insertion in 21% (379/1800) of all SP segments. Interestingly, 19 patients with bifidity in C7 were also found to be suitable for screw insertion.

The current study has some limitations. First, the evidence of the study is based on radiological measurements. With tomography, measurements, and reconstructions of cervical bone tissue can be made with extremely high quality and reliability. Nevertheless, differences can be manifested in the application of the recommended stabilization system in the surgical field. However, we believe that the use of different angled plates with multiple holes in the MMS system will reduce those negativities. Second, there is a need for biomechanical tests, which is a separate study subject of a separate study.

Conclusion

This study is the first in the literature to the best of our knowledge. In our radiological anatomy study, we found that cervical subaxial SPs were suitable for screw insertion in approximately half of the children aged 4–12 years, and three-fourths of the cases were suitable for stabilization involving at least one segmental SP unit with the MSS. Considering that PST options are limited in children, we believe that MMS might be used alone, to support the anterior stabilization system or as a salvage method in selected cervical trauma cases. It should be known that the possibility of screw insertion decreases significantly in the presence of bifidity in SP.

Ethics Committee Approval: This study was approved by the Bagcilar Training and Research Hospital Ethics Committee (Date: 26.06.2020, Decision No: 2020.06.2.05.089).

Peer-review: Internally peer-reviewed.

Authorship Contributions: Concept: İ.G., F.K.G., B.E.; Design: İ.G., F.K.G., B.E.; Supervision: İ.G., F.K.G., B.E.; Resource: İ.G., F.K.G., B.E.; Materials: İ.G., G.V.; Data: İ.G., G.V.; Analysis: İ.G., F.K.G., B.E.; Literature search: İ.G., F.K.G., B.E.; Writing: İ.G., F.K.G.; Critical revision: F.K.G., B.E., G.V.

Conflict of Interest: None declared.

Financial Disclosure: The authors declared that this study has received no financial support.

REFERENCES

- Hwang SW, Gressot LV, Rangel-Castilla L, Whitehead WE, Curry DJ, Bollo RJ, et al. Outcomes of instrumented fusion in the pediatric cervical spine. *J Neurosurg Spine* 2012;17:397–409. [CrossRef]
- Joaquim AF, Tan L, Riew KD. Posterior screw fixation in the subaxial cervical spine: A technique and literature review. *J Spine Surg* 2020;6:252–61.
- McGrory BJ, Klassen RA. Arthrodesis of the cervical spine for fractures and dislocations in children and adolescents. A long-term follow-up study. *J Bone Joint Surg Am* 1994;76:1606–16. [CrossRef]
- Mendenhall S, Mobasser D, Relyea K, Jea A. Spinal instrumentation

- in infants, children, and adolescents: A review. *J Neurosurg Pediatr* 2019;23:1–15. [CrossRef]
5. Hedequist D, Proctor M, Hresko T. Lateral mass screw fixation in children. *J Child Orthop* 2010;4:197–201. [CrossRef]
 6. Rajasekaran S, Kanna PR, Shetty AP. Safety of cervical pedicle screw insertion in children: A clinicoradiological evaluation of computer-assisted insertion of 51 cervical pedicle screws including 28 subaxial pedicle screws in 16 children. *Spine (Phila Pa 1976)* 2012;37:E216–23. [CrossRef]
 7. Chamoun RB, Relyea KM, Johnson KK, Whitehead WE, Curry DJ, Luerssen TG, et al. Use of axial and subaxial translaminar screw fixation in the management of upper cervical spinal instability in a series of 7 children. *Neurosurgery* 2009;64:734–9. [CrossRef]
 8. Hamoud K, Abbas J. A new technique for stabilization of injuries at C2-C3 in young children. *Injury* 2014;45:1791–5. [CrossRef]
 9. Özbek Z, Özkara E, Vural M, Arslantaş A. Treatment of cervical subaxial injury in the very young child. *Eur Spine J* 2018;27:1193–8. [CrossRef]
 10. Hirabayashi H, Takahashi J, Hashidate H, Ogihara N, Mukaiyama K, Kuraishi S, et al. Spinous process plate fixation for cervical spinal fusion after spinal trauma: Two case reports. *J Zhejiang Univ Sci B* 2013;14:855–8. [CrossRef]
 11. Neo M, Fujibayashi S, Yoshida M, Nakamura T. Spinous process plate fixation as a salvage operation for failed anterior cervical fusion: Technical note. *J Neurosurg Spine* 2006;4:78–81. [CrossRef]
 12. Mihara H, Cheng BC, David SM, Ohnari K, Zdeblick TA. Biomechanical comparison of posterior cervical fixation. *Spine (Phila Pa 1976)* 2001;26:1662–7. [CrossRef]
 13. Jenkins T, Kuhns C, Choma T, Gallizzi M, Pfeiffer F. Bailout screw placement in the posterior subaxial cervical spine: Is a spinolaminar screw a viable option? *J Spine Care* 2016;1:1–4. [CrossRef]
 14. Quinn JC, Patel N V, Tyagi R. Hybrid lateral mass screw sublaminar wire construct: A salvage technique for posterior cervical fixation in pediatric spine surgery. *J Clin Neurosci* 2016;25:118–21. [CrossRef]
 15. Mitchell A, Upasani VV, Bartley CE, Newton PO, Yaszay B. Rigid segmental cervical spine instrumentation is safe and efficacious in younger children. *Childs Nerv Syst* 2019;35:985–90. [CrossRef]
 16. Chern JJ, Chamoun RB, Whitehead WE, Curry DJ, Luerssen TG, Jea A. Computed tomography morphometric analysis for axial and subaxial translaminar screw placement in the pediatric cervical spine: Clinical article. *J Neurosurg Pediatr* 2009;3:121–8. [CrossRef]
 17. Al-Shamy G, Cherian J, Mata JA, Patel AJ, Hwang SW, Jea A. Computed tomography morphometric analysis for lateral mass screw placement in the pediatric subaxial cervical spine. *J Neurosurg Spine* 2012;17:390–6.
 18. Kast E, Mohr K, Richter HP, Börm W. Complications of transpedicular screw fixation in the cervical spine. *Eur Spine J* 2006;15:327–34. [CrossRef]
 19. Sairy K, Sakai T, Higashino K, Tamura T, Katoh S, Yasui N. Cervical and upper thoracic screwing for spinal fusion: Strategy for its safe insertion to avoid major complications. *Arch Orthop Trauma Surg* 2009;129:1447–52. [CrossRef]
 20. Kanna PR, Shetty AP, Rajasekaran S. Anatomical feasibility of pediatric cervical pedicle screw insertion by computed tomographic morphometric evaluation of 376 pediatric cervical pedicles. *Spine (Phila Pa 1976)* 2011;36:1297–304. [CrossRef]
 21. Ludwig SC, Kramer DL, Vaccaro AR, Albert TJ. Transpedicle screw fixation of the cervical spine. *Clin Orthop Relat Res* 1999;359:77–88.
 22. Yoshihara H, Passias PG, Errico TJ. Screw-related complications in the subaxial cervical spine with the use of lateral mass versus cervical pedicle screws: A systematic review. *J Neurosurg Spine* 2013;19:614–23. [CrossRef]
 23. Ludwisiak K, Podgórski M, Biernacka K, Stefańczyk L, Olewnik Ł, Majos A, et al. Variation in the morphology of spinous processes in the cervical spine-an objective and parametric assessment based on CT study. *PLoS One* 2019;14:1–11. [CrossRef]
 24. Wang Z, Leng J, Liu J, Liu Y. Morphological study of the posterior osseous structures of subaxial cervical spine in a population from northeastern China. *J Orthop Surg Res* 2015;10:1–12. [CrossRef]
 25. Asvat R. The configuration of cervical spinous processes in black and white South African skeletal samples. *J Forensic Sci* 2012;57:176–81.

ORİJİNAL ÇALIŞMA - ÖZ

Pediyatrik subaksiyal servikal omurlarda yeni bir posterior stabilizasyon tekniği: Mikroplak/vida sistemi ile spinöz süreçlerin stabilizasyonu: Radyolojik anatomi çalışması

Dr. İlker Gulec, Dr. Feyza Karagoz Guzey, Dr. Burak Eren, Dr. Gunay Vahabova

Sağlık Bilimleri Üniversitesi, Bağcılar Eğitim ve Araştırma Hastanesi, Beyin Cerrahi Kliniği, İstanbul

AMAÇ: Çocuklarda gelişen servikal subaksiyel instabilite durumunda omurların kemik boyutlarının küçük olması ve sık anatomik değişkenlik cerrahi seçenekleri önemli ölçüde sınırlandırır. Bu olgularda yanal kütle vidaları, pedikül vidaları ve sublaminar/interspinöz bağlama seçenekleri dışında posterior servikal stabilizasyon seçeneği bulunmamaktadır. Bu çalışma, daha önce yetişkinlerde kullanılan spinöz süreç (SP) stabilizasyonunun çocuklarda da kullanılıp kullanılmayacağını araştırmak için tasarlandı.

GEREÇ VE YÖNTEM: 2012–2020 yılları arasında hastanemize başvuran ve üç boyutlu servikal BT yapılan 4–12 yaş arası çocuklar geriye dönük olarak tarandı. Çalışmaya, servikal omurgasında kırık, tümör, deformite ve bilgisayarlı tomografisinde (BT) hareket artefaktları olmayan çocuklar dahil edildi. Kabul edilme kriterlerine sahip 870 çocuk tespit edildi. Ardından hasta havuzundan rastgele seçilen 360 çocuk dokuz farklı yaş grubuna veya üç farklı yaş grubuna (4–6 yaş, 7–9 yaş ve 10–12 yaş) ayrıldı. Çocuklara ait BT görüntüleri üzerinde subaksiyal SP'lerin uzunluğu, yüksekliği, kalınlığı ve anomalileri çalışıldı. SP'lerin mikroplak/vida stabilizasyon sistemi için uygunluğu araştırıldı.

BULGULAR: Subaksiyal vertebralarda, vida yerleştirilmesi için uygunluk oranı %57.6 ve en az bir segmental ünite stabilizasyon için uygunluk oranı %74.7 idi. C3, 4, 5, 6 ve 7 omurlarının tamamını kapsayan stabilizasyon için uygunluk oranı %16.1 idi. Ölçümler sonucunda, dokuz farklı stabilizasyon kombinasyonu tespit edildi. C6-7 segmental ünitesi (%71.9) bu kombinasyonlarda en sık oranda yer almaktaydı. Bifidite, çocukların %21'inde vida yerleştirilmesini engelledi. İstatistiksel olarak SP'nin vida için uygunluk oranının sekiz yaş civarında artmaya başladığını ve stabilizasyona katılabilen segmental ünite sayısının ise en fazla 10–12 yaşında olduğu saptandı.

TARTIŞMA: Literatürde ilk olan bu çalışmada, çocuklar için önerilen spinöz süreç stabilizasyon yöntemi az sayıda seçilmiş olguda bir kurtarma yöntemi olarak, anterior cerrahi stabilizasyonu desteklemek için veya tek başına kullanılabileceğine inanıyoruz.

Anahtar sözcükler: İnstabilite; pediyatrik; posterior; subaksiyal; teknik; vida.

Ulus Travma Acil Cerrahi Derg 2022;28(5):678-685 doi: 10.14744/tjtes.2021.24657