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Potential Risk Factors in Development of the "Halo Sign" in Patients Performed Transpedicular Screw Fixation Through the Posterior Spinal Approach

Posterior Spinal Yaklaşımla Transpediküler Vida Fiksasyonu Yapılan Hastalarda "Halo İşareti" Gelişimindeki Potansiyel Risk Faktörleri

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Abstract: It has been shown in literature that a fibrous tissue called "halo sign" in the radiological terminology can develop around the transpedicular screws implanted incompletely and/or incorrectly, which appears after movement of the screw in the cancellous bone. In this retrospective clinical study, 141 patients who underwent posterior spinal instrumentation for thoracic, lumbar or thoracolumbar vertebrae were evaluated using computed tomography (CT) and direct X-rays images for "halo sign" formation which refers in probable failure of spinal instrumentation. Hospital records included in the year 2014-2018 were examined and adult patients who were performed lumbar, thoracal, and thoracolumbar spinal instrumentation via posterior approach due to reasons such as "spine fracture", "spondylosis", "spondylolisthesis" and "intervertebral disc hernia" were included and evaluated in this study. The age and sex of the patients were recorded. Spinal X-ray and spinal CT images obtained during the postoperative follow-up period were examined. Halo sign was seen in 13 patients. Age (p=0.013), number of instrumented vertebrae (p=0.001) and number of transpedicular screws (p<0.001) values were different between the patients with halo sign and patients without halo sign. As a result, it was observed in this study that the formation of the halo sign in posterior spinal instrumentation system could develop in proportion to the number of transpedicular screw and patients' age. It was thought that the halo sign formation was not connected with the parameters called performed laminectomy, gender, inserted intervertebral cage, or vertebral region which were inserted transpedicular screws.

Keywords: transpedicular screw, spinal instrumentation, halo sign, posterior approach, fusion failure.

Özet: Omurgaya doğru şekilde yerleştirilmeyen transpediküler vidaların kemik yapı içerisinde hareketine ikincil olarak vidaların etrafında ortaya çıkabilen fibröz dokuya radyolojik terminolojide "halo işareti" adı verilmektedir. Bu retrospektif klinik çalışmada, torasik, lomber veya torakolomber vertebra için posterior spinal enstrümantasyon yapılan 141 hasta incelendi ve bu hastalardaki spinal enstrümantasyonun muhtemel başarısızlığını ortaya koyan "halo işareti" oluşumu bilgisayarlı tomografi (BT) ve direkt grafi görüntüleri kullanılarak değerlendirildi. Bu klinik çalışmada 2014-2018 yıllarına ait hastane kayıtları incelenerek "omurga kırığı", "spondiloz", "spondilolistez" ve "intervertebral disk hernisi" gibi nedenlerle posterior yaklaşımla lomber, torakal ve torakolomber spinal enstrümantasyon uygulanan yetişkin hastalar çalışmaya dahil edildi. Hastaların omurgaları, ameliyat sonrası takip döneminde elde edilen direkt grafi görüntüleri ve BT görüntüleri kullanılarak değerlendirildi. Bulgular: 13 hastada halo belirtisi görüldü. Halo işareti olan ve halo işareti olmayan hastalar arasında yaş (p = 0.013), vida kullanılan omurga sayısı (p = 0.001) ve transpediküler vida sayısı (p <0.001) değerleri farklıydı. Bu çalışmanın sonucunda, posterior spinal enstrümantasyon sisteminde halo işaretinin oluşumunun transpediküler vida sayısı ve hasta yaşı ile orantılı olarak gelişebileceği gözlendi. Halo işareti oluşumunda "laminektomi" uygulanmasının, "intervertebral kafes" uygulanmasının, cinsiyetin veya "transpediküler vidanın uygulandığı omurga seviyesi"nin etkili olmadığı düşünüldü.

Anahtar Kelimeler: transpediküler vida, spinal enstrümentasyon, halo işareti, posterior yaklaşım, füzyon yetmezliği

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1. Introduction

The transpedicular screw system developed by Roy-Camille (1) in 1986 has been successfully used for stabilization of vertebra fractures, spondylolisthesis, vertebral tumors, kyphosis and scoliosis since three decades. Up to now, many different methods for applying the transpedicular screw system have been described (such as drilling, tapping, or screwing only by making a small hole in the cortical bone) (2,3). Today, the main purpose of instrumentation applied to the spine is to prevent the spinal cord from being exposed to instability, to provide the fracture reduction and/ or bone fusion if there is fractured spine, spondylosis and / or spondylolisthesis. After this instrumentation, it has been shown that the mobility of the relevant spinal segment is significantly reduced and arthrodesis develops in this spinal segment (4,5).

On the other hand, it has been reported that short or long term complications related to this surgical procedure may also occur (such as malposition, spinal cord and / or nerve root injuries, major vascular injuries, infection, dura laceration, cerebrospinal fluid fistula and / or collection). It has also been pointed out that there may be screw loosening and screw / rod fracture problems during the operation or long term period postoperatively, and it has been argued that this may lead to system failure (6,7). Fusion failure after spinal instrumentation is usually resulted in poor bone structure or healing, poor alignment of the fusion, failure of the transpedicular screw to interface with the bone interface or instrument components, resulting in pain and eventual implant failure (5,8). It has been shown in the literature that a fibrous tissue can develop around the transpedicular screws placed on the vertebrae in incomplete and / or incorrectly implanted, which appears after the movement of the screw in the cancellous bone. This tissue was reported to appear as a space around the screw on both computed tomography (CT) and direct X-rays, and this gap was called "halo sign" in the radiological terminology (9,10).

In this retrospective clinical study, patients who underwent posterior spinal instrumentation for thoracic, lumbar or thoracolumbar vertebrae were evaluated using CT and direct X-rays images for "halo sign" formation which refers to probable failure of the spinal instrumentation. In addition, some factors that may be associated with the formation of the "halo sign" have been tried to be revealed.

2. Materials and Methods

This study was done after the decision of the local ethical committee.

In the study, hospital records included in the year 2014-2018 were examined. The adult patients who was performed lumbar, thoracal, and thoracolumbar spinal instrumentation via posterior approach due to reasons of the "spine fracture", "spondylosis", "spondylolisthesis" and "intervertebral disc hernia" were included in the study. Patients who had any reason described at below were excluded from the study:

- spinal instrumentation performed to cervical vertebrae
- any infection related to the instrument
- underwent corpectomy for any reason (such as vertebrae tumor, infection etc.)
- instrumentation on the anterolateral approach
- broken rod/screw
- children

The age and sex of the patients were recorded. Spinal X-ray and spinal computed tomography (CT) images obtained during the postoperative follow-up period of the study were examined and the following information about the patient was retrospectively recorded and evaluated:

- **Etiology**: the reason for the operation (fracture, spondylosis, spondylolisthesis, intervertebral disc hernia)
- **Region**: The lumbar, thoracic or thoracolumbar vertebrae segment in which the screws are placed
- **Level**: number of vertebrae applied the instrumentation device
- **Nscrew:** number of transpedicular screws

- **Laminectomy:** application of vertebral laminectomy
- **Fasetectomy:** application of facetectomy
- **Cage:** intervertebral cage
- **Graft:** use of bone graft for bone fusion
- **Halo:** halo sign formation

Statistical analysis

It was determined that the patients' data were not normal and homogeneous. Mann Whitney U test was used in the comparison of two groups and $p<0.05$ value was considered as statistically significant. Kruskall Wallis test was used to compare the data of all groups when there were more than two groups, $p<0.05$ value was considered to be significant. Mann Whitney U test and Bonferroni Correction test were used for binary comparisons of these groups and $p<0.01$ or $p<0.0083$ was considered statistically significant.
Spearma's rho test was used to examine the correlation between the parameters of the patients and $p<0.05$ was considered statistically significant.

3. Results

141 patients (female=80, male=61) were included in this study. When all patients data was examined, the following information was obtained: The mean age of the patients was 56 ± 13.74 years. Halo sign (Halo) was seen in 13 patients. It was observed that the instrumented vertebral segment (Region) was generally the lumbar region. The number of vertebrae performed laminectomy (Laminectomy) was 1 ± 1.04. The patients had not undergone the facetectomy in general. The number of vertebrae included in instrumentation (Level) was 3 ± 1.53 and the number of applied transpedicular screws (Nscrew) was 6 ± 2.07. Spinal instrumentation was generally applied to patients with lumbar spondylosis (Etiology). For bone fusion and augmentation of the spinal instrumentation device, bone grafts (autogenous and allograft bone mixture) were commonly used. The intervertebral cage (Cage) was not added to the instrumentation device in general. The mean follow-up period of the patients was 4 ± 1.20 years. (Table 1) When the patients were divided into two groups according to gender, it was observed that the values of Region ($p<0.001$) and Etiology ($p = 0.013$) were different among the groups (Table 2).

Table 1. Descriptive Table of All Patients

Variable	Minimum	Maximum	Median	SD
Age (Year)	20	82	56	13.74
Halo	0	1	0	0.29
Level	2	10	3	1.53
Regıon	1	3	1	0.83
Nscrew	4	14	6	2.07
Lamınectomy	0	5	1	1.04
Facetectomy	0	6	0	0.99
Etıology	1	4	2	0.98
Graft	0	1	1	0.50
Cage	0	6	0	0.98
Followup	1	5	4	1.20

(Etıology: the reason for the operation (fracture=1, spondylosis=2, spondylolisthesis=3, intervertebral disc hernia=3); Regıon: the vertebrae segment in which the screws are placed (lumbar=1, thoracic=2, thoracolumbar=3); Level: number of vertebrae applied the instrumentation device; Nscrew: number of transpedicular screws; Lamınectomy: application of vertebral laminectomy (no=0, yes=1); Fasetectomy: application of facetectomy (no=0, yes=1); CAGE: application of the intervertebral cage (no=0, yes=1); Graft: use of bone graft for bone fusion (no=0, yes=1); Halo: halo sign formation (no=0, yes=1); Min: minimum, Max: maximum, SD: standard deviation)

Table 2. When patients were divided into two groups according to the gender, it was seen that the most of the instrumented segment of the vertebrae was lumbar region and that the reason for the application was spondylosis. Mann Whithney U test, p<0.05.

Variable	Female (n=80)	Male (n=61)	P
Age	59±13.37	51±14.15	0.066
Halo	0±0.30	0±0.28	0.715
Level	3±1.24	3±1.79	0.054
Regıon	1±0.64	1±0.96	<0.001
Nscrew	6±1.82	6±2.35	0.252
Lamınectomy	2±0.95	1±1.15	0.118
Facetectomy	0±1.01	0±0.97	0.478
Etıology	2±0.88	2±1.07	0.013
Graft	1±0.48	0±0.50	0.084
Cage	0±0.92	0±1.06	0.571

Age (p = 0.013), Level (p = 0.001) and Nscrew (p <0.001) values were different between the patients with halo sign (n = 13) and patients without halo sign (n = 128) (Table 1). Halo sign was seen in 8 patients with lumbar spinal instrumentation (Figure 1, Figure 2, Figure 3) and 5 patient with thoracolumbar spinal instrumentation (Figure4). Eight of the 13 patients With Halo Sign Were Found To Be Applied Bone Grafts For Bone Fusion, But No Bone Fusion Was observed on follow-up radiological images of these patients. At least one level lumbar laminectomy was applied to all of these patients, but only one patient underwent facetectomy. (Table 3)

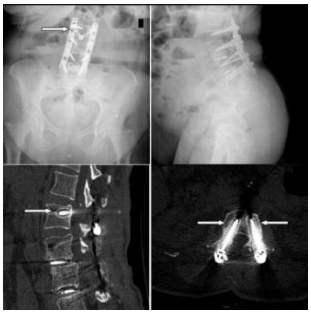

Figure 1. Loosening of the transpedicular screws applied to the lumbar region of the female patient with spondylolisthesis can be seen at the X-ray and reconstructed computerized tomography images (with white arrows).

Figure 2. Loosening of the transpedicular screws applied to the lumbar region of the male patient with degenerative spondylosis can be seen at the X-ray and reconstructed computerized tomography images (with white arrows).

Figure 3. Loosening of the transpedicular screws applied to the lumbar region of the female patient with degenerative spondylosis can be seen at the X-ray and reconstructed computerized tomography images (with white arrows).

Figure 4. Loosening of the transpedicular screws applied to the thoracolumbar region of the male patient with vertebral fractures can be seen at the X-ray and reconstructed computerized tomography images (with white arrows).

Table 3. When all patients were divided into two groups with and without halo sign, it was found that the halo sign was occured in older patients and when transpedicular screws were implanted more than four vertebrae. Mann-Whitney U test, p <0.05

Variable	Halo Sıgn (-) (n=128)	Halo Sıgn (+) (n=13)	P
Age	54±13.18	68±17.13	0.013*
Gender	0±0.50	0±0.51	0.715
Level	3±1.51	4±1.26	0.001*
Regıon	1±0.81	1±1.01	0.200
Nscrew	6±2.05	8±1.28	<0.001*
Lamınectomy	1±1.03	2±1.11	0.141
Facetectomy	0±1.03	0±0.55	0.877
Etıology	2±0.99	2±0.72	0.209
Graft	1±0.50	1±0.48	0.369
Cage	0±0.84	1±1.80	0.188

Patients were divided into three groups considering the lumbar (n = 105), thoracic (n = 5) or thoracolomber (n = 31) spine segments in which transpedicular screws were placed. The values of age (p = 0.002), gender (p = 0.001), Nscrew (p <0.001), Laminectomy (p = 0.007), Etiology (p <0.001) and Cage (p <0.001) were found to be different among the groups. At the end of the binary comparison of the groups, it was found that the values of Etiology (p <0.001) were different between the groups with lumbar and thoracic spine segments. The values of the age (P = 0.001), gender (p <0.001), Nscrew (p <0.001), Laminectomy (p = 0.007), Etiology (p <.001) and Cage (p <0.001) were different between the groups with lumbar and thoracolumbar spine segments (Table 4).

Table 4. When all the patients were divided into three groups according to the vertebral segments implanted transpedicular screws (lumbar, thoracic, thoracolumbar regions), it was observed that the incidence of the halo sign formation was not different between the groups. Kruskall Wallis test, p <0.05

Variable	Lumbar (n=105)	Thoracıc (n=5)	Thoracolumbar (n=31)	P
Age	58.50±11.57	46±9.26	48±17.69	0.002*
Gender	0±0.48	1±0.50	1±0.46	0.001*
Halo	0±0.26	0±0.00	0±0.37	0.285
Level	3±0.87	5.50±2.08	5±1.65	<0.001*
Nscrew	6±1.66	8.50±3.30	8±1.20	<0.001*
Lamınectomy	2±0.91	1±0.96	1±1.33	0.007*
Facetectomy	0±0.98	0±0.00	0±1.12	0.732
Etıology	2±0.87	1±0.00	1±0.67	<0.001*
Graft	1±0.49	0±0.50	1±0.51	0.374
Cage	1±1.00	0±0.00	0±0.80	<0.001*

According to the etiologic factors, the patients were divided into four groups as vertebral fracture (n = 39), spondylosis (n = 65), spondylolisthesis (n = 17) and intervebral disc hernia (n = 20). There was a significant difference among the groups in terms of age (p <0.001), sex (p =0.001), Level (p <0.001), Nscrew (p <0.001), Laminectomy (p = 0.001) and Cage (p <0.001). Binary comparison of groups revealed that all variables were different between fracture and spondylosis groups (p <0.083). All other parameters except for Laminectomy and gender parameters were different between fracture and spondylolisthesis groups (p <0.0083). The values of the Level (p <0.001), Nscrew (p <0.001), and Cage (p = 0.001) were different between the fracture and intervertebral disc herniation groups. Except the age value (p <0.001), there was no difference in terms of the variables between the spondylosis and intervertebral disc herniation groups and between spondylolisthesis and intervertebral disc herniation groups. (Table 5)

Table 5. When all patients were divided into four groups according to the etiologic factors (vertebral fracture, spondylosis, spondylolisthesis, intervertebral disc hernia), it was observed that the halo sign formation incidence was not different between the groups. Kruskall Wallis test, p <0.05

Variable	Fracture	Spondylosis	Spondylolisthesis	Disk Hernia	P
Age	48±16.50	60±10.26	62±11.25	47±11.045	<0.001*
Gender	1±.47	0±0.46	0±0.49	0±0.51	0.001
Halo	0±0.34	0±0.29	0±.332	0±0.00	0.432
Level	5±1.66	3±1.10	3±1.06	3±0.50	<0.001*
Regıon	3±0.82	1±0.35	1±0.48	1±0.45	<0.001*
Nscrew	8±2.08	6±1.80	6±2.12	6±0.98	<0.001*
Lamınectomy	1±1.04	2±0.90	2±1.30	1±0.88	0.001
Facetectomy	0±1.11	0±0.56	0±1.72	0±0.98	0.317
Graft	1±0.50	1±0.49	1±0.51	.50±0.51	0.789
Cage	0±0.35	1±1.10	1±1.20	0±0.50	<0.001*

Correlation analysis findings

The following findings were obtained from the correlation analysis made with all patients. There was a positive correlation between age and Halo (p = 0.012) and between age and Laminectomy (p = 0.004) while there was a negative correlation between age and Region (p <0.001). There was a positive correlation between values of gender and Laminectomy (p = 0.013), between gender and Etiology (p = 0.001), while there was a negative correlation between gender and Region values (p <0.001). There was a positive correlation between Halo

and Level (p = 0.001) and between Halo and Nscrew (p <0.001). Positive correlations were found between Level and Nscrew (p <0.001), between Level and Region (p <0.001) and between Region and Nscrew (p <0.001) values. There was a negative correlation between Level and Etiology (p <0.001), between Region and Laminectomy (p = 0.003), between Region and Etiology (p <0.001), between Nscrew and Etiology (p <0.001).

In male patients, a positive correlation was found between Halo and Level (p = 0.023), between Halo and Region (p = 0.045), between Halo and Nscrew (p = 0.030) variables. There was a positive correlation between Halo and age (p = 0.038), Halo and Level (p = 0.006), between Halo and Nscrew (p = 0.002), Halo and Laminectomy (p = 0.003) values in female patients.

In the correlation analysis of patients with halo sign, there was a positive correlation between gender and Region (p = 0.011); between Level and Region (p = 0.001), between Level and Nscrew (p <0.001), between Etiology and Laminectomy (p = 0.042), between Etiology and Cage (p = 0.033). In contrast, negative correlation was found between Etiyology and gender (p = 0.013), between Etiology and Level (p = 0.001), between Laminectomy and gender (p = 0.024), between Laminectomy and Region (p = 0.024).

In patients with lumbar spinal instrumentation device, a positive correlation was found between Halo and age (p = 0.004), between Halo and Level (p = 0.001), between Halo and Nscrew (p <0.001), between Halo and Laminectomy (p = 0.004), between Halo and Cage (p = 0.036).

According to the etiologic factors, positive correlation was found between Halo and Level (p = 0.002), between Halo and Nscrew (p = 0.001), between Halo and Laminectomy (p = 0.046) variables in patients with spondylosis.

4. Discussion

Although CT scan is frequently used to evaluate the transpedicular screw loosening, image distortion (artefact) caused by metal instrumentation material is a major disadvantage and can lead to false negative or false positive results (11,12). However, CT scan is still the only accepted method in literature to evaluate osseous progression after spinal fusion surgery, to determine screw positions, to confirm the integrity of instrumentation elements, to detect suspicious complications, to investigate new disease and / or disease progression (5,8,13,14). It is believed that the screw loosening aetiology is multifactorial and may depend on the patient characteristics (such as age, gender, weight bearing), strength type of screws, operation technique, and the length of the spinal segments to be fused (5,8,15). Indeed, On the other hand, screw loosening is thought to occur most frequently in patients with thoracolumbar posterior instrumentation (4,18,19,20). It is argued that the pulling force of the transpedicular screw is not only dependent on the bone volume between the screw threads, but also on the triangular area created by the reciprocated screws (5,8,21).

At the end of this study, when all patient findings were evaluated, it was found that the majority of the patients were female and the mean age was 56 ± 13.74 years. It was observed that the spinal instrumentation was commonly applied to the lomber region and to the patients with spondylosis, and laminectomy was performed during this surgical treatment, but the facet joints were not intervened. Generally, it was found that at least one cage was placed in the intervertebral space of the patients and the patient was given a chance to bone fusion by autogenous and / or allogeneic bone grafting, but no bone fusion occurred in any patient except one patient.

When all patients were divided into two group according to the gender, the age was higher and spondylosis (N: 46, 57.50%) required this surgical treatment in female patients. In female group, spinal instrumentation commonly was applied to the lumbar region and the follow-up period was longer. However, the spinal instrumentation used in male patient group was mainly aimed at treating the vertebral fracture (N: 27, 44.26%); the spinal region to which the instrumentation was applied was frequently thoracolumbar and thoracal regions. In this patient group, it was determined that there

was no intervertebral cage in general, the number of vertebra applied laminectomy was less and the follow up periods were shorter. There was no statistical difference either halo sign formation or number of transpedicular screws between male and female patients.

In literature, it was reported that screw loosening, migration, or screw pull-out rates are found to be higher in patients with osteoporosis (60% of the patients with osteoporosis) and / or diabetes mellitus in elderly population and bone mineral density and quality of the vertebrae could reduce with age progression and therefore the strength of the applied transpedicular screws could reduced (16,17). With the decrease in strength, it was thought that the applied screws moved in the vertebral body and there was occured a gap around the screws due to this movement (17,18). Altough this study did not include the results of bone mineral density measurements of the patients, the findings of present study revealed that only 13 (female: 8, male: 5) of the patients had halo sign and no correlation was found between gender and halo sign formation and between the age and halo sign formation. Therefore, the absence of a relationship between gender and halo sign formation in this study suggested that there could be no relationship between halo sign formation and post-menopausal osteopenia / osteoporosis.

When the results of patients with halo sign were compared to patients without halo sign, it was found in this group that the average age (68 ± 17.13), the number of instrumented vertebrae (4 ± 1.26) and the number of transpedicular screws (8 ± 1.28) of these patients were high. Laminectomy was applied to all of these patients, facet joints were found to have no intervention at all, and bone grafts were placed into the surgical area to provide bone fusion, but no bone fusion was occured. On the other hand, correlation analysis results revealed that if the number of applied screws increases, the resistance and orientation of the applied spinal instrumentation device are impaired, which may be considered to contribute to the formation of the halo sign by disrupting the spinal dynamic.

In literature, long-segment instrumentation is recommended to maintain stability especially at the level of the thoracolumbar junction (22). When the patients were evaluated according to the spinal segments called REGION (lumbar, thoracic, thoracolumbar) where transpedicular screws were applied, it was observed that the age of the patients who underwent lumbar stabilization were found to be more advanced, and this group was generally composed of female patients with spondylosis. In addition, laminectomy and intervertebral cage use was observed more frequently in the instrumentation surgery performed to the lumbar region. It was found that there was no difference in incidence of halo sign formation for all three spine segments. However, correlation analysis results revealed that as the number of instrumented vertebrae increased and the number of transpedicular screws used increased, the risk of halo sign formation increased. Based on these findings, it was concluded that the instrumented spine segment was not directly effective in the halo sign formation, but that the number of screws in the instrumentation applied to the thoracolumbar region was increased and related to this the halo sign could increase in this region. On the other hand, it was thought that the halo sign formation on the lumbar region was also related to the performed laminectomy as many as the number of the screws. It was thought that the performing laminectomy might impair the spinal dynamic and increase the transpedicular screw load and contribute to halo sign formation by causing instrument failure. There was no correlation between the values of patients with other etiologic factors and the occurrence of halo sign.

Limitations

Some limitations were identified in this study. *First*, the findings of the halo sign presented in this study were not based on the technical measures and objective data used to determine the screw loosening. On the contrary, the current method of identification was dependent on observers, radiologists, and neurosurgeons interpreting their imaging studies. However, to demonstrate the halo sign, subjective analysis of the CT and dynamic X-ray images which were accepted in the literature were used in current study.

The methods used in this study do not perfectly describe the screw loosening assessment but are currently the best available evidence and clinically practical method (14). *Second*, this study could not show the actual timing of the screw loosening event that could occur earlier from the clinical impairement. *Third*, since this study was a retrospective study, the results of bone mineral density measurements and body mass index of all the patients included the study could not be obtained. For this reason, the relationship of these parameters with the formation of the halo sign could not be clearly elucidated. *Fifth*, the technical characteristics of the instrumentation devices applied to the patients were not similar to each other. Moreover, the implementation of these devices was performed by different surgeons. For this reason, possible associations between halo sign formation and spinal instrumentation devices and the relationship between halo sign formation and surgical technique have not been properly demonstrated in this study. *Sixth*, this study was constructed to identify "halo sign" formation in patients who underwent posterior spinal instrumentation for thoracic, lumbar or thoracolumbar vertebrae and to show some factors associated with the formation of the "halo sign". Therefore, some clinical characteristics (such as physical and neurological examination findings, Visual Analog Scale scores, Oswestry Disability Index scores, morbidity and mortality rates, etc.) of the patients were not included into this study, since we thought that these parameters could confuse the study findings.

5. Conclusion

As a result, it was observed that the formation of the halo sign in posterior spinal instrumentation system was seen more in proportion to the number of transpedicular screws and patient age in the study group. Moreover, it was thought with these findings that halo sign formation did not directly connect with those parameters called performing the laminectomy, the gender, the spine segment, or inserting the intervertebral cage.

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