Original Article

J. of Advanced Spine Surgery
Volume 14, Number 2, pp33~40

JASS

Initial Clinical Experience with Spine-Jack® in Thoracolumbar Vertebral Compression Factures: A Comparative Analysis with Kyphoplasty

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Purpose: Thoracolumbar vertebral compression fractures (VCFs) are a leading cause of kyphosis and related biomechanical complications, often resulting in chronic back pain and reduced function. Balloon kyphoplasty has been widely used as a minimally invasive intervention to provide pain relief and restore vertebral height. The Spine-Jack system is a relatively novel technique that introduces mechanical distraction, offering potentially enhanced vertebral restoration. This study aims to compare these two effective treatments for thoracolumbar fractures.

Materials and Methods: This study analyzed 30 patients with thoracolumbar VCFs surgically treated, using the Spine-Jack system (n=10) or balloon kyphoplasty (n=20). Back pain was evaluated as VAS pain score and functional disability was assessed with Oswestry Disability Index (ODI) preoperatively and immediately postoperatively. Radiological outcomes were measured on plain lateral X-rays, including vertebral height restoration, segmental kyphosis angle, and sagittal vertical axis (SVA). Complications, such as cement leakage and adjacent vertebrae fractures, were recorded. Continuous variables – with t-tests and categorical variables- with chi-square tests, were analyzed. P-value less than 0.05 was considered statistically significant.

Results: Both the Spine-Jack system and balloon kyphoplasty were effective in reducing back pain and improving patients' function, with significant improvements in VAS and ODI scores. However, the Spine-Jack system demonstrated superior vertebral height restoration (85% vs. 72%, p=0.03) and segmental kyphosis angle correction (12° vs. 9°, p=0.032) when compared to balloon kyphoplasty. Complication rates were all low and comparable between the two groups.

Conclusions: Although the Spine-Jack system and balloon kyphoplasty are all effective for thoracolumbar VCFs, the Spine-Jack system offered superior radiological outcomes in selected cases. Further studies may explore their complementary roles in managing thoracolumbar VCFs.

Keywords: Thoracolumbar compression fractures, Spine-jack, Kyphoplasty, Vertebral height restoration, Minimally invasive spine surgery

Introduction

Thoracolumbar vertebral compression fractures (VCFs) are common among elderly and osteoporotic populations and can lead to significant morbidity.[1,2)] Kyphosis is often caused by thoracolumbar VCFs and clinical, biomechanical

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problems -such as chronic back pain, functional impairment, and further deformity progression- can hinder daily life in patients with VCFs.[3-6] In these cases, minimally invasive interventions like kyphoplasty are widely used for their effectiveness in pain relief, vertebral height restoration, and correction of kyphotic deformity. Balloon kyphoplasty, with its established reliability, has been the standard of care for many years.[7-9]

However, with advancements in medical technology, a relatively novel technique - the Spine -Jack system has been introduced as an alternative. While balloon kyphoplasty has established efficacy through many studies, this system employs mechanical distraction to enhance vertebral height restoration and segmental kyphosis correction, potentially offering improved outcomes in specific clinical scenarios.[10,11]

This study aims to compare the effectiveness of kyphoplasty with the relatively novel Spine-Jack system in managing thoracolumbar VCFs. We tried to compare the clinical and radiological outcomes of both treatments for thoracolumbar VCFs, highlighting their effectiveness and potential advantages.

Materials and Methods

This study was approved by the institutional review board at our institution (IRB file no. 4-2024-1436).

1. Study Design

This study is a retrospective observational study of VCF patients treated with kyphoplasty between June 2024 and December 2024. Adults aged from 50 to 85 years old with single-level thoracolumbar VCFs (from T10 to L2) caused by osteoporosis or trauma were included in the study. Patients with pathological fractures, multilevel VCFs, prior spine surgery done at the fracture level, or patients who had other systemic contraindications to surgical procedures were all excluded.

The patients underwent kyphoplasty surgery if they showed compression deformation between 30–60% and experienced severe back pain persisting after more than three weeks of conservative treatment. Among the 30 patients who underwent kyphoplasty surgery, 10 patients were treated with the Spine-Jack system, and the rest (20 patients) were treated with ordinary balloon kyphoplasty.

2. Surgical Procedure:

1) Spine-Jack system

The procedure starts with bilateral pedicular access under fluoroscopic guidance. The Spine-Jack® system (VEXIM, a Stryker Company, France) was used, consisting of a titanium implant designed for mechanical distraction. Once inserted into the vertebral body, the device was expanded incrementally to restore vertebral height. PMMA bone cement (SpinePlex®, Stryker) was injected in equal volumes of 2 cc on each access- 4 cc in total- through the access cannula to stabilize the restored vertebra and prevent further collapse (Fig. 1).

2) Balloon kyphoplasty

The kyphoplasty procedure also starts with bilateral pedicular access under fluoroscopic guidance. The Kyphon® Balloon Kyphoplasty System (Medtronic, USA) was used. Balloon tamps were inserted into the vertebral body through each access cannula and balloons were inflated to create a cavity and restore vertebral height. Once the desired cavity size was achieved, balloons were deflated and removed. PMMA cement (Kyphon HV-R®, Medtronic) was injected in equal volumes of 2 cc on each access- 4 cc in total- through the access cannula to stabilize the vertebra and maintain height restoration (Fig. 2).

3. Radiological and clinical outcome measurements

Vertebral height was measured on plain lateral X-rays preoperatively and immediately postoperatively as the anterior vertebral body height of the fractured vertebra. The anterior vertebral height was defined as the vertical distance between the anterior superior endplate and the anterior inferior endplate. Height restoration was definted as a percentage increase from the preoperative vertical height to the immediate postoperative vertical height, relative to the estimated normal vertical height. The estimated normal height was calculated by averaging the corresponding vertical heights of the unaffected adjacent vertebrae (one level above and below the fractured vertebra).

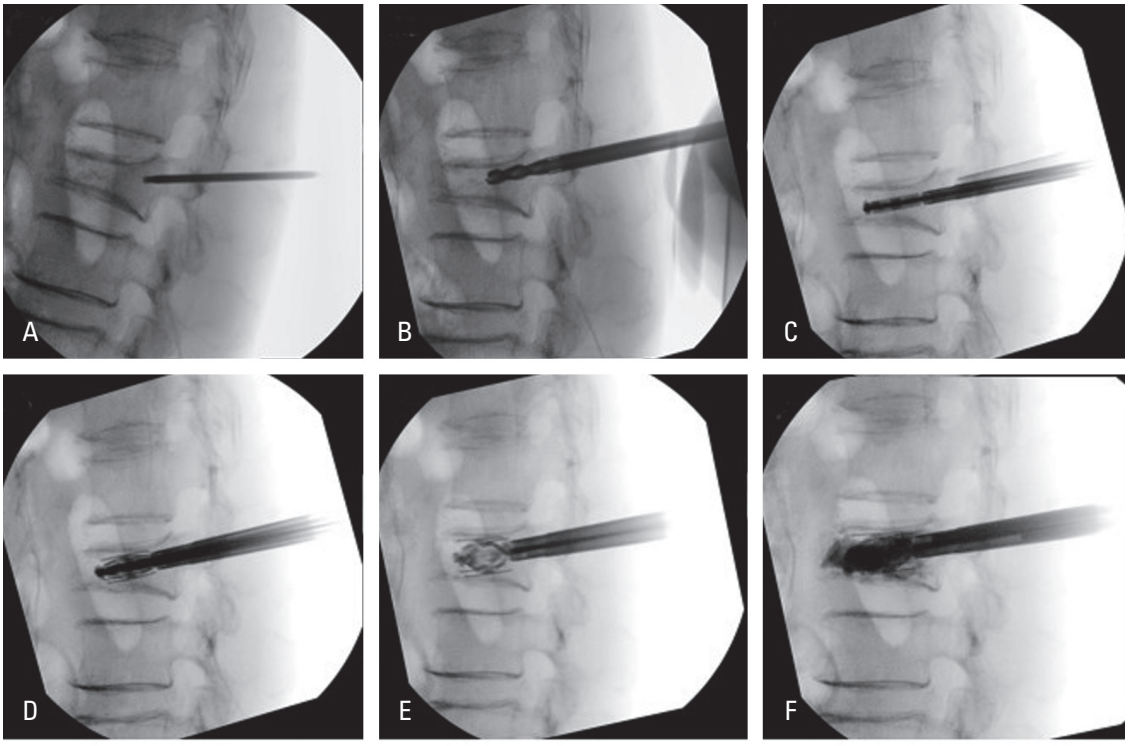

Fig. 1. Intraoperative radiographic images of kyphoplasty using the Spine-Jack system.
(A) Fluoroscopic lateral image of pedicular access to the vertebral compression fracture. **(B)** Reaming of vertebral body to acquire enough space for titanium implant. **(C)** Insertion of titanium implant into the vertebral body. **(D)** Incremental restoration of vertebral height by expanding the implant cranio-caudally. **(E)** Same procedure done through contralateral pedicular access. **(F)** Insertion of PMMA cement for stabilization.

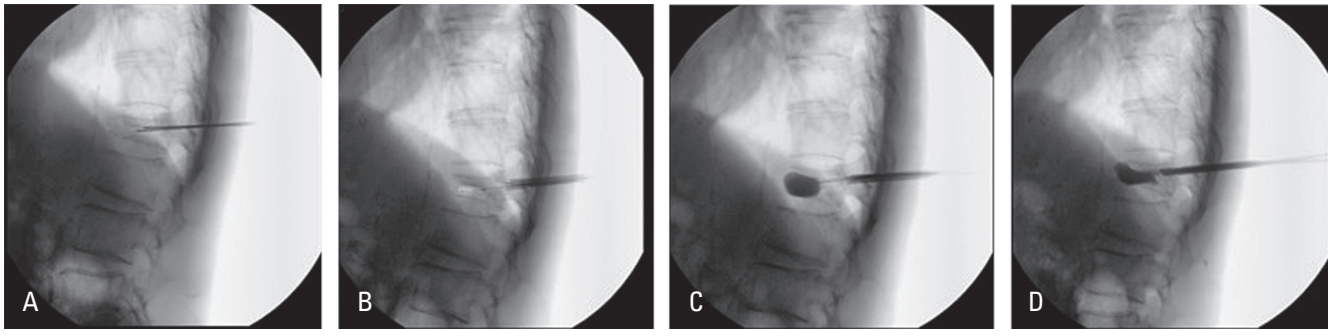

Fig. 2. Intraoperative radiographic images of balloon kyphoplasty.
(A) Fluoroscopic lateral image of bilateral pedicular access to the vertebral compression fracture. **(B)** Insertion of balloon tamps into the vertebral body. **(C)** Incremental inflation of balloon tamps to restore vertebral height After achieving the desired cavity size, balloon tamps are deflated and removed. **(D)** Insertion of PMMA cement to the cavity for stabilization.

1) The formula used was

Height Restoration (%)=[(Postoperative Height-Preoperative Height) / Estimated Normal Height]×100

Segmental kyphosis angle was measured using the Cobb's angle between the superior endplate one level above the fractured vertebra and the inferior endplate one level below the fractured vertebra. The Sagittal Vertical Axis (SVA) was measured using the distance from the C7 plumb line to the posterior superior corner of the sacrum, which indicates the global sagittal alignment of a patient.

Clinical outcomes were evaluated by measuring improvements in back pain using the Visual Analog Scale (VAS) and functional disability using the Oswestry Disability Index (ODI), recorded preoperatively and immediately postoperatively.

2) Statistical analysis

Statistical analysis was conducted using t-tests for continuous variables, such as VAS and ODI scores, and chi-square tests for categorical variables, such as complication rates. Data were analyzed using SPSS Statistics version 28.0 (IBM Corp., Armonk, NY, USA). P-values were reported to three decimal places, with statistical significance defined as p-value<0.05.

Results

In this study, the demographic characteristics of patients treated with the Spine-Jack system and balloon kyphoplasty were comparable without a statistically significant difference. The average age was 68.4±7.2 years in the Spine-Jack system group and 69.8±6.5 years in the balloon kyphoplasty group (p=0.652). The gender distribution also showed no significant difference, with a female-to-male ratio of 6:4 in the Spine-Jack system group and 14:6 in the balloon kyphoplasty group (p=0.743). The severity of osteoporosis measured as Bone Mineral Density (BMD) was similar between the two groups, with values of -2.4±0.5 g/cm² and -2.3±0.4 g/cm², respectively (p=0.581). The mean procedure time was significantly longer in the Spine-Jack system group at 35.4±5.6 minutes compared to 30.8±6.1 minutes for balloon kyphoplasty (p=0.014) (Table 1).

Table 1. General demographics

Variable	Spine Jack (n=10)	Kyphoplasty (n=20)	p-value
Mean age (years)	68.4±7.2	69.8±6.5	0.652
Gender (F/M)	6/4	14/6	0.743
BMD[a] (g/cm²)	-2.4±0.5	-2.3±0.4	0.581
Fractured level	T12 (5), L1 (3), L2 (2)	T12 (8), L1 (8), L2 (4)	-
Procedure time (min)	35.4±5.6	30.8±6.1	0.014

[a]BMD: Bone Mineral Density.

Both techniques demonstrated substantial improvements in clinical and radiological outcomes. For clinical outcomes, back pain VAS scores were significantly reduced in both groups, from 8.1±0.8 preoperatively to 2.3±0.6 postoperatively in the Spine-Jack system group, and from 8.0±0.7 to 2.5±0.5 in the balloon kyphoplasty group (p<0.01). Similarly, ODI scores improved significantly, with reductions from 72±10 to 28±8 in the Spine-Jack system group and from 71±9 to 30±7 in the balloon kyphoplasty group (p<0.01).

Radiological outcomes also showed better results for the Spine-Jack system. Vertebral height increased from 18.3±2.2 mm to 25.2±2.1 mm in the Spine-Jack system group, resulting in a height restoration of 37.70±4.3%. In the balloon kyphoplasty group, vertebral height improved from 18.5±2.3 mm to 23.4±2.2 mm, resulting in a height restoration of 26.67±3.7%. The difference in height restoration percentage between the two groups was statistically significant with a p-value of 0.035. Segmental kyphosis angle correction, measured as an improvement in Cobb's angle, was more pronounced in the Spine-Jack system group. The segmental kyphosis angle decreased from 18.2±3.5° to 5.8±1.2° in the Spine-Jack system group, while it decreased from 17.9±3.3° to 8.8±1.5° in the balloon kyphoplasty group (p=0.028). Sagittal Vertical Axis (SVA) also showed statistically significant improvement in the Spine-Jack system group, decreasing from 30.4±4.2 mm to 24.6±3.8 mm, when compared to the balloon kyphoplasty group, decreasing from 30.8±4.1

Table 2. Preoperative and postoperative clinical and radiological outcomes for the spine jack and Kyphoplasty groups

Outcome	Preoperative spine jack	Postoperative spine jack	Preoperative kyphoplasty	Postoperative kyphoplasty	p-value
VAS Score[a]	8.1±0.8	2.3±0.6	8.0±0.7	2.5±0.5	<0.01
ODI[b] (%)	72±10	28±8	71±9	30±7	<0.01
Vertebral height (mm)	18.3±2.2	25.2±2.1	18.5±2.3	23.4±2.2	0.035
Height restoration (%)	-	37.70±4.3	-	26.67±3.7	0.032
Cobb's angle (°)	18.2±3.5	5.8±1.2	17.9±3.3	8.8±1.5	0.028
SVA[c] (mm)	30.4±4.2	24.6±3.8	30.8±4.1	26.2±3.9	0.041

[a]VAS: Visual Analog Scale, [b]ODI: Oswestry Disability Index, [c]SVA: Sagittal Vertical Axis.

mm to 26.2±3.9 mm (p=0.041) (Table 2).

Regarding complications, both techniques were generally safe. The Spine-Jack system group had one case of asymptomatic cement leakage, while the balloon kyphoplasty group experienced three cases of cement leakage, one of which was symptomatic but resolved after conservative treatment.

Discussion

Kyphoplasty has long been established as an effective minimally invasive treatment for thoracolumbar vertebral compression fractures (VCFs). It provides reliable pain relief and functional improvement by stabilizing fractures and partially restoring vertebral height.[7,12,13] Our study showed that, although both procedures effectively reduced pain and improved functional outcomes, the Spine-Jack system achieved significantly superior radiological improvements, particularly in vertebral height restoration and segmental kyphosis angle correction.

One of the key advantages of the Spine-Jack system is its ability to provide uniform mechanical distraction during

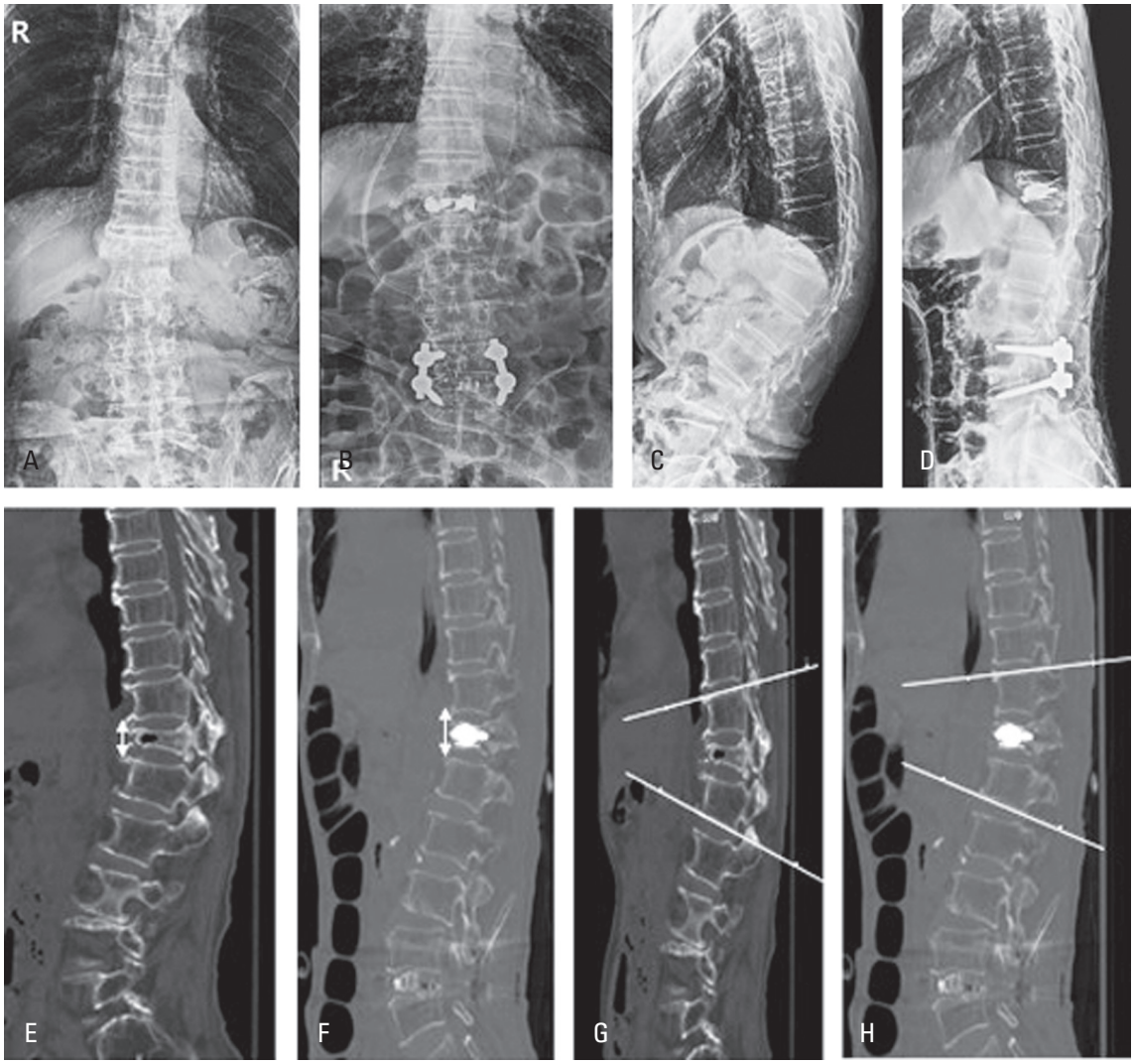

Fig. 3. Preoperative/Postoperative radiographic image of the Spine-Jack system.
(A, C) Preoperative plain anterior to posterior. **(B,D)** Postoperative plain lateral x-ray of the patient underwent kyphoplasty with the Spine-Jack system. **(E, G)** Preoperative. **(F, H)** Postoperative CT sagittal cut of the same patient. Notice the appropriate anterior vertebral height restoration **(E, F)** and segmental kyphosis angle correction. **(G, H)** after using the Spine-Jack system for kyphoplasty.

the procedure (Fig. 3). In this study, the Spine-Jack system group demonstrated a vertebral height restoration of 37.70%, significantly higher than the 26.67% observed in the balloon kyphoplasty group. This result shows agreement with previous studies, which emphasize the mechanical advantage of the Spine-Jack system in restoring vertebral body integrity.[14,15] This is also proven by cadevaric study conducted by Krüger et al. On 24 vertebrae of two intact, fresh human cadaveric spines, vertebral wedge compression fractures were made with a material testing machine. Anterior vertebral height was reduced to 40% of the initial size and each vertebra was placed on 100N loading frame. Among 24 vertebrae, 12 vertebral bodies were treated with the Spine-Jack system while the remaining 12 vertebral bodies were treated using balloon kyphoplasty. The anterior/central and posterior height restoration were all significantly higher in the Spine-Jack system group.[16]

Furthermore, the superior correction of segmental kyphosis in the Spine-Jack system group, which is evident by a greater reduction in segmental Cobb's angle (12.4° vs. 9.1°, p=0.028), underscores its ability to correct sagittal alignment more effectively than balloon kyphoplasty, which agrees with other previous studies.[17] This improvement has critical implications for reducing long-term biomechanical stress and the risk of adjacent segment degeneration afterward.

Despite its advantages, the Spine-Jack system was associated with a slightly longer procedure time (35.4±5.6 minutes vs. 30.8±6.1 minutes, p=0.014). This statistically significant difference may be attributable to the additional steps required for precise device placement and controlled distraction. Furthermore, the cost of the Spine-Jack system is relatively higher when compared to balloon kyphoplasty, which may hinder its broader adoption. Additionally, the reaming process required for implant placement in the Spine-Jack system may cause more intraoperative discomfort or pain, potentially requiring additional anesthesia management.[14] Importantly, the complication rates were low and comparable between the two groups. The Spine-Jack system group had one case of asymptomatic cement leakage, whereas the balloon kyphoplasty group experienced three cases, including one symptomatic event. This finding supports the safety of both procedures and maybe the Spine-Jack system potentially offers more controlled cement application.

The improved radiological outcomes of the Spine-Jack system may imply better long-term patient satisfaction and functional outcomes, although this requires validation through extended follow-up studies. Additionally, the greater kyphosis correction observed with the Spine-Jack system could reduce the risk of chronic pain and deformity progression, further enhancing its clinical utility.

1. Limitations

This study is limited by its small sample size (n=30) and short follow-up period, which only captured immediate postoperative outcomes. Long-term follow-up is necessary to assess the durability of radiological improvements, the impact on adjacent segment degeneration, and overall patient satisfaction.[18] Additionally, larger multicenter studies are needed to validate these findings across diverse patient populations.[19,20]

Conclusions

Spine Jack demonstrates similar or superior outcomes when compared to balloon kyphoplasty for thoracolumbar VCFs, particularly in height restoration and kyphosis correction. Future research with larger cohorts and extended follow-up is necessary to confirm these findings and evaluate long-term outcomes.

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Spine-Jack 을 이용한 흉요추부 추체 압박 골절 치료의 초기 임상 경험: 후만성형술과의 비교 분석

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연세대학교 의과대학 정형외과학교실,[1] 국민건강보험공단 일산병원,[2] 원주연세대학교 의과대학 원주세브란스기독병원 정형외과학교실,[3] 이화여자대학교 의과대학 이대서울병원 정형외과학교실[4]

목적: 흉-요추부 척추 압박 골절은 만성 허리 통증과 기능 저하를 초래하는 척추 후만증 및 관련된 생역학적 합병증의 주요한 원인이다. 그동안 풍선 후만성형술은 통증 완화 및 척추 높이 회복을 제공하는 최소 침습적 수술로 널리 사용되어 왔다. Spine-Jack 시스템은 기계적 추체 확장을 통해 좀 더 향상된 척추 높이 회복을 제공할 수 있는 비교적 새롭게 도입된 기술이다. 본 연구는 흉-요추부 골절에 대한 이 두 가지 효과적인 치료법을 비교하는 것을 목표로 하고 있다.
대상 및 방법: 본 연구는 Spine-Jack 시스템(n=10) 또는 풍선 후만성형술(n=20)을 사용하여 수술적으로 치료한 흉-요추부 척추 압박 골절 환자 30명을 분석하였다. 허리 통증은 VAS 통증 점수로 평가하였고, 환자의 기능 장애는 수술 전후 Oswestry Disability Index (ODI)로 평가하였다. 방사선학적 결과는 측면 단순 X선 사진에서 척추 높이 회복 정도, 분절 후만각, 및 시상 수직 축(SVA)을 측정하였고, 시멘트 누출 및 인접 척추체 골절과 같은 합병증도 기록하였다. 연속 변수는 t-검정을 사용하여, 범주형 변수는 카이제곱 검정을 사용하여 분석하였으며, p값이 0.05 미만인 경우 통계적으로 유의한 것으로 간주하였다.
결과: Spine-Jack 시스템과 풍선 후만성형술 모두 허리 통증을 줄이고 환자의 기능을 개선하는 데 효과적이었으며, VAS와 ODI 점수에서 유의한 개선을 보였다. 그러나 Spine-Jack 시스템은 풍선 후만성형술에 비해 척추 높이 회복(85% vs 72%, p=0.03)과 분절 후만각 교정정도 (12° vs 9°, p=0.032)에서 우수한 결과를 보였다. 합병증 발생률은 두 그룹 간 비슷한 정도로 낮게 확인되었다.
결론: Spine-Jack 시스템과 풍선 후만성형술 모두 흉-요추부 척추 압박 골절의 치료에 효과적이었으나, Spine-Jack 시스템이 몇몇 잘 선택된 사례에서는 더 우수한 방사선학적 결과를 제공할 수 있는 것으로 생각된다. 향후 연구에서는 흉-요추부 척추 압박 골절 환자에서 두 수술적 치료 방법의 상호 보완적 역할을 탐색할 수 있으리라고 기대된다.

색인 단어: 흉-요추부 압박 골절, Spine-Jack, 후만성형술, 척추 높이 회복, 최소 침습 척추 수술.