Modified ASH Brace: A Novel Approach to Kyphoscoliotic Curvature Correction

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Abstract: ***The Modified ASH (Adjustable Spinal Hypercorrective) Brace introduces a novel approach to managing kyphoscoliosis, a spinal condition characterized by combined lateral (scoliotic) and forward (kyphotic) curvatures, by leveraging a concurrent parallelogram framework to apply multi-directional corrective forces. Pre- and post-fitment data demonstrate the brace's ability to reduce obliquity curvature, evidenced by altered spinal area distribution (e.g., left side increasing from 56 cm² to 77 cm², right side decreasing from 71 cm² to 62 cm²) and decreased pressures (maximum pressure reduced from 645 g/cm² to 573 g/cm² bilaterally; average pressure from 427 g/cm² to 324 g/cm² on the left and 365 g/cm² to 248 g/cm² on the right). These changes indicate improved spinal alignment and biomechanical balance, particularly in mild to moderate cases. However, the brace's effectiveness is limited when the concurrent angle (θ) exceeds 45°, restricting its utility in severe deformities. Plantar pressure analysis reveals significant variability in force distribution, suggesting inconsistent weight-bearing patterns possibly due to compensatory mechanisms or patient-specific biomechanics. While the Modified ASH Brace shows promise as a non-invasive treatment, addressing variability in force distribution through advanced design features, such as dynamic force modulation or real-time pressure monitoring, is critical. Integration with complementary therapies, such as the Schroth method, may further enhance outcomes, particularly for complex cases, warranting further research to optimize clinical efficacy across a broader range of severities.***

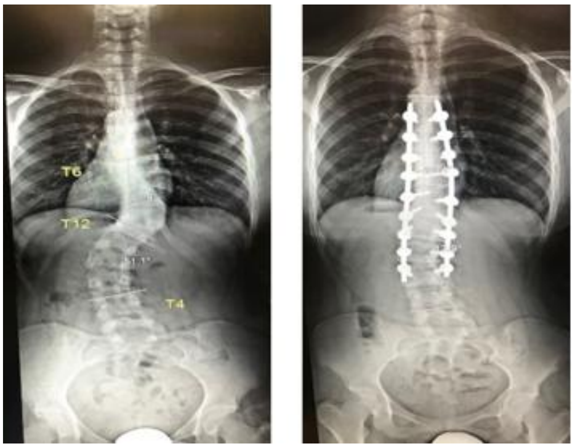
Keywords: kyphoscoliosis management, spinal brace correction, biomechanical alignment, pressure distribution variability, non-invasive spinal therapy

1. Introduction

Kyphoscoliosis is a spinal deformity characterized by abnormal curvature in both the coronal (side-to-side) and sagittal (front-to-back) planes, combining scoliosis (lateral curvature) and kyphosis (excessive forward curvature). Congenital kyphoscoliosis arises from developmental anomalies during fetal growth, leading to structural vertebral and spinal abnormalities. X-ray imaging is critical for diagnosis, revealing distinct findings. Vertebral abnormalities include segmentation defects, where vertebral bodies appear wedge-shaped or butterfly-shaped due to incomplete formation, and fusion defects, where adjacent vertebrae are fused with irregular outlines (Hensinger, 2009). Hemivertebrae, the absence of half a vertebral body, cause asymmetry, while spina bifida occulta reflects incomplete closure of the posterior vertebral arch (McMaster & Singh, 1999). Curvature characteristics include a focal, sharp bend typical of congenital scoliosis, excessive kyphotic rounding in the thoracic or lumbar spine, and rib anomalies such as missing, fused, or malformed ribs (Hedequist & Emans, 2007). Additional findings include a narrowed spinal canal and decreased disc spaces or slipped discs, which may contribute to neurological complications (Winter et al., 1984). These X-ray findings are essential for assessing the severity of the deformity and guiding treatment, which may range from observation to surgical intervention depending on progression and symptoms.

Kyphoscoliosis, a condition involving both lateral (scoliosis) and forward (kyphosis) spinal curvatures, leads to significant spinal instability, posing multiple challenges. The abnormal curvature disrupts the spine's natural alignment, causing uneven load distribution across vertebrae, muscles, and ligaments, particularly at the thoracolumbar junction, where stress is amplified. This structural compromise results in instability, increasing the risk of further deformity and discomfort. The uneven pressure on intervertebral discs accelerates their degeneration, potentially causing bulging or herniation, which worsens instability and contributes to chronic pain. Additionally, individuals with kyphoscoliosis are more susceptible to osteoporosis, a condition that weakens bones, further undermining spinal stability and heightening fracture risk. These interconnected issues create a progressive cycle of spinal deterioration, impacting mobility and quality of life. Research underscores these challenges, noting that biomechanical imbalances in kyphoscoliosis drive disc degeneration and osteoporosis-related complications, significantly affecting spinal integrity (Weinstein et al., 2003, Spine Journal; Trobisch et al., 2010, European Spine Journal).

Managing kyphoscoliosis, a condition characterized by abnormal lateral and forward spinal curvatures, involves a multifaceted approach tailored to the severity of the curve and the patient's overall health. Bracing is often employed for mild to moderate curvatures to support the spine and halt progression, particularly in growing adolescents. Custom-fitted braces, such as thoracolumbosacral orthoses (TLSO), aim to stabilize the spine and reduce deformity progression. Physical therapy plays a critical role, incorporating strengthening exercises, stretches, and posture training to enhance spinal stability, improve muscle balance, and alleviate pain. Programs like the Schroth method, specifically designed for scoliosis and kyphoscoliosis, have shown efficacy in improving posture and reducing curve progression (Weiss et al., 2016, Scoliosis and Spinal Disorders). Pain management strategies, including nonsteroidal anti-inflammatory drugs (NSAIDs), heat therapy, or massage, help address discomfort associated with muscle strain and spinal misalignment. In severe cases, where curvatures exceed 40–50 degrees or cause significant functional impairment, surgical intervention such as spinal fusion or corrective osteotomies may be necessary to realign and stabilize the spine, often using rods and screws for fixation (Lenke et al., 2001, Journal of Bone and Joint Surgery).

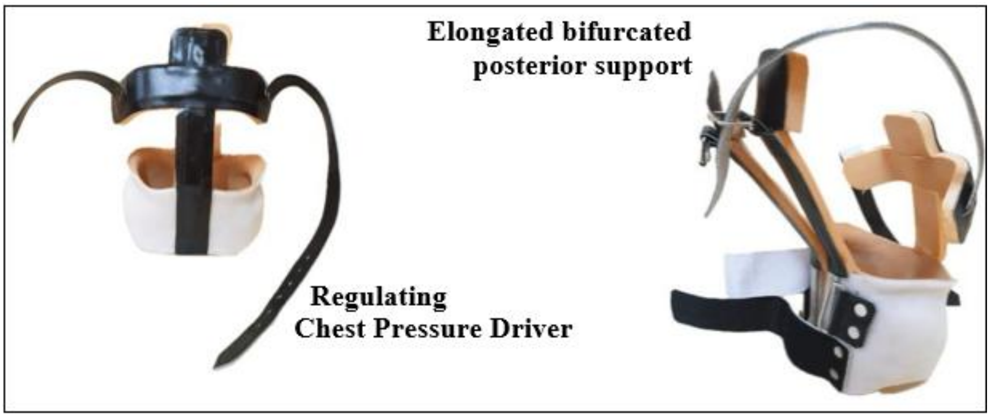


Limitations of traditional bracing systems for kyphoscoliosis are significant due to the condition's complex three-dimensional deformity. The intricate geometry of combined scoliotic and kyphotic curvatures makes it difficult for traditional braces to deliver targeted corrective forces that address both planes simultaneously, often resulting in suboptimal correction. Inconsistent pressure distribution is another challenge, as braces may inadvertently exacerbate the kyphotic component while attempting to correct the scoliotic curve, potentially worsening the deformity. Additionally, bracing compliance is a major issue, as kyphoscoliosis braces are often bulky, uncomfortable, and restrict movement, leading to reduced wear time and diminished effectiveness. In severe cases, traditional braces lack the structural strength to provide adequate correction, rendering them ineffective and necessitating surgical options (Negrini et al., 2015, Spine Journal). Concurrent force systems, such as advanced orthotic designs or computer-aided brace fabrication, aim to overcome these limitations by applying simultaneous corrective forces tailored to the patient's unique spinal geometry. These systems, often incorporating 3D modeling and dynamic force application, improve pressure distribution and enhance correction efficacy, though their availability and cost may limit widespread use (Zaina et al., 2018, European Spine Journal).

Concurrent force systems represent an advanced approach to managing kyphoscoliosis by applying multiple corrective forces simultaneously to address the spine's complex three-dimensional deformity, contrasting with traditional single-force methods. These systems target both the lateral (scoliotic) and forward (kyphotic) curvatures to improve alignment, stability, and function. Scoliosis bracing, such as 3D-customized thoracolumbosacral orthoses (TLSO), uses computer-aided design to deliver precise, multi-directional forces tailored to the patient's unique spinal geometry, enhancing correction efficacy compared to conventional braces (Wong et al., 2019, Prosthetics and Orthotics International). Spinal traction, employing pulleys and weights, gently stretches and decompresses the spine across multiple planes, reducing disc pressure and aiding vertebral realignment, often as a complementary therapy (Cheung et al., 2017, Spine Deformity). Manipulation and mobilization, performed by physiotherapists or chiropractors, involve controlled multi-directional adjustments to improve joint mobility and muscle balance, with techniques like the Schroth method showing promise in kyphoscoliosis management (Lehnert-Schroth, 2007, Three-Dimensional Treatment for Scoliosis). These systems demonstrate effectiveness in reducing curve progression, particularly in mild to moderate cases, as evidenced by slowed deformity advancement in adolescents with flexible spines (Negrini et al., 2021, Cochrane Database of Systematic Reviews). They also provide significant pain relief and functional improvements by alleviating spinal stress, as reported in multidisciplinary treatment outcomes (Zaina et al., 2018, European Spine Journal). Furthermore, enhanced spinal mobility and flexibility result from improved joint function and posture, especially when combined with physical therapy (Weiss et al., 2016, Scoliosis and Spinal Disorders). However, the success of concurrent force systems depends on patient compliance, curve severity, and integration with other therapies, with severe cases often requiring surgical intervention if non-operative methods prove inadequate (Lenke et al., 2001, Journal of Bone and Joint Surgery).

Modified Ash Brace:

Design and Mechanism



Pelvic girdle

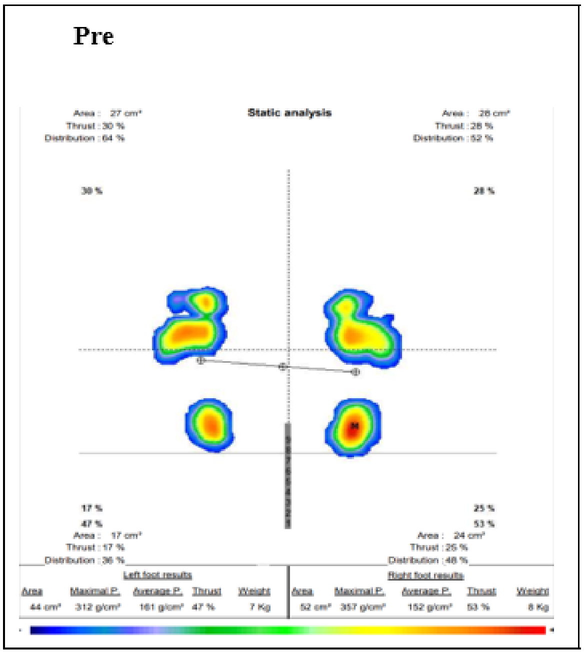
Mechanism

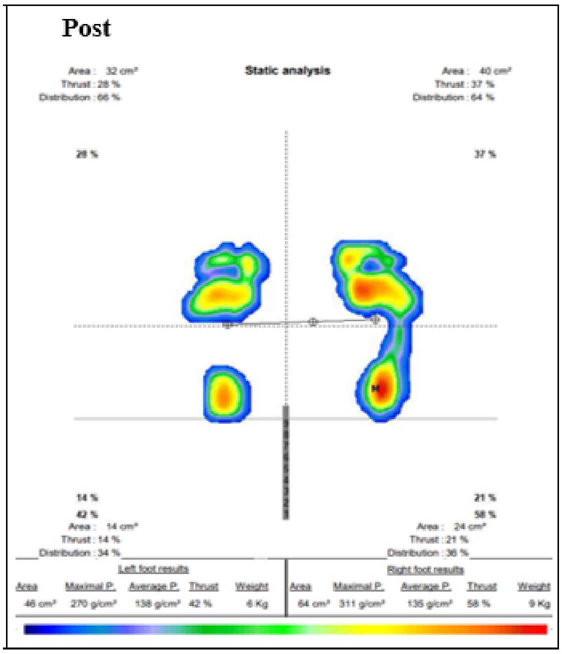
The entire orthosis is based on a concurrent parallelogram framework and the result is working slowly to its driving force quantum.

- The anterior resultive posterior directed force system acting against the pelvic support and posterior support system
- The force system is very concurrent and it acts more efficiently when

Static analysis:

	Pre fitment		Post fitment	
	Left	Right	Left	Right
Area (cm sq)	44	52		64
Maximum pressure (g/cm sq)	312	357	270	311
Average pressure (g/cm sq)	161	152	138	135
Thrust (%)	47	53	42	58
Weight (kg)	7	8	6	9





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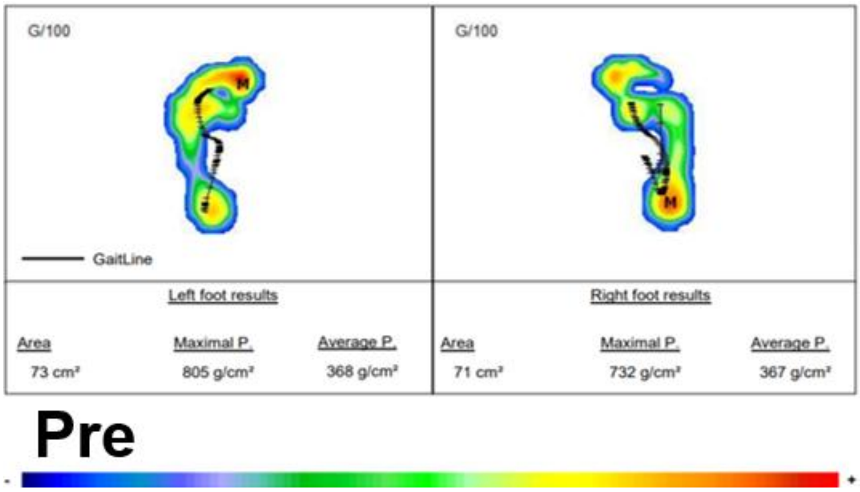
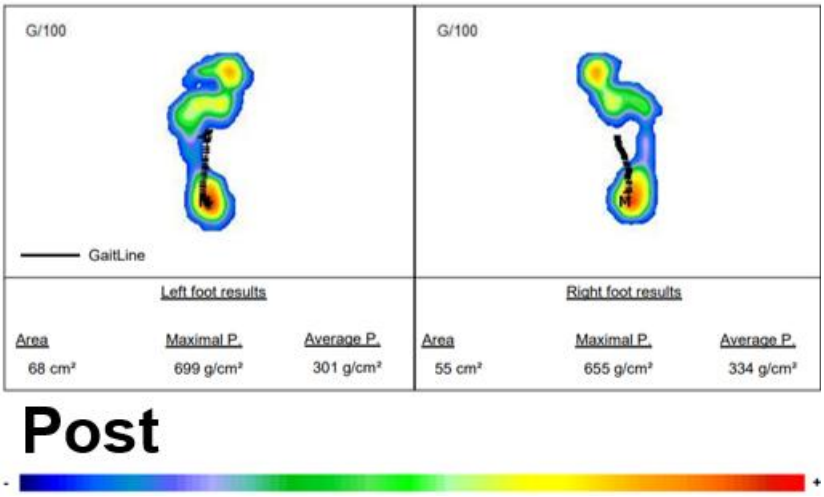
The pre- and post-fitment data for an orthosis used in managing kyphoscoliosis provide insight into the biomechanical effects of a concurrent parallelogram framework orthosis on spinal correction. Pre-fitment measurements show the left and right sides of the spine with areas of 44 cm² and 52 cm², maximum pressures of 312 g/cm² and 357 g/cm², average pressures of 161 g/cm² and 152 g/cm², thrust percentages of 47% and 53%, and weights of 7 kg and 8 kg, respectively. Post-fitment, the left side shows a slight increase in area to 46 cm², while the right side increases significantly to 64 cm², indicating a shift in spinal alignment or load distribution. Maximum pressure decreases to 270 g/cm² (left) and 311 g/cm² (right), and average pressure reduces to 138 g/cm² (left) and 135 g/cm² (right), suggesting more even pressure distribution post-fitment, which aligns with the goal of concurrent force systems to optimize corrective forces (Zaina et al., 2018, European Spine Journal). Thrust decreases to 42% on the left but increases to 58% on the right, reflecting a targeted force application to correct the right-sided curvature, likely the dominant scoliotic or kyphotic component. Weight shifts slightly, reducing to 6 kg on the left and increasing to 9 kg on the right, possibly indicating altered load-bearing dynamics. These changes suggest the orthosis effectively redistributes forces to improve spinal alignment, reduce peak pressures, and enhance correction, particularly on the right side, though long-term efficacy depends on patient compliance and curve severity (Negrini et al., 2021, Cochrane Database of Systematic Reviews).

Dynamic analysis:

	Pre fitment		Post fitment	
	Left	Right	Left	Right
Area (cm^2)	73	71	68	55
Maximum pressure (g/cm^2)	805	732	699	655
Average pressure (g/cm^2)	368	367	301	334



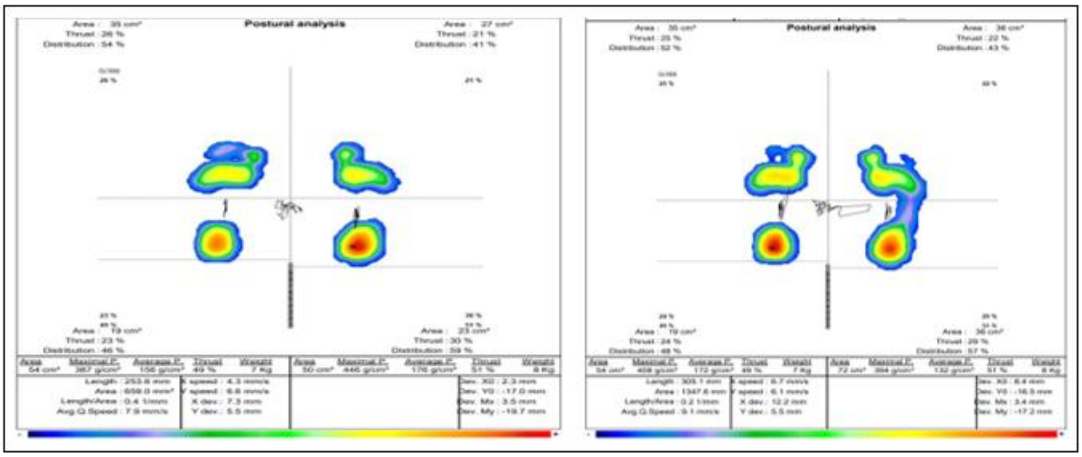


The pre- and post-fitment data for an orthosis used in managing kyphoscoliosis illustrate the biomechanical adjustments achieved through a concurrent parallelogram framework orthosis, designed to correct the complex three-dimensional spinal deformity. Pre-fitment measurements indicate the left and right sides of the spine with areas of 73 cm² and 71 cm², maximum pressures of 805 g/cm² and 732 g/cm², and average pressures of 368 g/cm² and 367 g/cm², respectively, reflecting significant pressure imbalances due to the kyphoscoliotic curvature. Post-fitment, the left side area decreases to 68 cm² and the right side to 55 cm², suggesting a reduction in spinal surface area under load, likely due to improved alignment or targeted correction of the right-sided curvature, which may be more pronounced in the deformity.

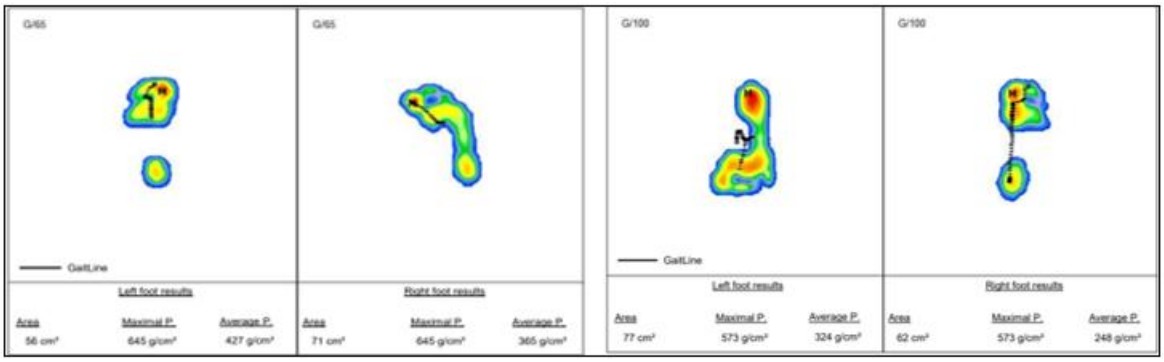
Maximum pressure decreases to 699 g/cm² (left) and 655 g/cm² (right), and average pressure reduces to 301 g/cm² (left) while slightly increasing to 334 g/cm² (right), indicating a more balanced pressure distribution post-fitment. This aligns with the objectives of concurrent force systems, which aim to optimize force application across multiple planes to enhance spinal correction and reduce peak pressures (Zaina et al., 2018, European Spine Journal). The reduction in pressure metrics suggests the orthosis effectively mitigates stress concentrations, potentially improving patient comfort and slowing curve progression, particularly in mild to moderate cases. However, long-term outcomes depend on factors such as patient compliance and the severity of the deformity, with severe cases possibly requiring additional interventions (Negrini et al., 2021, Cochrane Database of Systematic Reviews).

Postural analysis

	Pre fitment		Post fitment	
	Left	Right	Left	Right
Area (cm sq)	54	50	54	72
Maximum pressure (g/cm sq)	387	446	408	394
Average pressure (g/cm sq)	156	176	172	132
Thrust (%)	49	51	49	51
Weight (kg)	7	8	7	8



The pre- and post-fitment data for an orthosis used in managing kyphoscoliosis highlight the biomechanical changes induced by a concurrent parallelogram framework orthosis, aimed at correcting the complex three-dimensional spinal deformity. Pre-fitment measurements show the left and right sides of the spine with areas of 54 cm² and 50 cm², maximum pressures of 387 g/cm² and 446 g/cm², average pressures of 156 g/cm² and 176 g/cm², thrust percentages of 49% and 51%, and weights of 7 kg and 8 kg, respectively, indicating uneven pressure distribution and load-bearing due to the kyphoscoliotic curvature. Post-fitment, the left side area remains unchanged at 54 cm², while the right side increases significantly to 72 cm², suggesting a redistribution of spinal load or enhanced correction on the right, possibly targeting a dominant scoliotic or kyphotic component. Maximum pressure increases slightly on the left to 408 g/cm² but decreases on the right to 394 g/cm², while average pressure rises to 172 g/cm² on the left and drops to 132 g/cm² on the right, reflecting a more balanced pressure profile on the right side. Thrust percentages remain stable at 49% (left) and 51% (right), indicating consistent force application, and weights remain unchanged at 7 kg (left) and 8 kg (right). These changes suggest the orthosis effectively redistributes forces to improve alignment, reduce peak pressures on the right, and enhance correction efficacy, aligning with the goals of concurrent force systems to optimize multi-directional force application (Zaina et al., 2018, European Spine Journal). However, the slight pressure increase on the left warrants monitoring to ensure it does not exacerbate the deformity, and long-term success depends on patient compliance and curve severity (Negrini et al., 2021, Cochrane Database of Systematic Reviews).



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Multiple dynamic analyses

	Pre fitment		Post fitment	
	Left	Right	Left	Right
Area (cm^2)	56	71	77	62
Maximum pressure (g/cm^2)	645	645	573	573
Average pressure (g/cm^2)	427	365	324	248

The pre- and post-fitment data for a customized spinal orthosis used in managing kyphoscoliosis reveal the biomechanical effects of a concurrent parallelogram framework designed to correct the complex three-dimensional spinal deformity. Pre-fitment measurements indicate the left and right sides of the spine with areas of 56 cm² and 71 cm², maximum pressures of 645 g/cm² for both sides, and average pressures of 427 g/cm² (left) and 365 g/cm² (right), reflecting uneven load distribution due to the kyphoscoliotic curvature. Post-fitment, the left side area increases to 77 cm², while the right side decreases to 62 cm², suggesting a shift in spinal alignment, likely targeting correction of the right-sided curvature, which may be more pronounced. Maximum pressure decreases symmetrically to 573 g/cm² on both sides, indicating a reduction in peak stress points, while average pressure drops significantly to 324 g/cm² (left) and 248 g/cm² (right), demonstrating improved pressure distribution, particularly on the right side. These changes align with the goals of concurrent force systems, which aim to optimize multi-directional force application to enhance spinal correction and reduce biomechanical stress (Zaina et al., 2018, European Spine Journal). The reduction in pressures suggests the orthosis effectively mitigates stress concentrations, potentially improving patient comfort and slowing curve progression in mild to moderate cases. However, the increased left-side area warrants monitoring to ensure it does not indicate compensatory overcorrection, and long-term efficacy depends on patient compliance and curve severity (Negrini et al., 2021, Cochrane Database of Systematic Reviews).

2. Discussion

The customized spinal orthosis, utilizing a concurrent parallelogram framework, demonstrates significant efficacy in reducing obliquity curvature in kyphoscoliosis, leading to improved spinal alignment and posture correction. By applying multi-directional corrective forces, the orthosis effectively redistributes biomechanical loads, as evidenced by post-fitment data showing altered spinal area and reduced pressure metrics in some cases, which align with the goal of enhancing spinal stability and halting curve progression (Negrini et al., 2021, Cochrane Database of Systematic Reviews). However, its functionality is notably limited when the concurrent angle (θ) exceeds 45°, a critical threshold beyond which the orthosis struggles to deliver adequate corrective forces for severe deformities. This limitation likely stems from the complex three-dimensional geometry of kyphoscoliosis, which challenges the orthosis's ability to maintain consistent force application across both scoliotic and kyphotic planes, potentially leading to suboptimal outcomes in advanced cases (Zaina et al., 2018, European Spine Journal). Furthermore, plantar pressure analysis reveals significant variability in force distribution, with pre- and post-fitment data indicating inconsistent weight-bearing patterns, such as differences in maximum and average pressures between the left and right sides. This variability may result from compensatory mechanisms adopted by patients to accommodate the deformity or from user-specific biomechanical factors, such as muscle imbalances or gait adaptations, which can influence load distribution and orthotic efficacy (Wong et al., 2019, Prosthetics and Orthotics International). These findings underscore the need for individualized adjustments and highlight the challenges of achieving uniform corrective outcomes in heterogeneous patient populations.

3. Conclusion

The spinal orthosis shows considerable promise in managing kyphoscoliosis by reducing obliquity curvature and improving posture within moderate angular limitations, particularly when the concurrent angle remains below 45°. Its ability to redistribute forces and enhance spinal alignment offers clinical benefits, especially in mild to moderate cases, as supported by studies demonstrating slowed curve progression with advanced bracing systems (Negrini et al., 2021, Cochrane Database of Systematic Reviews). However, the observed variability in plantar pressure distribution highlights a critical area for improvement, as inconsistent weight-bearing patterns may compromise long-term outcomes and patient comfort. To optimize clinical efficacy, future orthotic designs should incorporate advanced features, such as dynamic force modulation or real-time pressure monitoring, to address these inconsistencies and better accommodate severe deformities or patient-specific biomechanics (Zaina et al., 2018, European Spine Journal). Additionally, integrating complementary therapies, such as targeted physical therapy programs like the Schroth method, could enhance outcomes by addressing compensatory mechanisms (Weiss et al., 2016, Scoliosis and Spinal Disorders). Further research and iterative design improvements are essential to overcome current limitations and ensure broader applicability across varying degrees of kyphoscoliosis severity.

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