J Korean Acad Rehab Med 2011; 35: 259-264
Original Article

Attenuation of Spinal Curvature and Pelvic Obliquity by Body Shape Molded Inner System in Cerebral Palsy with Non-Fixed Scoliosis

Young Joo Suh, B.S., Eun Sang Kim, M.D., Eun Sook Park, M.D., Ph.D., Hong Souk Park, M.D., Young Kwan Yoon, M.D., Sung-Rae Cho, M.D., Ph.D.

Department & Research Institute of Rehabilitation Medicine, Yonsei University College of Medicine, Seoul 120-752, Korea

Objective To investigate the effect of the body shape molded inner system on attenuation of spinal curvature and pelvic obliquity in cerebral palsy (CP) with scoliosis.

Method Fifteen patients with CP who had fixed or non-fixed scoliosis were recruited. By radiographic studies, Cobb's angle and pelvic obliquity were measured with or without sitting in the body shape molded inner system.

Results Spinal curvature assessed by Cobb's angle was significantly reduced when CP patients were seated in the body shape molded inner system rather than in conventional seats. Although pelvic obliquity was not improved in patients with fixed scoliosis, it was significantly ameliorated in patients with non-fixed scoliosis when seated in the body shape molded inner system.

Conclusion The body shape molded inner system attenuated spinal curvature and pelvic obliquity in CP patients with non-fixed scoliosis which had a flexible spinal curve.

Key Words Body shape molded inner system, Scoliosis, Pelvic obliquity, Cerebral palsy

INTRODUCTION

Abnormal muscle tone and musculoskeletal deformity caused by cerebral palsy (CP) can affect the quality of life and their management is required throughout life. Between the adolescent and adult periods, the CP patients are faced with numerous problems related to the deterioration of quality of life. The rapid growth in the adolescent is likely to cause musculoskeletal deformity, and complications such as chronic pain may be accompanied in the adulthood.[1] This musculoskeletal deformity developed in CP is primarily caused by spasticity and contracture, and the deformities of spine and lower extremities have been reported frequently.[2]

Scoliosis is defined as a deformity that spine is deviated laterally or rotated, and the incidence of scoliosis in CP has been reported to range from 15% to 61%.[3] Scoliosis in CP is caused by the imbalance of muscle power, spasticity, and abnormal posture. As scoliosis shows the gradual increase of the deformed angle, it may induce pain, emotional disorder, pressure sores, cardiopulmonary dysfunction, and other secondary problems.[4] Furthermore, it interferes with the sitting function in cases accompanied with pelvic obliquity.[5-7] In

Received April 5, 2010; Accepted December 8, 2010
Corresponding author: Sung-Rae Cho
Department of Rehabilitation Medicine, Yonsei University College of Medicine, 134, Shinchon-dong, Seodamun-gu, Seoul 120-752, Korea
Tel: +82-2-2228-3715, Fax: +82-2-363-2795, E-mail: srcho918@yuhs.ac

contrast with idiopathic scoliosis, it has a tendency to progress from a flexible curvature to a permanent deformity because the progression continues even after the end of growth. Particularly, in cases with pelvic obliquity, the prognosis may become worse.[8,9] As scoliosis may progress even after the completion of bony growth, it is very important to prevent the progression by detecting it at an early phase.[3]

Non-surgical treatments for scoliosis are the use of spinal orthosis and special seats. However, spinal orthoses are less effective in these neurological patients. On the other hand, a special seat may be used primarily for the patients who are unable to walk or maintain a sitting position.[10,11] The body shape molded inner system is a special seat fabricated by molding the back and seat plate directly from the body shape of patient. As compared with previous conventional seats, it could be anticipated to be not only more comfortable and well-fitted to the patient, but also effective in reducing scoliosis and pelvic obliquity. In this study, we investigated whether the body shape molded inner system has the effect of reducing spinal curvature and pelvic obliquity in CP with scoliosis, and investigated the associated factors such as age, functional level, CP subtype, and scoliosis type.

MATERIALS AND METHODS

Subjects

Fifteen CP patients (8 males and 7 females) showing scoliosis in the sitting position participated in this study. Mean age of the subjects was 24.5±10.3 years (age range 8-39 years). When they were classified as a function of the subtype of CP, 7 patients were spastic CP, and 8 patients were dyskinetic CP. When the functional levels of subjects were also divided, 8 patients had no self mobility and were dependent on wheelchair ambulation, and 7 patients had limited self mobility and could propel a wheelchair, but needed assistance with maneuvering in limited space. In addition, when they were classified according to the type of scoliosis,[12-14] 6 patients had non-fixed or functional scoliosis which has mainly a flexible component and no structural deformity, and 9 patients had fixed or structural scoliosis which has mainly a non-flexible component and rotational deformity. In cases of non-fixed scoliosis, spinal curvature becomes markedly increased in the antigravity position, whereas the scoliosis is not definite in the supine position. On the contrary, in cases of fixed scoliosis, spinal curvature is usually not changed in both the sitting and supine positions.

Methods

Manufacture of body shape molded inner system: The manufacture of the body shape molded inner system consists of several steps, which include the steps to produce the plaster molded directly from patient's body, the step to combine the plaster product with a pre-existing chair frame, the step to fill foaming urethane into the inside of the frame of the chair to which the plaster product is attached, the step to seal the chair frame filled with foaming urethane and harden for a determined duration, and the step to retrieve the restored product after hardening of the urethane (Fig. 1).

In detail, the first step is to prepare the plaster product with the back and seat fitted to patient's body,

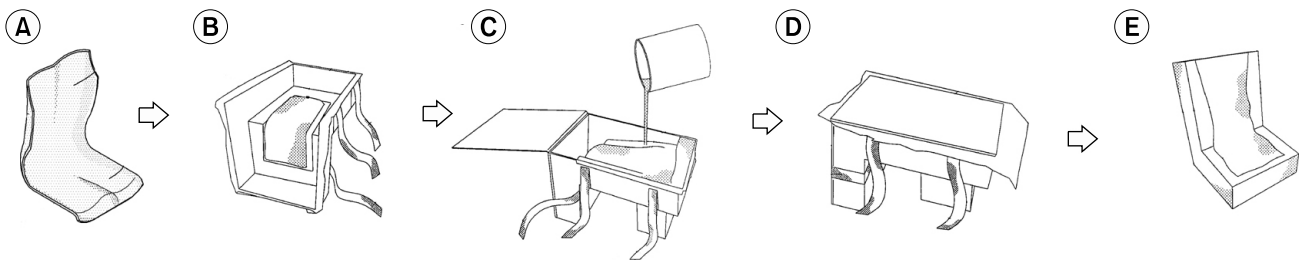

Fig. 1. Manufacturing Procedure of Body Shape Molded Inner System. A schematic view of a flowchart illustrating the method for manufacturing the body shape molded inner system having a back plate and a seat plate designed to fit a body shape. In detail, the first step is to prepare the plaster product with the back and seat fitted to patient's body (A). Next, the plaster product was fixed to a pre-existing chair frame (B). After the fixation of the plaster product to the chair, the chair frame was filled with foaming urethane through the upper opening (C). The hardening of urethane was completed in -30 minutes and after that time (D), the body shape molded inner system was taken out (E).

while an individual patient maintains to sit upright as straight as possible, supported by helpers. Afterward, the plaster product was fixed to a pre-existing chair frame. After the fixation of the plaster product to the chair, the chair frame was filled with foaming urethane through the upper opening. The hardening of urethane was completed in 30 minutes, after which, the body shape molded inner system was taken out. The back and seat plates of this molded product directly reflect the physical condition of the patient.

Assessment of the effect of reducing spinal curvature and pelvic obliquity: The degree of spinal curvature when seated on the body shape molded inner system and when seated on a conventional chair was assessed by measuring the Cobb's angle and pelvic obliquity using plain radiographic images. The Cobb's angle, the maximal angle formed by the upper and lower margins of the curved spine, was measured.[13,15] The pelvic obliquity, the angle formed by the extended line of the iliac crest and the horizontal line, was also measured.[5]

Statistical analysis: The Cobb's angle and pelvic obliquity when seated on the body shape molded inner system and a conventional wheelchair were analyzed by the Wilcoxon signed-ranks test according to age, functional level, CP subtype, and scoliosis type. SPSS 13.0 software was used for statistical analysis. $p < 0.05$ was defined for statistical significance.

RESULTS

Effect of the body shape molded inner system on scoliosis

The Cobb's angle measured without sitting on the body shape molded inner system was 41.8±24.6°. When the Cobb's angle was measured with sitting on the inner system, it was significantly attenuated to 33.7±26.5° ($p < 0.05$) (Table 1). However, the pelvic obliquity was not significantly reduced after sitting on the inner system (11.2±10.5° without the inner system, and 9.4±8.3° with the inner system) (Table 1).

Effect of the body shape molded inner system according to CP subtype

The Cobb's angle measured without sitting on the body shape molded inner system was 39.1±24.8° in spastic CP. After sitting on the inner system, it was significantly decreased to 32.0±29.0° ($p < 0.05$). Similarly, it was decreased from 44.1±25.9° to 35.2±26.0° in dyskinetic CP ($p < 0.05$) (Table 2). However, the pelvic obliquity was not statistically changed after sitting on the inner system in both spastic CP and dyskinetic CP (Table 2).

Table 1. Cobb's Angle and Pelvic Obliquity with Body Shape Molded Inner System in Cerebral Palsy

	No. of subjects (n=15)	
	Without inner system	With inner system
Cobb's angle (°)	41.8±24.6	33.7±26.5*
Pelvic obliquity (°)	11.2±10.5	9.4±8.3

Values are mean±standard deviation.
*$p < 0.05$ by Wilcoxon signed ranks test

Effect of the body shape molded inner system according to functional level

The Cobb's angle of the patients with limited self mobility without sitting on the body shape molded inner system was 26.5±3.6°. After sitting on the inner system, it was significantly decreased to 16.8±8.8° ($p < 0.05$). In the patients with no self mobility, it was also significantly decreased from 55.1±27.7° to 48.5±28.3° ($p < 0.05$) (Table 2). However, the pelvic obliquity was not statistically changed after sitting on the inner system in the patients with limited self mobility and the patients with no self mobility (Table 2).

Effect of the body shape molded inner system according to scoliosis type

The Cobb's angle of the patients with non-fixed scoliosis was 26.8±3.7° without sitting on the body shape molded inner system. After sitting on the inner system, it was significantly decreased to 15.0±8.4° ($p < 0.05$) (Fig. 2-A, B). Similarly, in patients with fixed scoliosis, it was significantly decreased from 51.8±27.8° to 46.2±27.3° ($p < 0.05$) (Fig. 2-C, D) (Table 2). In addition, pelvic obliquity in patients with non-fixed scoliosis was significantly attenuated from 8.4±5.7° to 3.9±1.8° after sitting on the inner system ($p < 0.05$). However, it was not significantly changed in patients with fixed scoliosis (Table 2).

Table 2. Cobb's Angle and Pelvic Obliquity with Body Shape Molded Inner System According to Age, CP Subtype, Functional Level, and Scoliosis Type in Cerebral Palsy

Inner system	Without	With	Without	With
	Spastic type (n=7)		Dyskinetic type (n=8)	
Cobb's angle (°)	39.1±24.8	32.0±29.0*	44.1±25.9	35.2±26.0*
Pelvic obliquity (°)	13.8±8.6	10.8±11.0	8.6±12.3	7.9±4.8
	Limited self mobility (n=7)		No self mobility (n=8)	
Cobb's angle (°)	26.5±3.6	16.8±8.8*	55.1±27.7	48.5±28.3*
Pelvic obliquity (°)	6.4±6.1	4.7±2.6	16.0±12.2	14.0±9.5
	Non-fixed scoliosis (n=6)		Fixed scoliosis (n=9)	
Cobb's angle (°)	26.8±3.7	15.0±8.4*	51.8±27.8	46.2±27.3*
Pelvic obliquity (°)	8.4±5.7	3.9±1.8*	13.3±13.1	13.4±9.0

Values are mean±standard deviation.
*$p < 0.05$ by Wilcoxon signed-ranks test

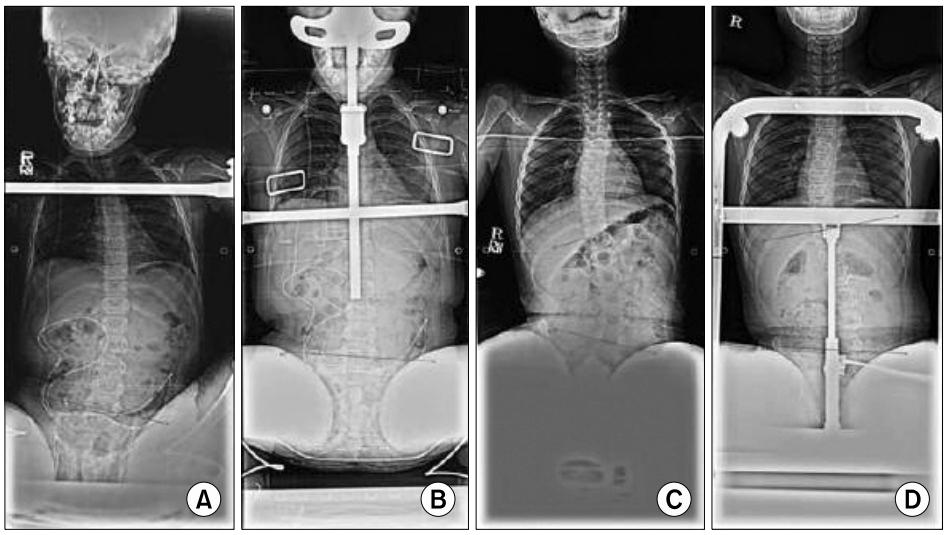

Fig. 2. Attenuation of Spinal Curvature and Pelvic Obliquity in CP Patients with the Body Shape Molded Inner System According to Scoliosis Type. In CP patients with non-fixed scoliosis, Cobb's angle and pelvic obliquity were reduced with the body shape molded inner system (B) than in the conventional seat (A), while Cobb's angle was reduced with the body shape molded inner system (D) than in the conventional seat (C) in CP patients with fixed scoliosis. The frame which fixed the body shape molded inner system is shown.

DISCUSSION

The previous method used to produce an inner seat consisted of a first step to measure the physical size of the patient in the posture of sitting on a chair; the fitting step to prepare the back and seat plates to appropriate sizes; another step to carve the back and seat plates using diverse tools, and to repeat the carving until the body and the chair fit well; and the last step to cover the back and seat plates with an outer cover, and to install various accessories. However, the manufacturing steps were very inconvenient, and it is difficult to properly fit the patient's body because the fitting to the body is done using a series of carvings based on assumptions, and followed by additional fitting trials. This supplementary works may be ineffective or hardly required for the disabled patients.

In this study, the body shape molded inner system was manufactured by directly molding a cast of the back and seat plates from the patient's body and subsequently fitting the cast. This process not only made the manufacturing procedure simple and easy, but also provided a method to produce an inner seat that could be used comfortably and stably, by manufacturing it while fitting to the individual body. Because the inner system was manufactured using the method of assembling the plaster product molded directly from the patient's body and to pour foaming urethane, a chair mold that reflected the physical characteristics of patients could be readily produced, and the method ultimately could eliminate the burden and discomfort resulting from a series of processes involving repeated

carvings and sitting trials.

According to the study reported by Lee et al.[2] the scoliosis of CP patients was related to the motor function. In other words, spinal curvature was increased in the cases with the lower functional levels, and the spinal curvature was reduced as the ambulatory status improved. In addition, the spinal curvature was shown to be significantly increased as the migration index of the hip joint became larger, and thus it showed a correlation to other skeletal deformities. If non-ambulatory CP patients with low functional levels spend a long time in a sitting position, the posture will become asymmetry and associated with skeletal deformities. Because the skeletal deformities caused by scoliosis will progress, not only the exercises for strengthening paraspinal muscles, but also intensive treatments to correctly maintain the sitting position, such as the use of spinal braces and postural orthoses, are required.[9-11] Furthermore, Vialle et al.[7] and Lonstein and Akbarnia[16] suggest that invasive methods such as surgical treatments can be considered for the reduction of scoliosis and pelvic obliquity.

In this study, the body shape molded inner system was used as a non-invasive treatment, and its effects on attenuation of the spinal curvature and pelvic obliquity were assessed. When the Cobb's angle and pelvic obliquity were measured while sitting on a conventional seat and on the inner system, it was found that the Cobb's angle was particularly decreased. In addition, when the effects of the inner system according to functional level, CP subtype, and scoliosis type were investigated, the Cobb's angle was significantly reduced in all groups. However, pelvic obliquity was attenuated only in the patients with non-fixed scoliosis. Therefore, we suggest that the body shape molded inner system is recommended especially for CP patients with non-fixed scoliosis to prevent the progression of spinal curvature and the deterioration to fixed scoliosis.

Our study was performed on only 15 patients with CP. Hence, when they were classified according to subgroups, the numbers of subjects became smaller, and thus it had the limitation that the results of our study may not apply for all CP patients. A study with a larger number of patients and the affecting factors including age, CP subtype, scoliosis type, functional level, and time sitting on the inner system during a day should be performed in the future. Furthermore, additional longitudinal studies to investigate the long-term effects of the body shape molded inner system on correction of spinal curve and pelvic obliquity using regular observation should be performed.

CONCLUSION

In our study, it was found that the body shape molded inner system had the effect of attenuating the spinal curvature in CP patients with scoliosis. In addition, the effect of reducing the pelvic obliquity was particularly shown in cases with non-fixed scoliosis rather than the patients with fixed scoliosis.

ACKNOWLEDGEMENTS

This study was supported by a grant from Eugene Medicare Co., LTD (7-2007-0036), and National Research Foundation (NRF 2010-0020408; 2010-0024334) funded by the Ministry Science and Technology, Republic of Korea.

REFERENCES

1) Gajdosik CG, Cicirello N. Secondary conditions of the musculoskeletal system in adolescents and adults with cerebral palsy. Phys Occup Ther Pediatr 2001; 21: 49-68
2) Lee JS, Lee KB, Kim CW, Choi YN, Jung DH, Park SD, Lee WR. Deformities of spine and lower extremities in teenagers with cerebral palsy. J Korean Acad Rehab Med 2008; 32: 135-142
3) Morrell DS, Pearson JM, Sauser DD. Progressive bone and joint abnormalities of the spine and lower extremities in cerebral palsy. Radiographics 2002; 22: 257-268
4) Madigan RR, Wallace SL. Scoliosis in the institutionalized cerebral palsy population. Spine 1981; 6: 583-590
5) Dubousset J. Pelvic obliquity: a review. Orthopedics 1991; 14: 479-481
6) Majd ME, Muldowny DS, Holt RT. Natural history of scoliosis in the institutionalized adult cerebral palsy population. Spine 1997; 22: 1461-1466
7) Vialle R, Delecourt C, Morin C. Surgical treatment of scoliosis with pelvic obliquity in cerebral palsy: the influence of intraoperative traction. Spine 2006; 31: 1461-1466
8) Saito N, Ebara S, Ohotsuka K, Kumeta H, Takaoka K. Natural history of scoliosis in spastic cerebral palsy. Lancet 1998; 351: 1687-1692
9) Ferguson RL, Allen BL Jr. Considerations in the treatment of cerebral palsy patients with spinal deformities. Orthop Clin North Am 1988; 19: 419-425
10) Chase AP, Bader DL, Houghton GR. The biomechanical

effectiveness of the Boston brace in the management of adolescent idiopathic scoliosis. Spine 1989; 14: 636-642
11) Aubin CE, Dansereau J, de Guise JA, Labelle H. Rib cage-spine coupling patterns involved in brace treatment of adolescent idiopathic scoliosis. Spine 1997; 22: 629-635
12) Kanayama M, Tadano S, Kaneda K, Ukai T, Abumi K. A mathematical expression of three-dimensional configuration of the scoliotic spine. J Biomech Eng 1996; 118: 247-252
13) Stokes IA, Gardner-Morse M. Analysis of the interaction between vertebral lateral deviation and axial rotation in scoliosis. J Biomech 1991; 24: 753-759
14) Suzuki S, Kasahara Y, Yamamoto S, Seto Y, Furukawa K, Nishino Y. Three-dimensional spinal deformity in scoliosis associated with cerebral palsy and with progressive muscular dystrophy. Spine 1993; 18: 2290-2294
15) Delorme S, Labelle H, Aubin CE, de Guise JA, Dansereau J. Comparison between clinical Cobb angles and measurements performed on vertebral bodies, pedicle centroids and spinous processes. Ann Chir 1999; 53: 792-797
16) Lonstein JE, Akbarnia A. Operative treatment of spinal deformities in patients with cerebral palsy or mental retardation. An analysis of one hundred and seven cases. J Bone Joint Surg Am 1983; 65: 43-55