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Clinical Study

Preoperative computer-based simulations for the correction of kyphotic deformities in ankylosing spondylitis patients

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Abstract

BACKGROUND CONTEXT: A preoperative plan is important to obtain appropriate balance of the sagittal plane in patients with kyphotic deformity. Previous methods to calculate the correction angle are inconvenient and complicated, whereas the method using computer simulations may be very effective and much simpler than existing methods.

PURPOSE: To evaluate the efficacy of preoperative measurements using a computer simulation for corrective osteotomy for the surgical treatment of kyphosis caused by ankylosing spondylitis (AS).

STUDY DESIGN: Retrospective clinical data analysis.

PATIENT SAMPLE: The sample comprises 18 AS patients with fixed kyphotic deformity who underwent corrective osteotomies at our hospital between October 2007 and January 2010.

OUTCOME MEASURES: Thoracic kyphosis, lumbar lordosis, and the sagittal vertical axis (SVA) of the spine were evaluated by preoperative computer simulation and radiologic measurement. Clinical assessments were performed according to the Bath Ankylosing Spondylitis Disease Activity Index (BASDAI), Bath Ankylosing Spondylitis Functional Index (BASFI), Short Form-36 (SF-36), and EuroQol-5 dimension (EQ-5D) before and after the surgery.

METHODS: The coincidence between the preoperative computer simulation and postoperative radiologic parameters was evaluated. We also analyzed the changes derived from each clinical and radiologic measurement before and after the surgery.

RESULTS: Mean thoracic kyphosis changed from 32.4° to 31.9°, mean lumbar lordosis was corrected from 11.5° to 26.9°, and the SVA was improved from 125.7 to 65.1 mm after surgery ($p<.001$). The correlation coefficients within groups between the computer simulations and radiologic parameters were 0.9, 0.6, and 0.7, showing significant congruency. Although BASDAI and BASFI did not significantly differ ($p=.53$ and $p=.45$, respectively), SF-36 and EQ-5D were significantly increased ($p<.05$ and $p<.001$, respectively).

CONCLUSIONS: Comparisons of preoperative simulations and actual surgical outcomes showed significant coincidences; thus, evaluations through computer simulations before surgery are expected to help predict the level of correction possible after surgery and improve surgical planning.

Keywords: Ankylosing spondylitis; Kyphotic deformity; Corrective osteotomy; Preoperative measurement; Computer simulation; Sagittal vertical axis

FDA device/drug status: Not applicable.

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Conflict of interest: The manuscript submitted does not contain information about medical device(s)/drug(s).

Approved for the study by the institutional review board (IRB) on Human Subjects Research and Ethics Committees, Hanyang University Guri Hospital, Korea.

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Introduction

Ankylosing spondylitis (AS) is a chronic inflammatory disease that primarily invades the spine and sacroiliac joint [1–3]. As the disease progresses, it moves to the upper part of the spine and the mobility of the joints disappears. In some patients, destructive lesions, such as Andersson lesions, are seen alongside fixed kyphosis because of reduced lumbar lordosis or increased thoracic kyphosis [4]. The prevalence of AS ranges from 0.1% to 1.1%, and spinal deformity may be reduced by the use of antitumor necrosis factor [5]. Because there are few compensatory mechanisms for kyphosis caused by AS, it causes many limitations in everyday life and may generate problems with walking and communication because it is impossible for patients to face forward. Therefore, surgical correction is necessary.

Corrective osteotomy of fixed kyphosis is very difficult. It is thought to be very effective in patients with long segment kyphosis who lose compensation of sagittal imbalance. Pedicle subtraction osteotomy was first introduced by Thomasen [6], and today, it is widely used for the correction of fixed sagittal curvature. Through this technique, corrections up to 40° can be derived by segmental osteotomy. It is necessary to define a preoperative plan and calculate the correction angle to obtain appropriate balance of the sagittal plane [7]. Previous studies have addressed methods that use the chin-brow vertical angle [8], radiograph cutout [9], tangent [10], and pelvic parameters [11]; however, most of these methods are inconvenient and complicated.

When designing the preoperative plan for an osteotomy, especially for the treatment of kyphotic deformity in patients with AS, computer simulations can be very effective and are much simpler than the existing methods. We evaluated the feasibility of preoperative computer measurements for kyphosis correction in patients with AS.

Methods

In this retrospective study, we reviewed the records of 18 patients with AS accompanied by fixed kyphotic deformity and who underwent pedicle subtraction osteotomy from October 2007 to January 2010. The average age of the patients was 36.5 years (30–53 years). Seventeen of the patients were male, whereas one was female. The enrolled subjects were followed-up for an average of 37.2 months (25.3–51.7 months). The correction angle was measured through a computer simulation before pedicle subtraction osteotomy for every patient. Inability to maintain standing posture or face forward while standing were the main indications for operation.

Surgimap Spine software (Nemaris, Inc., New York, NY, USA) was used for computer simulations. The distances of thoracic kyphosis, lumbar lordosis, and the sagittal plane from the posterosuperior end plate of S1 were measured through long-cassette standing lateral spinal radiographs, and computer simulations were promoted by setting an appropriate angle at the lumbar spine (Fig. 1). To select the segment for corrective osteotomy, simulations of osteotomies in three different vertebral bodies, including the upper and lower vertebral bodies of the apex of kyphosis, were conducted to compare the sagittal vertical axis (SVA) in each segment. The segment that realized the best correction of the SVA was selected for surgery (Fig. 2). To determine the correction angle, osteotomies in the shapes of isosceles and right triangles at the selected segment were simulated. When conducting the isosceles triangle osteotomy simulation, the correction angle was the largest and the SVA were most improved; thus, isosceles triangle osteotomies were conducted (Fig. 3). The segment and angle determined via computer simulations were used in the actual surgeries.

Long-cassette standing lateral spinal radiographs that were taken in the standing posture before and after surgery

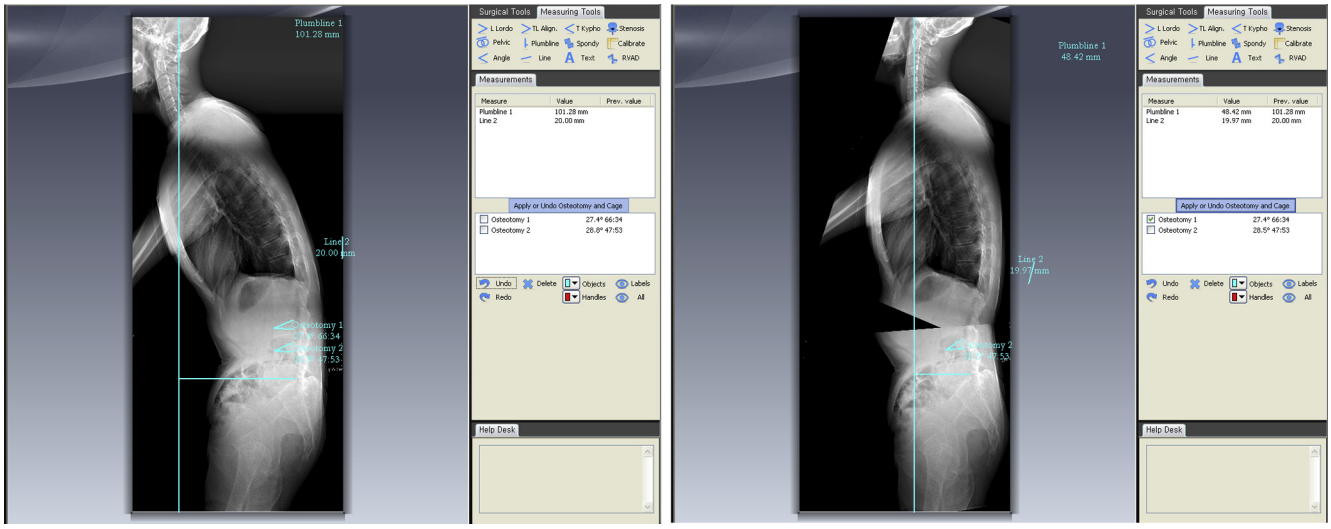

Fig. 1. Surgimap Spine is a software tool that organizes simulated postoperative results via intuitive mouse clicks.