In pediatric patients with lumbar spondylolysis, the ideal goal is to achieve bone healing conservatively. Indeed, there have been some reports of successful bone healing in pediatric patients with spondylolysis in which various kinds of braces, such as the Boston brace (Boston Brace Co.) and a soft corset, have been used.\textsuperscript{5,8,19,27} A biomechanics study reported that extension and axial rotation caused greater mechanical stress at the pars interarticularis, which may lead to stress fractures of the pars (spondylolysis).\textsuperscript{13} Furthermore, spondylolysis affects the physiological lumbar biomechanics, leading to rotational instability.\textsuperscript{18} These biomechanical investigations indicate that restriction of the extension and rotation of the trunk is very important to attain bone healing with conservative treatment in lumbar spondylolysis in children.

Before we were aware of the aforementioned biomechanical features of lumbar spondylolysis, we used a soft corset to treat pediatric and young patients.\textsuperscript{19} After January 2006, we prospectively started to use a hard thoracolumbosacral type of brace for treatment. The preliminary results showed that better healing rates were obtained in the group treated with the hard brace than in the group treated with the soft corset. Thus, we now use the hard brace to attempt bone healing for pediatric lumbar spondylolysis.
Conservative treatment for pediatric spondylolysis

The purpose of the present study was to determine in what types of spondylolysis bone healing can be achieved and how long it takes to achieve bone healing for each type if it is treated with the hard brace.

Methods

Ethics committee approval was obtained from our institution. A total of 63 pars defects (spondylolysis) in 37 patients younger than 18 years (mean 13.5 ± 2.7 years) were treated using a hard brace. The youngest child was 8 years old. Of these 37 patients, 26 had bilateral pars defects and 11 had unilateral defects. There were 25 boys and 12 girls, and all but one were very active in sports. The basic concept in this study was to attempt bone healing of the defect. Previously, it was reported that terminal-stage defects cannot achieve bone healing, because the terminal stage is the stage of pseudarthrosis. Therefore, patients with only bilateral or unilateral terminal-stage defects were not treated using brace therapy. All 37 patients had at least a single early- or progressive-stage defect. In some cases, slippage can be seen in addition to spondylolysis. Such spondylolysis is usually seen in cases of bilateral terminal defects. All patients in this study had comparatively fresh spondylolyses, and none of the patients had slippage. All patients were required to agree and comply with brace therapy and cease any sports activity during the treatment. Before starting the brace therapy, we explained the therapy to the children and their parents. Eleven patients did not agree with the treatment and did not want to discontinue their sports activities; therefore, these patients were excluded from this study. All 37 patients who agreed to undergo the treatment completed the brace therapy.

To immobilize the trunk, a hard brace was used (Fig. 1). This brace is designed to restrict trunk rotation by holding the rib cage and pelvis, as well as to restrict extension. The patients were divided into 4 groups according to the characteristics of the defects as determined by CT and MRI (Table 1). The STIR MRI findings were used to divide the defects into those showing high signal intensity at the pedicle and those with low signal intensity (Fig. 2), as described by Sairyo et al. Early-stage defects show hairline fractures, progressive-stage defects show a clear bone gap, and terminal-stage defects correspond to pseudarthrosis.

All of the early-stage defects showed high signal intensity, and all terminal defects showed low signal intensity. Thus, on the basis of the CT and MRI information, we divided the cases into 4 groups: early stage, progressive stage with high signal intensity, progressive stage with low signal intensity, and terminal stage. Bone healing was confirmed using 1-mm fine-cut CT scanning. Approximately every 3 months, CT scanning was performed to evaluate bone healing until approximately 6 months. When CT showed nonunion at 6 months with the bracing, the treatment was terminated. The patients were allowed to remove the brace and return to their original sports activity. The healing ratio was evaluated with respect to CT stage and the appearance high signal intensity on MRI.

Results

Union Rate With Reference to CT Stage

There were 33, 22, and 8 defects in the early, progressive, and terminal stages, respectively. The union rate of the early-stage defects was 94%, and the rate for progressive-stage defects was 46%. No terminal defect healed with the conservative treatment.

![Fig. 1. Photographs showing a hard trunk brace. This brace holds the rib cage and pelvis to restrict lumbar rotation as well as extension.](image1)

![Fig. 2. The STIR MRI study showing a high signal change at the adjacent pedicle. The left pedicle shows high signal intensity (arrow), whereas the right pedicle does not.](image2)
Among the 44 defects with high signal intensity and 19 defects with low signal intensity, the healing rates were 86% and 16%, respectively.

On the basis of the CT and MRI information, the 63 defects were divided into 4 subgroups (Table 1). The union rates were 94%, 64%, 27%, and 0% for early, progressive with high signal intensity, progressive with low signal intensity, and terminal defects, respectively. The durations for healing of those defects that showed bone healing were 3.2, 5.4, and 5.7 months for the early, progressive with high signal intensity, and progressive with low signal intensity groups, respectively.

**Illustrative Cases**

**Case 1**

This 13-year-old boy who played soccer was diagnosed with left unilateral spondylolysis at L-4, and CT showed an early-stage defect. High signal intensity at the pedicle adjacent to the defect was noted on T2-weighted MRI (Fig. 4). After 3 months of conservative treatment using the hard brace as well as stopping sports, bone healing was achieved.

**Case 2**

This 14-year-old girl who played volleyball had bilateral progressive defects noted on CT scanning at her initial presentation (Fig. 5). On T2-weighted MRI, there was no marrow edema adjacent to the defects, indicated by low signal intensity. We asked her to stop sports activities and to wear the hard brace. Seven months later, bone healing of both defects was achieved.

**Discussion**

Lumbar spondylolysis is a stress fracture of the pars interarticularis. The incidence of the condition depends on race. The highest prevalence of about 50% is found in the Inuit population and the lowest of 1%–2% in African people. Caucasians and Asians showed a similar incidence of about 6%. Spondylolysis is reported to be a high risk factor for low-back pain in young athletes. More than 70% of rugby players and football players experience low-back pain, and about 40% of players without any radiological abnormalities experience pain. Some athletes require direct surgical repair of pars defects because of chronic low-back pain. Older patients with spondylolysis present with a specific
Conservative treatment for pediatric spondylolysis

pathology termed “ragged edge,” which may cause radiculopathy by impinging the nerve root at the lateral recess.\(^2,3,15\) As for the development of spondylolisthesis, lytic vertebrae sometimes suffer slippage during adolescence.\(^11,12,22,24\) More than 70% of patients with bilateral spondylolysis have been reported to have forward slippage to some extent,\(^21\) and slippage sometimes requires surgical treatment.\(^23\) Thus, to prevent these more severe clinical conditions, achieving bone healing of the defects at the earliest possible stage during childhood should be the ideal goal of treatment.

In the past, various kinds of trunk braces were used to achieve bone healing of pediatric lumbar spondylolysis. Sys et al.\(^27\) treated 28 athletes with this disorder using a Boston Overlap Brace with a hinged extension to the thigh. Fujii et al.\(^5\) and Sairyo et al.\(^19\) used a soft corset for that purpose. As noted earlier, lumbar extension and axial rotation can be very important biomechanical motions that promote lumbar spondylolysis.\(^10,13\) Thus, we assumed that conservative treatment using a brace that can restrict trunk extension and rotation would be the optimal method to achieve bone healing. From this biomechanical perspective, the Boston Overlap Brace with a hinged extension to the thigh would, theoretically, be the best brace to use.\(^27\)

Our group used a corset for this purpose until 2005,\(^5,19\) and since 2006 we have been using a molded plastic hard thoracolumbosacral orthosis. The pilot investigation comparing the union rates between a soft corset and a hard brace indicated that the hard brace provided a better union rate. Thus, we no longer use a soft corset for the purpose of achieving bone healing. The hard brace holds the rib cage, and the posterior wall covers the buttocks, thus restricting extension and rotation, even though it does not have a hinged extension to the thigh like the brace used by Sys et al.\(^27\) If the spondylolysis can be treated in the early stage, the healing rate will be very high (approximately 93%).

As predictors of bone healing, early-stage defects seen on CT scanning,\(^5,19\) high positive signal at the adjacent pedicle on T2-weighted MRI,\(^19\) and activity (hot spots) on bone scintigraphy have been proposed.\(^27\) In this study, we confirmed the usefulness of CT scanning and MRI to predict bone healing. Early-stage defects on CT and high signal at the pedicle on T2-weighted MRI can be good predictors of bone healing with conservative care. In other words, pediatric lumbar spondylolysis with these 2 radiological characteristics is the best time to start conservative treatment to achieve the bone healing with a hard-type trunk brace.

The most powerful result from the current study was to clarify the duration required for bone healing in each subgroup of spondylolysis. This information is extremely useful for counseling pediatric patients and their parents on whether to consider conservative therapy. Usually, pediatric patients will accept brace therapy for a period of 3 months along with stopping their sports activities. Thus, they usually accept the treatment in the early stage. For the progressive-stage defects, healing generally took approximately 6 months. In such patients, we need to discuss the treatment with them and their parents. It is obvious that a very skeletally immature spine with spondylolysis is likely to develop spondylolisthesis.\(^15\) Therefore, we strongly recommend that skeletally immature patients, such as elementary school children, undergo conservative treatment to avoid slippage.

Fredrickson et al.’s landmark study\(^4\) has shown that the majority of the spondylolytic lesions occur by the age of 6 years (4.4%). If children had spondylolysis before the age of 6 years, their spondylolysis could be at the terminal (psuedarthrosis) stage by the time they present to a doctor around the age of 13 years because of pain. The pain could be due to the communicating synovitis of the pseudarthrosis\(^16\) and not due to the stress fracture reaction. We excluded patients with bilateral and unilateral terminal-stage defects in this study. Moreover, none of our patients were younger than 6 years. Fredrickson et al. reported that by the age of 6 years, 4.4% of the population has spondylolysis. By the age of 20 years, this percentage increases to 6%. Thus, 1.6% of the population develops spondylolisthesis between the ages of 6 and 20 years.

**Conclusions**

Patients with early-stage defects are the best candidates for conservative treatment with a hard brace because more than 90% of such cases can be healed in 3 months.

**Disclosure**

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Sairyo. Acquisition of data: Sairyo. Analysis and interpretation of data: Sakai, Sairyo. Drafting the article: Sakai, Sairyo. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Sairyo. Study supervision: Yasui, Dezawa.

**References**

7. Ishimoto J, Abe H, Tsukimura Y, Wakano K: Relationship...

K. Sairyo et al.