Distraction techniques with a variety of external and internal distraction systems have been successfully used to advance the midface. However, external distraction devices generally cannot deliver adequate distraction forces for lengthening; as a result, the distraction achieved is limited. On the other hand, internal distraction devices do not allow control of the post-fixation distraction vector. We have developed a hybrid facial osteogenesis distraction system that combines the advantages of external and internal distraction devices to enable control of both the distraction distance and vector. However, when the advanced maxilla has excessive clockwise rotation and shifts more downward vertically than planned, it might be impossible to pull it up to correct it. We invented devices attached to external distraction systems that can control the vertical vector of distraction to resolve this problem. The purpose of this article is to describe the result of utilizing the distraction system for syndromic craniosynostosis.

Background: We have developed a hybrid facial osteogenesis distraction system that combines the advantages of external and internal distraction devices to enable control of both the distraction distance and vector. However, when the advanced maxilla has excessive clockwise rotation and shifts more downward vertically than planned, it might be impossible to pull it up to correct it. We invented devices attached to external distraction systems that can control the vertical vector of distraction to resolve this problem. The purpose of this article is to describe the result of utilizing the distraction system for syndromic craniosynostosis.

Methods: In addition to a previously reported hybrid facial distraction system, the devices for controlling the vertical direction of the advanced maxilla were attached to the external distraction device. The vertical direction of the advanced maxilla can be controlled by adjustment of the spindle units. This system was used for 2 patients with Crouzon and Apert syndrome.

Results: The system enabled control of the vertical distance, with no complications during the procedures. As a result, the maxilla could be advanced into the planned position including overcorrection without excessive clockwise rotation of distraction.

Conclusion: Our system can alter the cases and bring them into the planned position, by controlling the vertical vector of distraction. We believe that this system might be effective in infants with syndromic craniosynostosis as it involves 2 osteotomies and horizontal and vertical direction of elongation can be controlled. (Plast Reconstr Surg Glob Open 2014;2:e113; doi: 10.1097/GOX.0000000000000060; Published online 26 February 2014)
control the vertical vector of distraction. The purpose of this article is to describe the result of application of the distraction system for syndromic craniosynostosis.

**METHODS**

When the advanced maxilla undergoes excessive clockwise rotation and is shifted more downward vertically than the planned position, it might be possible to pull it back into the planned position by vertical distraction device. We invented devices that can control the vertical vector of distraction (Figs. 1A–C). First, a previously reported HFDS, composed of a conventional halo-type external distraction device (KLS-Martin) and an internal distraction device with a 3-dimensional adjustable angle to interlock with the halo-type distraction device, was attached. Then, the new devices, which can control the vertical direction of the advanced maxilla, were attached to the external distraction device. For this, screws were fixed above the bilateral upper primary molars or first molars and spindle units were attached on contact with attachment on the side of external distraction device (Figs. 1D, E). Then, surgical wires were attached to both the screws and spindle units after they were penetrated through the scalp. The vertical direction of the advanced maxilla can be controlled by the adjustment of spindle units.
CASE REPORTS

Patient 1
A 12-year-old male patient with Crouzon syndrome (Fig. 2). The patient underwent Le Fort III osteotomy and our systems were placed. Internal and external devices for this system were attached, and a total of 6 surgical wires were attached to spindle units of the external devices. Although the maxillary position showed slight anticlockwise rotation at the distraction phase, it was corrected by the vertical wires. Immediately after the overcorrection, the external devices were removed. After an additional 3 months, all devices including the internal devices were removed. The 6-month postoperative results indicated that point Or and A were advanced by 22 and 23 mm, respectively (Fig. 3A).

Patient 2
A 10-year-old female patient with Apert syndrome (Fig. 4). She underwent an osteotomy with a bone incision similar to Le Fort II through the

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Fig. 2. Patient 1: A 12-year-old male patient with Crouzon syndrome. A, Preoperative view. He had severe maxillary retrusion and a class III soft-tissue profile. B, Preoperative lateral cephalogram. C, Six months postoperatively. After 4 months of advancement, all devices including the internal devices were removed. D, Postoperative lateral cephalogram. Point Or and A were advanced by 22 and 23 mm, respectively.
inside of infraorbital foramen in addition to Le Fort III for the correction of midfacial retrusion. Using this system, the direction of the zygomatic bones was controlled by 2 wires, which were passed through a 2-mm transmaxillary Kirschner wire, and the middle maxilla was controlled by 2 wires which were passed through a miniplate attached to the inferior border of the anterior nasal aperture and another 2 wires which were passed from the mouth through scalp. Immediately after advancement, the external devices were removed. After an additional 3 months, the rest of all devices were removed. The 1-year postoperative results indicated that point Or and A were advanced by 18 and 16 mm, respectively (Fig. 3B).

**DISCUSSION**

We developed a flexible facial distraction system in which new devices that control the vertical direction of the advanced maxilla can be added to a previously reported HFDS. We believe that this system would allow easy and reproducible overcorrection in distraction osteogenesis and the main indications of this system would be the cases that need a distraction distance of 20 mm over or multiple osteotomy.

External distraction allows for control and adjustment of horizontal and vertical movements of the midface after the distraction process has been initiated and favors skeletal movements with minimal dental changes.

Although the external distraction devices help to control the distraction vector, the possible distraction distance may be generally limited. Our system can help to bring the cases into the planned position, because the vertical vector of distraction can be controlled for an adjuvant of the external distraction. And also, it is possible for this system to have early removal of external devices because the internal devices can prevent relapse. If the wires of external devices were used to change the vector of more than 10 degrees during advancement, the devices should not be removed immediately after advancement.

The Or and point A are evaluated by cephalometric analysis to determine different distraction vector positions for infant syndromic craniosynostosis. The vectors of Or and point A in Apert syndrome are commonly planned different from those of Crouzon
syndrome before operation because of short facial height. That is, the vector of point A is set more downward than the vector of Or.\textsuperscript{11} But, it is difficult to advance the maxilla to the planned position. The advancement to the planned vector of Or and point A differs when the distraction distance is greater. Correction of these cases may require additional procedures, such as Le Fort II osteotomy in addition to Le Fort III surgery.\textsuperscript{12-14} Advancement of the maxilla to the planned position could be controlled by combining the 2 osteotomies and this system in Apert syndrome.

**CONCLUSIONS**

Our system can alter the cases and bring them into the planned position by controlling the vertical vector of distraction. We believe that this system might be effective in infants with syndromic craniosynostosis as it involves 2 osteotomies, and hori-
Horizontal and vertical direction of elongation can be controlled.

**PATIENT CONSENT**

Parents or guardians provided written consent for the use of the patients’ image.

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