The expansive open-door laminoplasty (EOLP) has been proven effective in treating patients with cervical myelopathy caused by bony cervical stenosis or ossification of the posterior longitudinal ligament. The aim of the EOLP was to help patients gain neurological improvement by decompressing the spinal cord and nerve root. The trough preparation was a critical procedure for successful EOLP, for which the appropriate trough position and drilling depth mattered the most. For now, the trough preparation was solely based on the surgeon’s experience. Although the surgery-related complications were uncommon, the consequences were severe. Rich experience was required to reduce the incidence of surgery-related complications. However, under some circumstances where the junction between the lamina and the lateral mass was obscure, it was even challenging for an experienced surgeon to accomplish the proper trough preparation. Here, we presented a case of EOLP using the three-dimensional printed patient-specific drilling. Using the computer-aided design (CAD) and rapid prototyping (RP) techniques, the positions of troughs and drilling depths were simulated preoperatively, and the drilling templates were fabricated to guide the trough preparation intraoperatively.

A 55-year-old male with 2-year history of gradually progressing difficulty in walking was admitted to the Department of Orthopedic Surgery, West China Hospital. The physical examination revealed positive Hoffman sign on both sides and decreased muscle strength (Grade IV) of the wrist extensors on the right side. The Japanese Orthopaedic Association (JOA) score was only 9 out of a total 17 points. The Pavlov values for C3–C7 levels were 0.62, 0.68, 0.68, 0.65, and 0.77, respectively. The T2-weighted magnetic resonance imaging (MRI) showed mild high-intensity change at the C4–C5 levels. The reconstructed sagittal computed tomography (CT) showed ossification of the posterior longitudinal ligament at C4, C5, and C6 levels [Figure 1]. The patient was diagnosed with cervical myelopathy, and the EOLP was planned.

The patient’s preoperative CT data were imported into the Mimosics 17.0 software (Materialise, Leuven, Belgium) for the three-dimensional reconstruction of the cervical spine. The surgery simulation and drilling template designing were then conducted using the 3-Matic 9.0 software (Materialise, Leuven, Belgium). First, the spinous processes were cut. Second, two drilling paths were simulated and placed at the junction between the lamina and the lateral mass to simulate the trough position. The location of the drilling paths for each level was adjusted according to the surgeon’s suggestion. Third, for each level, the back surface of the lamina and lateral mass was reverse engineered to form the template body. On the open-side, the thickness of the template was designed just to allow the drill to penetrate the ventral cortex of the lamina. On the hinge-side, the thickness of the template was thinner, aiming to keep the ventral cortex of the lamina intact. Fourth, two screw paths were designed for the anchorage of the drilling template to the lamina. Finally, the virtual drilling templates were converted into physical templates by stereolithography, one of the rapid prototype techniques [Figure 1].

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After general anesthesia, the patient was put in a prone position with the head fixed by the Mayfield head holder. A midline cervical incision was made to expose the spinous processes, laminae, and the lateral masses from C2 to C7 level. After the exposure was done, the remaining soft tissue attached to the lamina was stripped off as clearly as possible for better contact between the drilling template and the lamina. Thereafter, for each level, the sterilized drilling template was pressed to the back of the lamina. Two mini screws were used to anchor the drilling template to the lamina through the designed screw paths. Then, the high-speed drill was used to prepare the open-side and hinge-side troughs under the guide of the drilling templates. After the drilling template had been removed away, the lamina was carefully elevated after removing the adhesion of dural mater and ligamentum flavum. Finally, appropriately sized laminoplasty mini-plates were used to secure the opened lamina to the lateral masses.

In this case, no perioperative complications occurred. The postoperative radiograph confirmed the good position of the screws and plates. The MRI showed that the cervical vertebral canal was well decompresed. The postoperative CT demonstrated that the trough positions were properly located, at the junction between the lamina and the lateral mass. The actual trough positions and the simulated trough positions were well matched. No complete hinge fracture was observed on the postoperative CT.

The patient’s neurological function improved remarkably after surgery. At the 6-month follow-up, the muscle strength of the upper extremity fully recovered. The difficulty in walking condition improved significantly. The JOA score increased from 9 to 14.

After the soft tissues attached to the lamina were clearly stripped off, the template could easily straddle on the remaining of the spinal process and sit on the lamina. Once the mini-screws were placed into the lamina, the drilling template would be firmly anchored. No shift of template was noticed during the drilling process. Therefore, using the mini-screws to anchor the template seemed to overcome the problem of templates instability mentioned in the previous studies.

Proper trough positions were confirmed by the postoperative CT scan. By comparing the simulated trough positions on preoperative CT with the actual trough positions on postoperative CT, it was clearly indicated that they were well matched. Using the CAD/RP technique, the trough positions could be planned preoperatorly by surgical simulation. Thus, it could help avoid the vertebral artery injury caused by excessive laterally located trough. In addition, it could help avoid excessive medially located troughs which might contribute to not enough spinal decompression. Usually, surgeons with rich experience in performing the EOLP can prepare the troughs at the proper locations. However, when the junction between the lamina and lateral mass was not obvious, it was still challenging to accomplish proper trough preparation. In our previous cadaveric study, a young surgeon with less experience in performing the EOLP would always prepare the troughs lateral to the planned position without the use of the drilling templates. We believed that the drilling template was of great help to prepare the trough at the proper position.
The drilling template was also designed to have depth stop function. On the open side, the thickness of the drilling template was designed just to allow the high-speed bur to penetrate the ventral cortex of the lamina. During the surgery, the high-speed bur could not go deeper once the designed drilling depth was reached. Thus, using the drilling templates could reduce the incidence of iatrogenic injury to the spinal cord or the nerve root. On the hinge side, the thickness of the drilling depth was thinner, which was equal to the thickness of dorsal cortex and cancellous bone of the lamina combined, to avoid complete hinge fracture by keeping the ventral cortex of the lamina intact. Complete hinge fracture was supposed to be related to the lamina displacement into the spinal canal, which might compress the spinal cord or encroach the nerve root causing neurological deterioration.[5] In short, we believed that using the drilling templates could help the surgeon prepare the open-side and hinge-side troughs more safely.

In conclusion, this was an EOLP accomplished with the aid of patient-specific three-dimensional printed drilling templates. This case demonstrated that the CAD/RP technique was feasible for the EOLP. Our hands-on experience suggested that the patient-specific drilling templates might help surgeon prepare the troughs in a more precise manner.

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**Conflicts of interest**
There are no conflicts of interest.

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