Biomechanical Analysis of Novel Occiput-C1-C2 Fixation Techniques

1,2Takigawa, T; 1Simon, P; 1Espinoza Orías, A A; 1,3 Hong, J T; 2Ito, Y; Inoue, N, 1,3An, H S
+1Rush University Medical Center, Chicago, IL, 2Kobe Red Cross Hospital, Hyogo, Japan,
3St Vincent’s Hospital, Catholic University of Korea, Suwon, Korea
han@rushortho.com

Introduction
The etiology of occipitocervical instability is vast and includes trauma, rheumatoid arthritis, infection, tumor, congenital deformity, and degenerative processes. The development of instability in this region can result in intractable pain with or without neurological deficit and requires surgical treatment. Surgical management has evolved during the past decades, and currently, incorporation of an occipital plate system and C2 pedicle screws or C1-C2 transarticular screws for occipitocervical fixation is recommended. However, there are unique clinical situations in which this occipital plate system may not be possible (e.g. postoperation of posterior fossa decompression), may have already failed, or may require the addition of supplemental fixation. For these unique salvage or rescue situations, two novel techniques which utilize the occipital condyle as screw purchase in posterior approach have been recently introduced1-2. One of the novel techniques is the C0-C1 transarticular screw (TA) technique. Another is the direct occipital condyle screw (OcC) technique which is applied with a C1 lateral mass screw. Clinical application and anatomical feasibility of these two techniques have been reported3,4. However, to our knowledge, there is no biomechanical study comparing these two techniques. The purpose of this study was to evaluate and compare the construct stability provided by C0-C1 transarticular screws or occipital condyle screws, especially as a salvage or rescue, reinforcement, or alternative technique.

Methods
Sixteen fresh-frozen cadaveric spines (10M/6F, mean age 57.4 y) were used. As a non-destructive kinematic test, a maximum 2.0 N-m pure moment was applied in smooth continuous flexion/extension, lateral bending, and axial rotation motions using a specially designed testing apparatus. The range of motion (ROM) was measured using an optoelectronic motion-tracking system. Following the intact-state test, each specimen was highly destabilized at C0-C1 and C1-C2 levels. Then the specimens were divided into TA group (n = 7) and OcC group (n = 7) by matching sex and bone mineral density. In addition to the intact state, a total of 5 different constructs were tested and compared (Figure 1). All constructs cooperated with C2 pedicle screw fixation. The OcC screw was incorporated with the C1 lateral mass screw. After the kinematic test, a destructive forward-flexion test was carried out on the TA alone and OcC alone constructs, and the maximum moment was compared.

Results
All fixation methods significantly reduced ROM compared with intact state (mean intact C0-C2 ROM ± SD; flexion/extension: 29.5 ± 11.0°, lateral bending: 4.3 ± 4.6°, axial rotation: 62.3 ± 13.0°). Comparison of two novel methods (TA vs. OcC):
There were no statistical differences between TA alone and OcC alone in the kinematic test (Figure 2) and the destructive test (Figure 3). Supplementation of occipital plate produced lower ROM in TA in flexion/extension and in both TA and OcC in axial rotation.

Alternative of standard plate (Standard vs. TA or OcC alone):
The standard plate and TA/OcC alone provided similar stability in flexion-extension. ROM in TA and OcC alone was lower than the standard plate in lateral bending, and larger than standard in axial rotation.

Reinforcement effect on standard plate (Standard vs. TA or OcC plate):
Application of TA or OcC to the standard plate construct reduced ROM in all cases, although no statistical differences were found.

Discussion
The occipital plate fixation provided higher stability compared with TA or OcC alone due to increased anchoring points. Interestingly, stability with the standard technique in lateral bending was lower than that in TA or OcC alone, indicating fixation at the C1 level is more effective in lateral bending. It should be noted, however, that all fixation techniques tested in the current study showed significantly higher stability as compared with the intact specimen and differences in ROM among the different fixation techniques were less than 1.5°, which appears minimal in the clinical setting.

Although the atlanto-occipital joint is the only articulation between C0 and C1, the occipital condyle has not been considered as a viable structure for screw placement. However, technological developments (e.g. precise imaging techniques or navigation systems) are making possible to approach this unique structure. The clinical indication of these novel techniques would be basically the same, and both methods could provide similar stability. Clinicians can select one of these methods depending on the patient.

In conclusion, the C0-C1 transarticular screw and direct occipital condyle screw with C1 lateral mass screw techniques can provide equivalent stability. Reinforcement effect of these techniques on the standard plate construct is minimal. Both methods are effectively alternative or salvage fixation techniques when occipital plate fixation is not feasible.

Figure 1. Five types of C0-C2 fixation constructs.
a: standard occipital plate with C2 pedicle screw; b: C0-C1 transarticular screw with C2 pedicle screw; c: construct b plus occipital plate; d: occipital condyle screw with C1 lateral mass screw and C2 pedicle screw; e: construct d plus occipital plate.

Figure 2. Range of motion in kinematic test. *: P < 0.05.

Figure 3. Failure moment in destructive forward-flexion test. NS: not significant (P = 0.77)

References