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한국인에 대한 새로운 관절주위 잠김금속판의 해부학적 적합성: 사체를 이용한 연구

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- Abstract -

Anatomic Conformity of New Periarticular Locking Plates for Koreans: A Biomechanical Cadaveric Study

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Purpose: This study was conducted to confirm the anatomic conformity of the new periarticular locking plates designed by Zimmer on Korean adult bones and to identify the structures at risk during the application of these implants.

Methods: The study was performed on the humerus, radius, and tibia of 10 adult cadavers(6 males and 4 females) procured from the cadaveric lab of our hospital. Anteroposterior (AP) and lateral X-rays were taken to confirm that the cadavers were free of any unusual lesions or anatomic variations. We used the 3.5-mm proximal humerus plate, 2.7-mm distal radius plate, 3.5- and 5.0-mm proximal tibia plates, and 3.5-mm distal tibia plate developed by Zimmer, Inc. (Zimmer periarticular locking plate). The longest plate from each group was used to confirm anatomical conformity. Standard approaches were used for each area, and soft tissue was retracted in order to pass the plate beneath the muscle. The position of the plate was confirmed using standard AP and lateral view X-rays. After this procedure had been completed, the region was dissected along the length of the implant to determine the conformity of the implant to bone and the penetrations of screws into the articular surface or violations of any vital structures, such as nerves, blood vessels, or tendons.

Results: Excellent anatomical conformity was observed with Zimmer periarticular locking plates for Korean adults. The tibial nerve and the posterior tibial artery were found to be structures at risk when applying a distal tibial plate.

Conclusion: Additional posterolateral fixation is recommended when dealing with cases of tibial plateau fracture when the fracture line extends to the posterolateral cortex. We recommend taking proper views using

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10~15 degrees of internal rotation to ensure correct screw length and, thus, avoid penetration of vital structures and tendons.

Key Words: Biomechanics, Cadaver

I. Introduction

Locking compression plates (LCP) are a recent development in fracture fixation. The need for these locking plates arose because standard plate and screw constructs fail to meet the physical demands of osteoporotic bones and periarticular fractures. By providing a fixed angle construct, the LCP provides better pull-out strength in these special situations.(1) With the use of LCP, it is now possible to perform minimally invasive and indirect bridging fixation to provide a favorable environment for secondary bone healing. Because LCP are mainly used in the periarticular region of bone, which has a specific anatomy, it is essential to have pre-shaped implants for various periarticular regions in order to achieve a perfect match. With advances in laser scanning technology, it is now possible to map the anatomy of various bones more precisely in order to achieve detailed information about bone surface morphology. This has helped in developing anatomically pre-shaped implants that are improved over previous LCPs, which were unnecessarily large and ill-fitting to the bone surface. As a result, anatomically pre-shaped plate systems are becoming increasingly popular. However, such systems are produced using study models that are mainly based upon Western populations, and it is not yet known whether these implants fit the bone surfaces of Koreans.

This study aims to confirm the anatomic conformity of the new periarticular locking plates designed by Zimmer on Korean adult bones, and to identify structures at risk during the application of these implants.

II. Materials and Methods

We performed this study in the cadaver lab at our hospital. A total of 10 cadavers(6 male and 4 female) were procured from the lab. The mean age of the cadavers was 50 years (range 22~67 years). Anteroposterior (AP) and lateral X-rays were taken to confirm that the cadavers were free of any unusual lesions or anatomic variations. A total of 20 humerus, radius, and tibia from 10 adult cadavers were used for this study. We used the ZPLP (Zimmer Periarticular Locking Plate) system developed by Zimmer, Inc. The plates used in this study were the 3.5 mm proximal humerus plate, 2.7 mm distal radius plate, 3.5 and 5.0 mm proximal tibia plates, and distal tibia plate. The longest plate from each group was used to confirm anatomical conformity. All the surgeries on cadavers were performed by a senior orthopedic consultant with more than 15 years of experience. Standard approaches were used for each area, and soft tissue was retracted in order to pass the plate beneath the muscle.

1. ZPLP Proximal humerus plate

A standard deltoid splitting approach was used to make a tunnel for insertion of the proximal humerus plate. The distal end of the plate was passed below the brachialis muscle, which was split after retracting the biceps. After confirming the location of the axillary nerve, the plate was inserted sub-muscularly. The plate was positioned just lateral to the intertubercular sulcus. Upon completion of screw insertion, the specimen was dissected all around

2. ZPLP distal radius plate

A standard approach was used between the flexor carpi radialis and the radial artery. The pronator quadratus was removed from its radial border and the plate was applied to the volar surface of the distal radius.

3. ZPLP 3.5 proximal tibia plate and ZPLP 5.0 proximal tibia plate

Proximal tibia was approached by a standard anterolateral approach. Incision is made from a point above the fibular head to Gerdy's tubercle; carry the dissection directly down to the IT band split the IT band in line with its fibers directly over the proximal tibia.

4. ZPLP distal tibia plate

A longitudinal and straight incision centered at the ankle joint was madeparallel to the fourth metatarsal distally. The proximal extension of the incision ended seven or eight centimeters above the joint. Distally, the incision was extended to the level of the talonavicular joint.

The position of the plate was confirmed using standard AP and lateral view X-rays, and readjustments were made to avoid the intraarticular placement of screws. Once the implant position was found to be satisfactory on a C-arm image, it was provisionally fixed with a 3.0-mm Steinman pin, and locking screws were inserted into all holes one by one. After completing this procedure, the region was dissected along the length of the implant to determine the following:

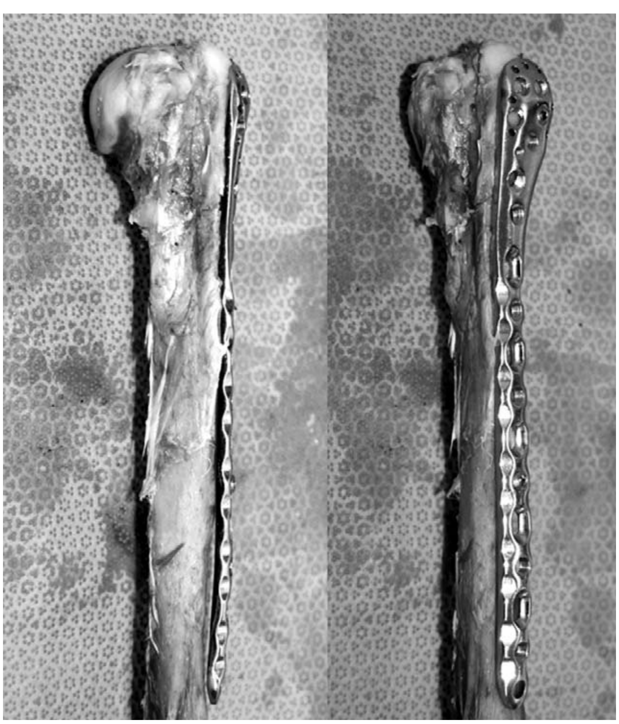

Fig. 1. ZPLP PH on a proximal humerus showing excellent conformity

1) Conformity of the implant to bone,

The conformity was assessed by the amount of discrepancy between the plate and the bone. The discrepancy was measured by the distance from the inner surface of the plate to the cortex. More the discrepancy, lesser the conformity.

2) Penetration of screws into the articular surface,

Once the implant is securely fixed to the bone, the corresponding bone is disarticulated and looked for any articular breach of screws. After radiological confirmation of optimal conformity of the plate, screws are inserted to the plate. Hence any articular breach suggests despite the good radiological picture, conformity is not optimal.

3) Violation of any vital structures, like nerves, blood vessels, or tendons.

After complete fixation of plate to the bone, soft tissues were released around the bone to watch for any impingement of the screw tips on vital structures.

III. Results

1. ZPLP Proximal humerus plate

We observed satisfactory conformity in all cases, and there was no penetration of screws over any articular surface (Fig. 1). We did not identify any vital structures or tendons violated by any of the screws.

2. ZPLP distal radius plate

Upon dissection of the specimen, we observed excellent conformity of the plate to the bone. None of the screws penetrated the distal radial articular surface. In addition, we found that the plate adequately covered the ulnar side to provide fixation of the lateral column (Fig. 2).

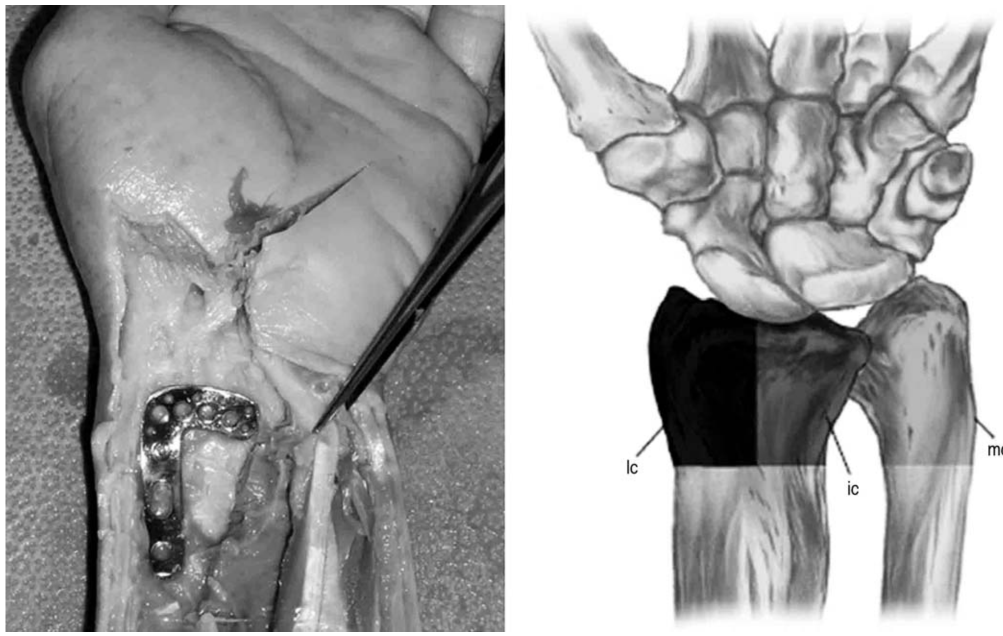

Fig. 2. Radial column plate covers part of the ulnar column at the head of the plate
lc: lateral column, ic: intermediate column, mc: medial column

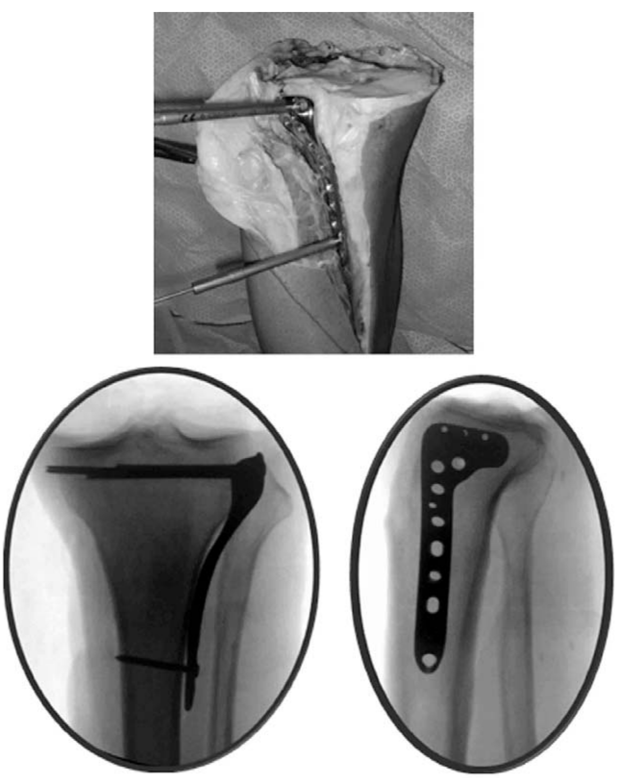

Fig. 3. ZPLP 3.5 proximal tibia lateral view showing excellent conformity with very good rafting of the proximal locking screws

3. ZPLP 3.5 proximal tibia plate

Even through the lateral and proximal tibia show great individual variation, we found good conformity between the plate and bone (Fig. 3). Following plate application, we confirmed the position of the screws inside the tibial plateau using a CT scan. We confirmed that a 10~15 mm portion of the poster lateral corner of the tibial plateau was not covered by the rafting screws used through plate (Fig. 4). During surgical dissection of the specimen, we could not observe any vital structures being violated by the screws, nor did we find any penetration of screws to the joint surface.

4. ZPLP 5.0 proximal tibia plate

We observed excellent conformity similar to the 3.5 proximal tibia plate by the same approach (Fig. 5).

5. ZPLP distal tibia plate

The plate showed excellent anatomical conformity. However, in 9 out of 20 cases we observed penetration of the tibialis posterior tendon, 4 cases with penetration of the flexor digitorum longus tendon and 2 cases with penetration of the flexor halluces longus tendon. The tibial nerve was at risk in 4 cases, while the posterior tibial artery was at risk in 1 case (Fig. 6). Tibialis posterior and flexor digitorum tendons were usually affected by the 1st or 2nd of the 4 medially directed screws and neurovascular bundle and flexor hallucis tendons were at risk commonly by the 3rd or 4th screw.

IV. Discussion

With standard dynamic compression plates (DCP), contouring of the plate is vital to a successful outcome.(2) This is because the bone surface is not always straight, especially in the periarticular region where the metaphysis meets the diaphysis. If the screws are tightened without contouring the plate applied to a periarticular region, the bone

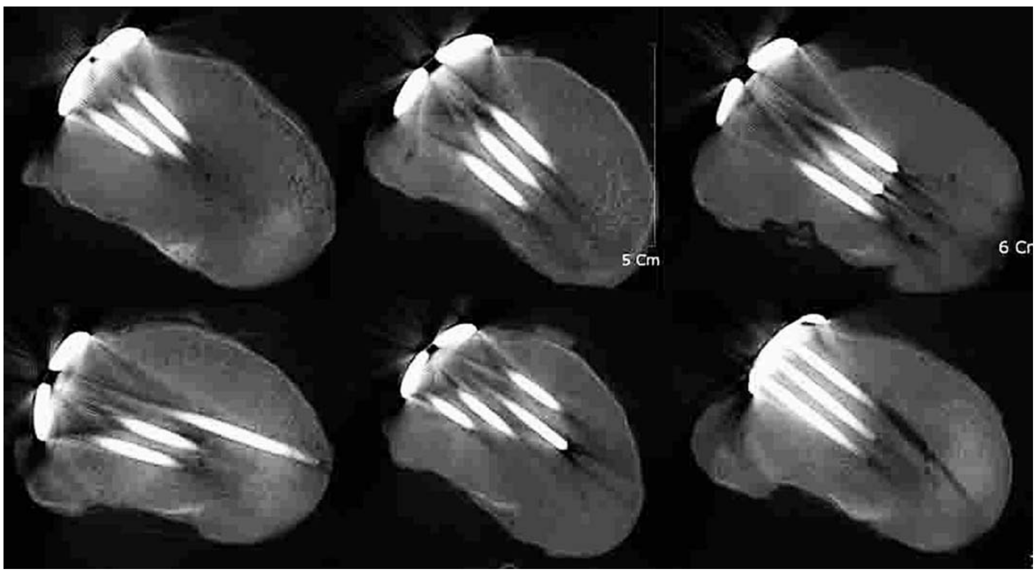

Fig. 4. Axial CT images showing bear area of rafting at the posterolateral aspect of the lateral tibial condyle

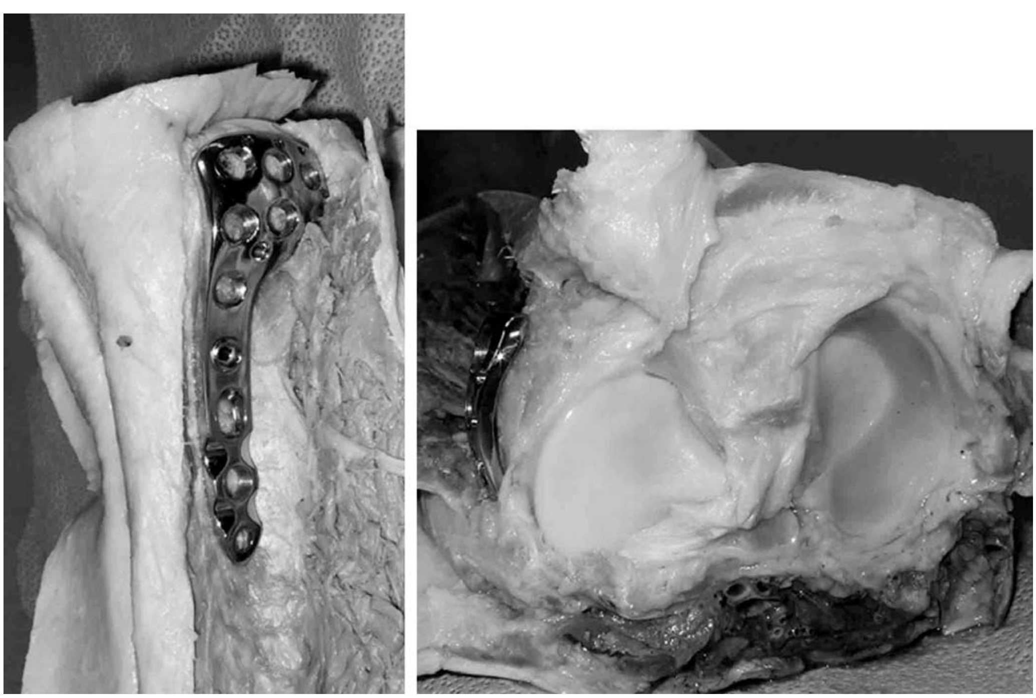

Fig. 5. ZPLP 5.0 Proximal tibia lateral view

fragments are pulled towards the plate and out of alignment with the axis. With the advent of locking plates, the management of periarticular fractures has become easy. One of the advantages of LCPs is that they do not require contouring in the same way as DCPs. This is because with LCPs, the screw locks with the plate and there is no friction at the plate-bone interface, and thus no chance of fragments being pulled towards the plate.(3,4) However, under special circumstances, non-locking compression screws through the LCP must be applied first, followed by locking screws, in order to compress the fracture site. In such situations, it is always better to use a contoured plate, even if it is a LCP. However, the commonly available LCPs are too difficult to bend during surgery, and the bending itself can be time-consuming. Accordingly, researchers have developed anatomically contoured LCPs. An ideal periarticular plate should not only be contoured to match the bone profile, but should also be of decreased thickness towards the end to reduce the potential for soft-tissue irritation over the joint line. The reduced thickness can allow the implant to “auto contour” as the screws draw the plate towards the bone.If the locking plate does not fit the bone profile, it can sometimes present a serious problem. A mismatch between the contour of the plate and bone can lead to impingement of the implant over soft tissue, which can ultimately end in breakage of the protective soft tissue envelope.

The plates selected in our study were specifically designed for the right and left sides, with a transitioned profile that is thinner in the metaphyseal and thicker in the diaphyseal areas in order to provide a perfect fit that requires little or no additional bending.

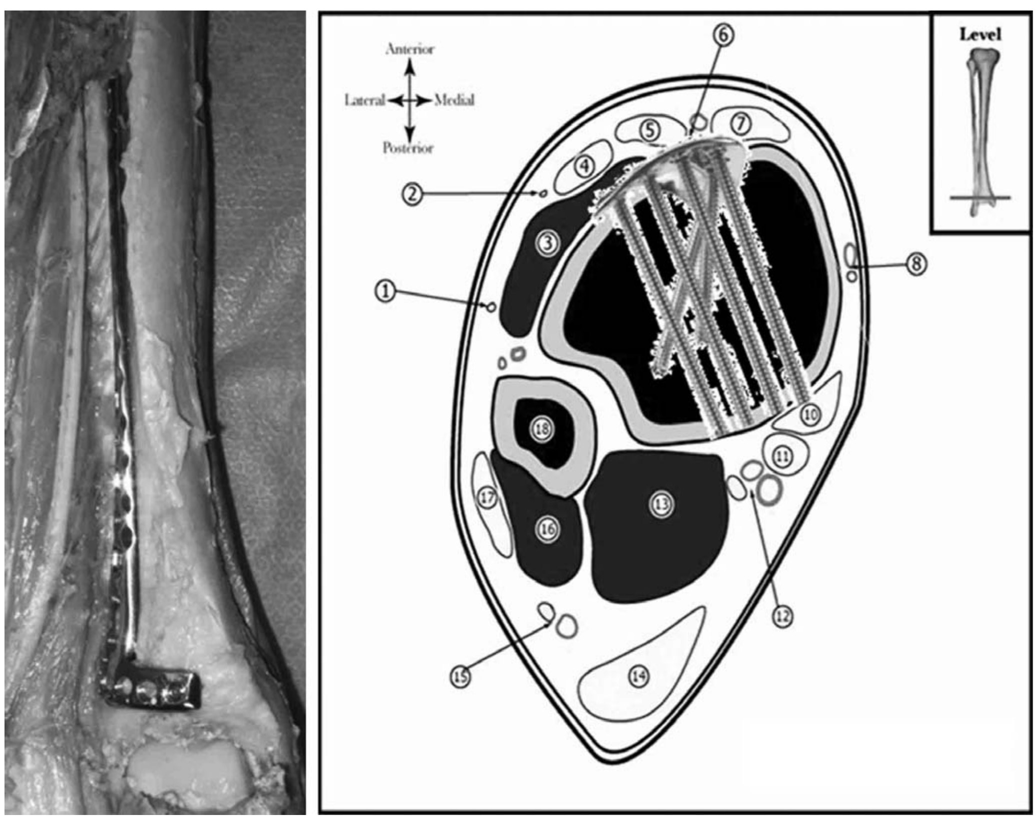

Fig. 6. ZPLP on distal tibia. Cross-sectional image illustrating the direction of the cannulated locking screws, which point to the posteromedial corner of the distal tibia
① Intermediate Dorsal Cutaneous branch of Superficial peroneal nerve ② Medial Dorsal Cutaneous branch of Superficial peroneal nerve ③ Peroneus tertius ④ Extensor Digitorum Longus ⑤ Extensor Hallucis Longus ⑥ Deep Peroneal Nerve and Anterior Tibial Vessels ⑦ Tibialis Anterior ⑧ Great saphenous vein and saphenous nerve ⑨ Tibia ⑩ Tibialis Posterior ⑪ Flexor digitorum longus (FDL) ⑫ Tibial Nerve and Posterior Tibial Vessels ⑬ Flexor Hallucis Longus ⑭ Achilles tendon ⑮ Sural Nerve and Lesser Saphenous Vein ⑯ Peroneus brevis ⑰ Peroneus longus ⑱ Fibula

During our cadaveric study, we found excellent anatomical conformity of all Zimmer periarticular locking plates to Korean subjects. Using the standard approaches and techniques described in the product manual, there was no penetration of the articular surfaces. There was incomplete coverage of the posterolateral corner when using the proximal lateral tibial plate. For anatomical reasons, the plate could not be positioned more posteriorly due to the fibular head. Clinically, additionalposterolateral plate fixation may be needed or modification of plate design with new screw projectile covering the posterolateral surface is required. Because rafting solely by the lateral plate has limitations in covering the posterolateral corner of the tibial plateau.

Distal tibial plate application resulted in violation of vital structures. This was because the actual screw lengths were greater than what appeared on the C-arm image. We recommend taking proper views using 10~15 degrees of internal rotation to ensure correct screw length and thus avoid penetration of vital structures and tendons. Further modification may be suggested in its design.

V. Conclusion

Excellent anatomical conformity was observed with Zimmer periarticular locking plates for the proximal humerus, distal radius, and proximal and distal tibia. Additional posterolateral fixation is recommended when dealing with cases of tibial plateau fracture when the fracture line extends to the posterolateral cortex.

Caution must be exercised when choosing a screw length for the distal tibial plate in order to avoid penetration of vital structures.

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