



## 권역외상센터의 중증 외상 환자에서 대퇴 전외측 유리피판술의 유용성

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## Usefulness of Anterolateral Thigh Flap for Severe Trauma Patients at the Regional Trauma Center

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**Purpose:** The purpose of the research is to identify the result of using anterolateral thigh (ALT) flap to multiple trauma patients with open fracture accompanying soft tissue injuries.

**Methods:** The subjects were 18 patients who visited the regional trauma center with open fracture and treated with the ALT flap from February 2013 to September 2017. According to the injured body regions, there were 7 cases of foot injuries, 5 of lower extremity, 3 of ankle, 2 of hand, and 1 of forearm. The cause of injuries was car accidents in 10 cases including the pedestrian struck in 4 cases.

**Results:** Except for one case that the patient's flap was lost due to the artery thrombosis, the rest of cases showed that the flap was survived. Average healing time to a bone union was 8.1 months.

**Conclusion:** During the surgery of the multiple trauma patients with open fracture, no change of patient position is required and no pressure to abdomen or chest was applied. Also, the ALT flap with relatively long pedicle seems to be more useful than other flap surgeries.

**Key Words:** Multiple traumas, Open fracture, Free flaps

## INTRODUCTION

In the past, there were a lot of multiple trauma patients injured during the war, but recently, the number of pa-

tients who got involved in car accidents or industrial accidents is increasing. Although the definition of polytrauma is hard to define, it is usually defined as the injury severity score (ISS)<sup>1</sup> being greater than 15 or an abbreviated

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injury scale<sup>2</sup> being greater than 3 for at least two different body regions while having at least one of the following conditions: not more than 90 mmHg systolic blood pressure, not more than 9 points of Glasgow coma scale, less than -6.0 of base excess, coagulopathy with more than 40 seconds of partial Thromboplastin time or more than 1.4 of international normalized ratio or age over 70 years<sup>3,4</sup>.

Polytrauma patients who visited the regional trauma center which is in charge of the department of orthopedics would be treated for the injuries accompanying two or more proximal long bone fractures, severe soft tissue injuries, proximal amputations of an upper arm or an above-knee, pelvic fracture. Recently, there is an increase of polytrauma patients with head, chest or abdomen injuries or open fracture accompanying severe soft tissue injuries at upper or lower body<sup>5</sup>.

In case of open fracture with severe soft tissue injury, it is common that the open wound is contaminated and the soft tissue around the fracture is necrotized. For the treatment of soft tissue injury associated with open fractures, it is known to bring the best results if you used the external fixation in the early injury stage and then performed the flap approach (fix and flap concept) depending on the

patient's medical condition<sup>6,7</sup>.

The treatment for the soft tissue injury is applying wet dressing, which is for skin graft covering. And if the injury is too severe to cover with skin graft, there are other options such as local flap, muscle flap, and free flap. The authors report the usefulness of the anterolateral thigh (ALT) flap with benefits of long vascular pedicle and no position change of patients during operation with open fracture and severe soft tissue injury<sup>8,9</sup>.

## MATERIALS AND METHODS

The authors carried out a retrospective study on 18 multiple trauma patients who visited the regional trauma center with being ISS more than 15 with open fracture of Gustilo–Anderson type IIIb and IIIc accompanying the soft tissue injuries, therefore, underwent ALT flap from February 2013 to September 2017. The average age of the patients was 49.3 years (ranging from 8 to 79 years) with 12 males and 6 females. In the case of open fracture, there were 10 cases related to motor vehicle accident, 2 cases to falling accident, 2 cases to being crushed under a heavy object, 2 case to being crushed by machine pres-

**Table 1.** Demographic data of study groups

| Case No. | Sex | Age (yr) | Site      | Mechanism of injury  | Classification of open fracture* |
|----------|-----|----------|-----------|----------------------|----------------------------------|
| 1        | F   | 70       | Hand      | Crushed by machines  | IIIc                             |
| 2        | F   | 79       | Foot      | Out-car TA           | IIIb                             |
| 3        | M   | 52       | Foot      | Out-car TA           | IIIb                             |
| 4        | M   | 41       | Ankle     | Crushed by pipes     | IIIb                             |
| 5        | M   | 52       | Ankle     | Suicide attempt      | IIIc                             |
| 6        | M   | 66       | Lower leg | In-car TA            | IIIb                             |
| 7        | M   | 56       | Foot      | Entangled by roap    | IIIb                             |
| 8        | M   | 43       | Lower leg | Crushed by gas tanks | IIIc                             |
| 9        | F   | 60       | Hand      | Out-car TA           | IIIc                             |
| 10       | M   | 35       | Foot      | Motorcycle TA        | IIIb                             |
| 11       | M   | 72       | Foot      | In-car TA            | IIIc                             |
| 12       | F   | 38       | Foot      | Fall down            | IIIb                             |
| 13       | M   | 66       | Lower leg | In-car TA            | IIIc                             |
| 14       | M   | 23       | Forearm   | Motorcycle TA        | IIIc                             |
| 15       | F   | 8        | Lower leg | Out-car TA           | IIIb                             |
| 16       | M   | 47       | Lower leg | Motorcycle TA        | IIIb                             |
| 17       | F   | 28       | Foot      | Fall down            | IIIb                             |
| 18       | M   | 51       | Ankle     | Crushed by machines  | IIIb                             |

F: female, M: male, TA: traffic accident.

\*Classification according to the Gustilo–Anderson.

Table 2. Demographic data of study groups for associated injuries\*

| Case No. | Head or neck   | Face                               | Chest  | Abdominal or pelvic contents           | Extremities or pelvic girdle   |
|----------|--|------------------------------------|--|--|--|
| 1        | -  | BOF, maxillar fx.                  | -  | -                                      | Multiple fingers amputation and degloving injury, distal radius, humerus fx. |
| 2        | -  | -                                  | Lung contusion, MRF                                | -                                      | Multiple metatarsal bone open fx.  |
| 3        | SDH, SAH, skull fx.                                      | -                                  | Lung contusion                                     | -                                      | Toe amputation   |
| 4        | -  | Chin laceration, mandible fx.      | Pneumothorax                                       | -                                      | Distal tibiofibular comminuted open fx.                                      |
| 5        | SDH, skull fx.   | -                                  | -  | -                                      | Forearm amputation   |
| 6        | Scalp laceration   | -                                  | Lung contusion                                     | Duodenal perforation, kidney contusion | Tibiofibular open fx., metatarsal bone fx.                                   |
| 7        | SDH, brain contusion                                     | Forehead laceration                | MRF  | -                                      | Calcaneus open fx., ankle bimalleolar fx., ankle dislocation                 |
| 8        | -  | -                                  | MRF, pneumothorax                                  | -                                      | Proximal tibia comminuted open fx., tibial artery injury                     |
| 9        | SAH  | -                                  | -  | -                                      | SI joint disruption, pelvis fx.  |
| 10       | SDH, SAH, skull fx., pneumocephalus, cerebral contusion, | Maxillar fx.                       | MRF  | -                                      | -  |
| 11       | SDH, SAH, skull fx.                                      | Forehead laceration                | Hemothorax, lung contusion, MRF, cardiac tamponade | -                                      | Foot crushing injury, fibular fx.  |
| 12       | SAH, ICH, EDH  | -                                  | MRF, lung contusion                                | Hemoperitoneum                         | Pelvic bone, vertebral, tibiofibular fx.                                     |
| 13       | -  | -                                  | -  | Hemoperitoneum, liver laceration       | Tibia shaft open fx.   |
| 14       | -  | Mandible fx.                       | -  | -                                      | Forearm amputation   |
| 15       | -  | -                                  | Hemothorax, MRF                                    | Spleen injury (pseudoaneurysm)         | Distal tibiofibular open fx.   |
| 16       | Skull fx.  | NBF, maxillar fx., BOF, zygoma fx. | -  | -                                      | Femur I-T, tibia, foot fx.   |
| 17       | -  | -                                  | Hemothorax, lung contusion, MRF                    | -                                      | Vertebral, tibia, foot fx.   |
| 18       | -  | -                                  | MRF, pneumothorax                                  | Kidney laceration                      | Distal tibia comminuted open fx., tendon injury                              |

BOF: blow-out fracture, fx.: fracture, MRF: multiple rib fracture, SDH: subdural hemorrhage, SAH: subarachnoid hemorrhage, SI: sacroiliac, ICH: intracerebral hemorrhage, EDH: extradural hemorrhage, NBF: nasal bone fracture, I-T: intertrochanteric fracture.

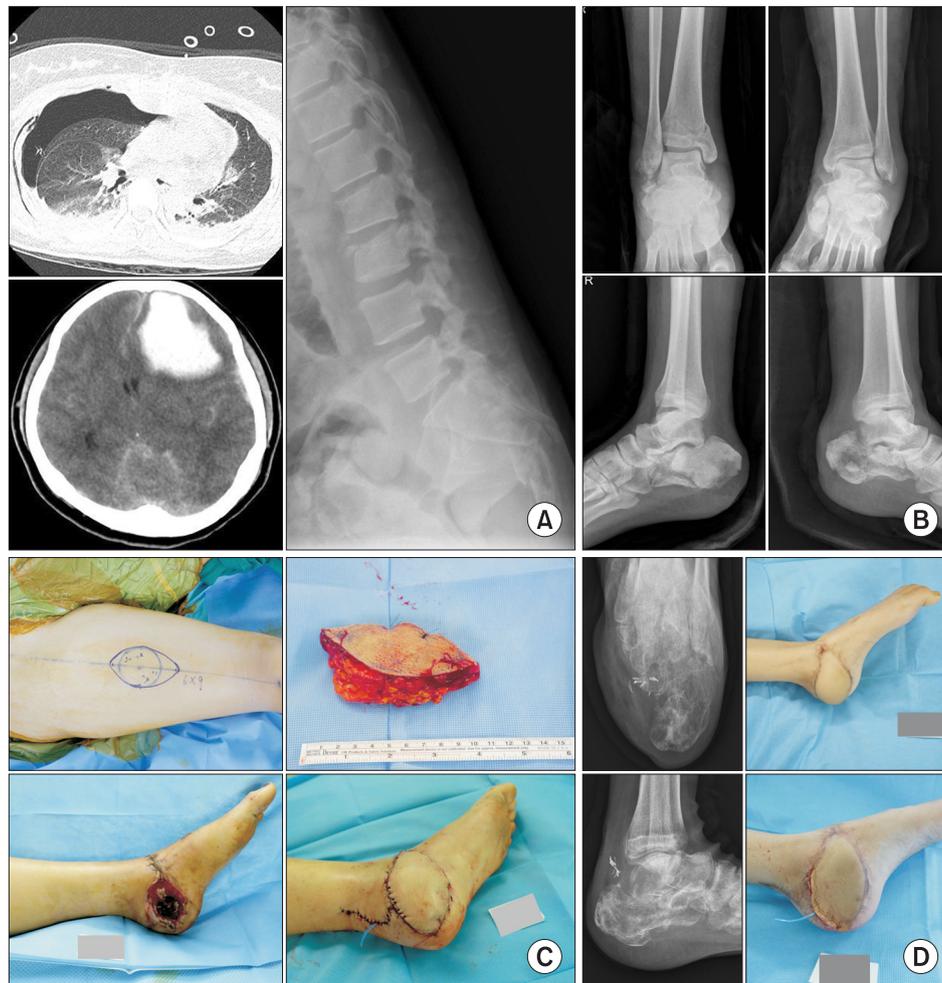
\*Divided by 6 body regions for injury severity score scoring. No contents for external region omitted.

sure, 1 case to legs being wrapped by a ship rope, and 1 case to jumping down onto the subway track. According to the injured body region, 7 out of 18 patients suffered from the fracture of foot, 5 of lower leg, 3 of ankle, 2 of hand, and 1 of forearm (Table 1).

Accompanying trauma were nine cases of head or neck injuries (skull fracture and traumatic cerebral hemorrhage, 50.0%), seven cases of face trauma (blow-out

fracture, maxillar fracture, etc., 38.9%), twelve cases of chest trauma (hemothorax, pneumothorax, fracture of rib, 66.7%), five cases of injury of abdomen (enteric injuries, kidney injuries, 27.8%), and no case of external region (Table 2).

The timing of performing ALT flap procedure was decided depending on general condition of the patients, level of injury and contamination of open wounds. The



**Fig. 1.** (A) A 38-year-old female patient visited the regional trauma center after falling from the 4-5th level of floor. By observation through the assessment of each part of body, intracerebral hemorrhage, subarachnoid hemorrhage, and subdural hemorrhage, cardiac tamponade, right atrium rupture, sternum fracture, pneumothorax, multiple rib fracture, traumatic hemothorax, lung contusion, traumatic hemoperitoneum were found. Apart from them, sacral fracture and acetabular fracture were diagnosed at pelvic part, lumbar vertebral burst fracture at spine. (B) Both talus body fracture, both calcaneus open fracture and right distal tibiofibular fracture were diagnosed at the both ankles, and at the time of visit, the patient was in coma with injury severity score 66, Gustilo–Anderson classification type IIIb. (C) When the vital signs became stabilized after the emergency operation by neuro and thoracic surgery, the initial orthopedic surgery (anterolateral thigh flap) could be performed, which was after 26 days. The treatment for the spinal fracture and cerebral hemorrhage was not completed but the flap procedure could be done successfully. Although other simpler techniques such as sural flap can be done, the scar remained at the donor site was considered because the patient was a young female. (D) After 8 months, the patient achieved the bone union, and the defatting of the flap area and cement bead removal were performed.

soft tissue injured area ranged from minimum 36 cm<sup>2</sup> to maximum 192 cm<sup>2</sup> with average of 91.7 cm<sup>2</sup>. The result of the flap procedure was assessed by numbers from 1 to 4 according to the condition of the flap; 1: no flap problems, 2: minor flap complications but no actions taken, 3: flap complications requiring intervention, and 4: complete flap failure<sup>10</sup>. Also, the infection of donor site and recipient site, and hematoma were assessed (Table 1).

The IBM SPSS software ver. 21.0 for Windows (IBM Corp., Armonk, NY, USA) was used to statistically analyze the result. To insert a graphic image, the GraphPad Prism Software ver. 5.0 for Windows (GraphPad Software, La Jolla, CA, USA) was used. If the p-value is less than 0.05, it was called statistically significant.

## RESULTS

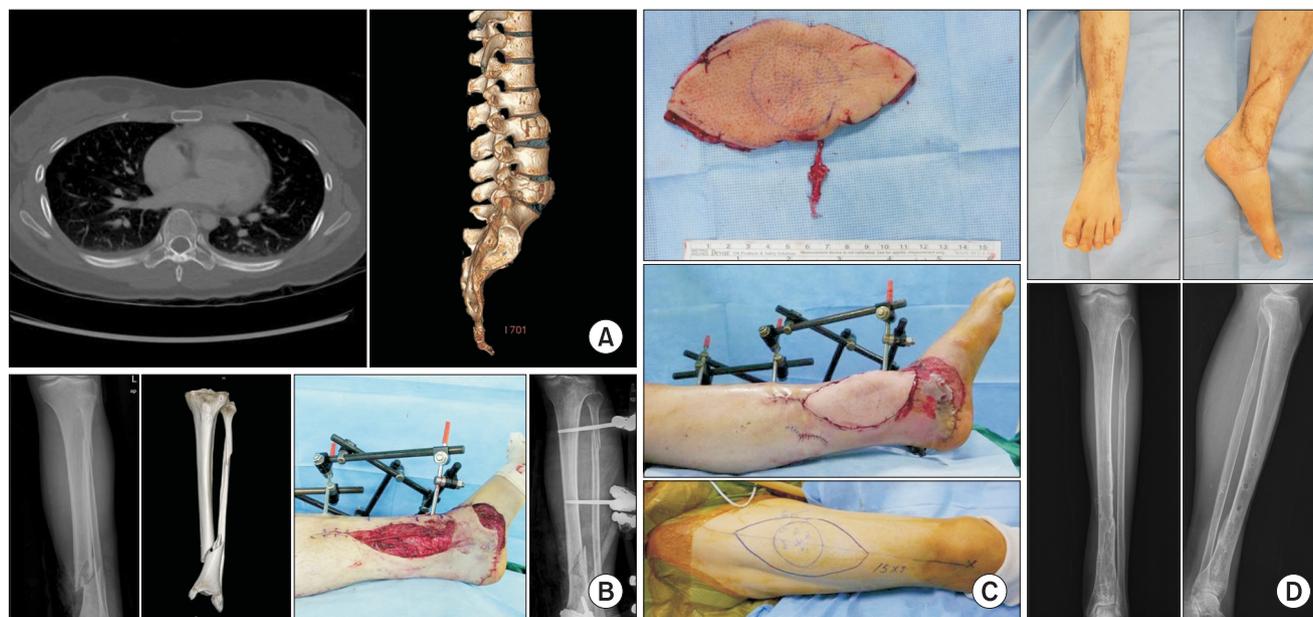
Seventeen out of 18 patients who were treated with the ALT flap to reconstruct a soft tissue which accounted for 94.4% showed that the flap was survived, and the

average size of the flap was 98.4 cm<sup>2</sup>. Three out of 18 cases developed complication such as osteomyelitis and nonunion, which delayed the performance of procedure for more than six months. Except for these three cases, 15 cases took average 32.1 days until performing the flap procedure. The average time required for bone union was 8.1 months and every patient achieved the bone union (Fig. 1, 2).

The average flap score<sup>10</sup> was 2.1 points with one case of flap necrosis, one case of donor site infection, and two cases of osteomyelitis and infected nonunion (Table 3).

## DISCUSSION

For multiple trauma patients with open fractures with soft tissue injury, it is common to undergo emergency or elective surgery with other parts such as trauma surgery or neurosurgery. Additionally, if the patients are found to have abdominal, head or spinal injuries, orthopedic surgery can be pushed out of priority. Or, because of their



**Fig. 2.** (A) A 51-year-old male patient was suspected of having a multiple trauma after a car accident and visited the regional trauma center, and he was diagnosed with traumatic hemothorax and lung contusion. (B) In orthopedic department he was diagnosed with left distal tibia open comminuted fracture and gastrocnemius muscle partial rupture. As an emergency surgery, the orthopedic surgeon performed the posterior decompression and fusion for the spine fracture, open reduction, irrigation and debridement, and external fixation for the left lower leg. (C) The inflammation at the left lower leg with skin loss showed an improvement, the anterolateral thigh flap was performed on the 8th day. The patient who had undergone a surgery for a spine fracture underwent the flap surgery but showed no complications. (D) After 6 months, he underwent a defatting and metal removal and at 7 months, the bone union was achieved.

**Table 3.** The results of anterolateral thigh flap

| Case No. | Bone union (mo) | Complications          | Flap score | Flap survival | ISS | Time to initial orthopedic surgery (hr) | Time to ALT flap (d) |
|----------|-----------------|------------------------|------------|---------------|-----|---|----------------------|
| 1        | 5               | None                   | 1          | O             | 29  | 3.7                                     | 21                   |
| 2        | 10              | None                   | 3          | O             | 25  | 10.5                                    | 30                   |
| 3        | 9               | None                   | 2          | O             | 26  | 4.3                                     | 20                   |
| 4        | 8               | None                   | 1          | O             | 17  | 5.8                                     | 23                   |
| 5        | 7               | OM                     | 2          | O             | 32  | 8.0                                     | 51                   |
| 6        | 15              | Flap partial loss      | 3          | O             | 22  | 9.0                                     | 51                   |
| 7        | 6               | None                   | 3          | O             | 20  | 17.2                                    | 21                   |
| 8        | 18              | None                   | 3          | O             | 18  | 2.5                                     | 43                   |
| 9        | 7               | None                   | 3          | O             | 21  | 2.5                                     | 34                   |
| 10       | 5               | None                   | 1          | O             | 29  | 3.7                                     | 9*                   |
| 11       | 7               | None                   | 2          | O             | 26  | 5.0                                     | 33                   |
| 12       | 4               | None                   | 1          | O             | 66  | 264.0                                   | 26                   |
| 13       | 10              | Flap complete loss, OM | 4          | X             | 19  | 2.1                                     | 33*                  |
| 14       | 7               | None                   | 3          | O             | 20  | 4.0                                     | 15*                  |
| 15       | 12              | Flap partial loss      | 3          | O             | 22  | 3.1                                     | 50                   |
| 16       | 4               | None                   | 1          | O             | 17  | 7.6                                     | 32                   |
| 17       | 3               | None                   | 1          | O             | 22  | 10.8                                    | 38                   |
| 18       | 7               | None                   | 1          | O             | 22  | 8.0                                     | 8                    |

ISS: injury severity score, ALT: anterolateral thigh, OM: osteomyelitis.

\*Unit: months.

severe general condition, orthopedic emergency surgery may not be preceded. As a result, the therapeutic outcome may be unsatisfactory, or the patient may have a disability.

In general, flap surgery can be performed for the treatment of severe soft tissue injuries. However, several surgical debridement procedures are necessary, and contamination and inflammation may remain on the open wound. Therefore, flap surgery should be discussed depending on the general condition of the patient and the size of the open wound.

Immediate soft tissue reconstruction is known to prevent severe complications such as secondary infection of the injured site or osteomyelitis<sup>11</sup>. However, in patients with other trauma problems, orthopedic problems may be hampered by priorities, and difficult to reconstruct at proper times due to poor general condition of the patient.

Before discussing soft tissue reconstruction using free flap techniques, the size of defect, related structure, quality of surrounding blood vessels and blood vessels of four limbs, quality of donor site, and the length of flap

pedicle should be evaluated. Also, the type of flap should be selected based on the patient's general condition prior to surgery and the practicality and relevance of injured regions and soft tissue defect<sup>12</sup>. The advantages of ALT flap are as follows: a long pedicle, constancy of vascular system, donor-site morbidity, availability of flow-through flap, use of thin flap, and no need for changing the position during surgery<sup>13</sup>.

Most of the patients who visited the regional trauma center had multiple comorbid trauma such as head, facial, spinal, chest, and abdominal injuries. Therefore, they had to undergo several surgeries at the same time. Since ALT flap does not require the posture change of the patient during surgery, the risk of additional damage to other site injuries can be minimized. In addition, the flap can be harvested when the patient is in the supine position and allows only limited operations in the lower limbs. This is a very important advantage for patients who cannot tolerate general anesthesia because of poor general condition or damage to the lungs or the liver. In this case, epidural anesthesia can be an alternative. This permits the opera-

tor to perform ALT flap as early as possible which can bring a good result. Also, the flap can cover large defect areas or defects of more than two parts, depending on the severity of the trauma. And when necessary, muscular flap is available. In particular, ALT flap provides the long length of flap pedicle, therefore, vein graft can be avoided and microvascular anastomosis is possible far from the zone of injury.

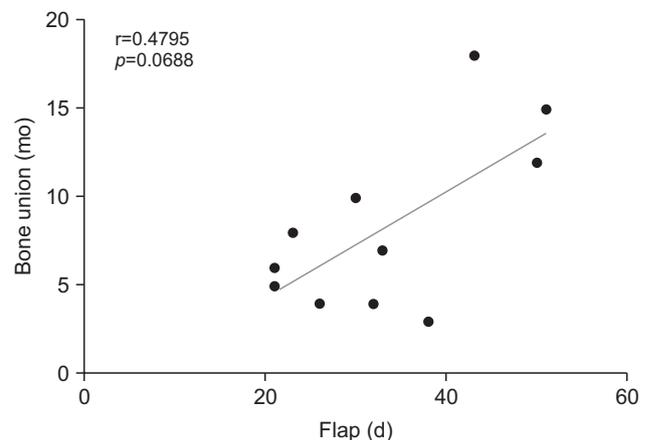
Meanwhile, the surgical timing of fracture and flap is still controversial in multiple trauma patients. The timing of fracture operation in multiple trauma patients was changed from early total care to damage control orthopedics, and now to early appropriate care<sup>14</sup> or safe definitive surgery<sup>15</sup>. Still, there is a lack of research on the timing of soft tissue reconstruction in multiple trauma patients. However, Heller and Levin<sup>16</sup> reported that urgent flap surgery performed within five to seven days after injuries would lead to a great prognosis. This timing is similar to the period of five to ten days which is called the time window opportunity that is the period between the initial inflammation stage of two to four days after surgery and immunologic inhibition stage at the second week of surgery. In other research, Philandrianos et al.<sup>17</sup> reported that the operating timing for the first flap procedure was an average of 20.2 days. Meanwhile, Steiert et al.<sup>18</sup> carried out the negative pressure wound therapy for an average of 28 days and performed delayed flap surgery to the patients, then, one of 33 patients showed flap necrosis, which was a good result comparable to the case of the early flap surgery. In this research, it took an average of 32.1 days and one of 18 patients (5.6%) showed flap necrosis.

Most of the reasons for the relatively delayed long days until the flap was performed were related to other part of problems. In particular, in the case of the multiple trauma patients with head, chest or abdomen injuries and not in a good condition to carry out the surgery, it was hard to perform the early surgical procedure in the center. Therefore, these patients had to undergo the surgeries for the accompanied trauma, which took some time to get recovered and might have increased the risk of complication.

Also, to find out the relationship between the timing of

the flap procedure and the healing time for a bone union, the authors used the Pearson correlation coefficient for static analysis. The p-values were turned out to be 0.0688 which was not a statistically significant figure due to the small number of surgery cases, but the result showed the positive relationship (Fig. 3). In other words, the immediate skin reconstruction to the soft tissue injuries using the flap surgery would minimize the risk of complication such as contamination of the wounded part and the surgical treatment to fracture would advance the date of achieving bone union. Therefore, if patients were in a condition suitable for surgery, flap as early as possible would lead to good results. According to Philandrianos et al.<sup>17</sup>, the time to bone union was 12.2 months on average and the result using latissimus dorsi muscle was 10.4 months. And in this study, the mean was 8.1 months. In this research, the multiple trauma patients took a long time to get recovery and rehabilitation after the surgery, but the healing time for a bone union took a lesser time compared to other research.

The incidence of osteomyelitis was 11.1% which was not the case with nonunion, because free flap surgery reconstructed the skin of open fractured part and provided the blood supply and helped to control contamination and to create the condition suitable for bone union. Demirtas et al.<sup>19</sup> performed the ALT flap to 23 patients with open



**Fig. 3.** The authors used the Pearson correlation coefficient method to confirm the correlation between the timing of the flap and the time of union. The p-value of 0.0688 showed no significant statistical significance but a positive correlation.

fracture and the result accounting for 8.7% with an average flap score of 2.0 points showed accompanying osteomyelitis, and in this study, the average flap score was 2.1 points which was not significantly different. It means the evaluation of flap itself, which is not related to multiple trauma problems.

The main limitations of this study were the facts that it was a retrospective study and only a few numbers of cases were involved.

## CONCLUSION

In the multiple trauma patients who visited the trauma center, the healing time for bone union between subjects that underwent ALT flap for open fracture accompanied with severe soft tissue injury and the others with the general fracture treatment showed no significant differences. Also, the statistical data analyzed the relationship between the timing of ALT flap and the healing time for bone union showed that performing the flap surgery as early as possible would be beneficial to the treatment of fracture in multiple trauma patients. Therefore, ALT flap can be an excellent therapeutic option for multiple trauma patients with abdomen, chest and spinal injuries.

## CONFLICTS OF INTEREST

The authors have nothing to disclose.

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## 권역외상센터의 중증 외상 환자에서 대퇴 전외측 유리피판술의 유용성

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**목적:** 권역외상센터에 내원한 다발성 외상 환자 중 연부 조직 손상이 심한 개방성 골절에서 대퇴 전외측 유리피판술을 사용하여 치료한 결과를 보고하고자 한다.

**방법:** 2013년 2월부터 2017년 9월까지 권역외상센터를 통해 내원한 다발성 외상 환자 중 대퇴 전외측 유리피판술을 시행한 개방성 골절 환자 18명을 대상으로 하였다. 수상 부위별로, 족부 7예, 하퇴부 6예, 발목과 수부 각 2예, 전완부 1예였다. 수상 원인 중 흔한 것은 교통 사고(10예), 특히 보행자 사고(4예)였다.

**결과:** 동맥 혈전으로 인해 피판이 완전 소실된 1예를 제외하고는, 모든 경우에 피판이 생존하였다. 평균 골유합 달성 기간은 8.1개월이었다.

**결론:** 다발성 외상을 동반한 개방성 골절 환자에서는 수술 시 자세 변화가 없으며 복부나 흉부에 압박을 주지 않으며 혈관경이 비교적 긴 대퇴 전외측 유리피판술은 다른 피판술에 비하여 유용한 피판술이라고 생각된다.

**색인단어:** 다발성 외상, 개방성 골절, 유리피판술

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