Surgical Outcomes of Transmastoid Facial Nerve Decompression for Patients With Traumatic Facial Nerve Paralysis

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OBJECTIVE: To evaluate the facial nerve function and audiological results of delayed (by at least one month after the insult) transmastoid facial nerve decompression (FND) in traumatic facial nerve paralysis (FNP).

METHODS: Medical records of 57 patients with traumatic FNP were reviewed and surgical results of 13 patients (mean age 28.0 ± 17.67, range 3-67) undergoing transmastoid FND were analyzed. Preoperative and postoperative mean hearing thresholds were compared using 0.5, 1, 2, and 3 kHz. Facial nerve function was graded according to the House–Brackmann scale (HB) before and after surgery. HB scale results of grade III or better were accepted as good results postoperatively.

RESULTS: Preoperative HB grades were V in 5 and VI in 8 patients. Twelve of 13 patients had good recovery of facial nerve function regardless of the operation timing. When mean preoperative and postoperative air–bone gap (ABG) values were compared (except the patients with total sensorineural hearing loss), the mean preoperative ABG was 33 ± 15.9 dB, and mean postoperative ABG was 17.2 ± 8.68 dB. There was a mean hearing gain of 15.8 dB after transmastoid facial nerve decompression surgery. Surgery and anesthesia-related complications were not seen in any patients.

CONCLUSION: The transmastoid route can be used safely and effectively with elimination of the risks of craniotomy and middle fossa surgery for patients with traumatic FNP. Hearing improvement can be achieved by performing ossicular chain reconstruction during decompression surgery for patients with conductive or mixed hearing loss (HL).

KEYWORDS: Facial nerve, decompression, facial paralysis

INTRODUCTION
Facial nerve paralysis (FNP) may develop from many causes, such as trauma, infections, and tumors. The most common causes of FNP are idiopathic (Bell’s palsy), head, or temporal bone traumas.1 Iatrogenic trauma to the facial nerve during the otologic surgery may also cause FNP. Surgical procedures for cerebellopontine angle lesions, congenital aural atresia, and chronic otitis media with or without cholesteatoma have a risk of facial nerve injury.2 FNP can occur in 10% of all temporal bone fractures (TBF), and these fractures occur mostly due to vehicle accidents.3 They are classified as otic capsule-violating and otic capsule-sparing fractures.4 Another classification indicates linear, transverse, and mixed type, depending on the relation between the fracture line and the long axis of the petrous bone. Eighty percent of all TBFs are longitudinal; facial paralysis occurs in 20% of them. Transverse fractures comprise 20% of all TBFs; FNP occurs in 50% of them.5 The remainder are the mixed type TBFs.

The aim of this study was to evaluate the facial nerve motor function and audiological results of the transmastoid facial nerve decompression (FND) surgery in the late period (delayed by at least one month after the traumatic insult) after traumatic FNP.
MATERIALS AND METHODS
Medical records of 57 patients with traumatic FNP were reviewed and 13 patients who underwent transmastoid FND between 2010 and 2017 were retrospectively analyzed.

Inclusion Criteria
We studied the records of patients who met the following criteria:

i. House–Brackman (HB) grade V and VI FNP one month after trauma;
ii. Patients with traumatic FNP who were administered systemic corticosteroid treatment, with no observable recovery;
iii. Patients with traumatic FNP who did not have any middle ear disease or cerebellopontine angle tumors;
iv. Patients with traumatic FNP undergoing transmastoid approach (TMA) for FND.

Exclusion Criteria
i. Patients recovering spontaneously or after medical treatment;
ii. Patients with HB grades I through IV;
iii. Patients who needed another advanced surgical approach other than FND.

This study was approved by the local institutional review board (No:2019/315). All traumatic FNP patients had been hospitalized in the intensive care unit (ICU) and had undergone mechanical ventilation. High-dose prednisolone or dexamethasone had been administered to the patients in the ICU. These patients had been referred to our department at least one month after the traumatic insult and after their recovery from the mechanical ventilation and unconscious state. Therefore, FNDs had been performed within 1 to 3 months after trauma (Table 1). Patients had undergone a delayed FND (at least 1 month after the insult)6,7 depending on the delay in their admission.

Surgical Indications
i. Presence of fibrillation, spike potentials, and total axonal degeneration on EMG (electromyography);
ii. Absence of volunteer potentials and facial movement;
iii. Fracture line apparently the crossing fallopian canal as seen on high-resolution computerized tomography (HRCT);
iv. Severe facial nerve paralysis (H–B grade V-VI).

Electromyographical examinations were performed during the first examination. The HRCTs of temporal bone were obtained from all patients preoperatively. Fracture types and localizations were classified and noted. Audiometric evaluations were performed preoperatively and postoperatively in the 3rd and 12th months. Preoperative and postoperative hearing outcomes were compared with a 4-frequency pure-tone average (PTA) using 0.5, 1, 2, and 3 kHz. Air–bone gap (ABG) values were calculated by subtracting bone PTA values from air PTA values. Hearing gains were calculated by subtracting the postoperative (first year after decompression) ABG values from the preoperative ones. Auditory brainstem response was tested in 1 patient who was a 3 year-old boy. Facial nerve function was graded according to the HB system both preoperatively and 12 months postoperatively. HB scale results of grade III or better were evaluated as good results. Electroneuronography was not performed on any patient since all of them were admitted 4 weeks after trauma.

Surgical Technique
Facial Nerve Decompression
Under general anesthesia, a complete mastoidectomy was performed through a retroauricular incision. The facial nerve was found in the posterior edge of the posterior tympanotomy. For most cases where the main insult was at the perigeniculate region, if bony spurs could be eliminated effectively and the nerve could be decompressed, then the incus was not removed, especially in patients with a wide epitympanic region. However, the incudostapedial joint was separated and the incus was removed to access the perigeniculate region if the traumatized area could not be achieved. The facial nerve bony canal was examined and removed 180 degrees, from the labyrinthine segment and the geniculate ganglion to the stylomastoid foramen, under the operating microscope. Bony spicules embedding in the nerve were removed during surgery. Surgical microscope was used with a wide epitympanic region. The nerve was removed during surgery. In the case with bilateral FNP (Patient 12), there was complete nerve cutting on the left side. A cable graft was used to bridge the gap.

Table 1. Patients’ Demographic and Clinical Features

| P. no | Age/Gender | Side | Etiology               | Preop HB | Postop HB | Timing of Surgery* | EMG Findings                      |
|-------|------------|------|------------------------|----------|-----------|-------------------|-----------------------------------|
| 1     | 20/M       | R    | Motorbike accident     | 5        | 3         | 3 months          | Total axonal degeneration         |
| 2     | 18/M       | R    | Motorbike accident     | 5        | 2         | 2 months          | No voluntary MUP                  |
| 3     | 37/M       | R    | Traffic accident       | 6        | 3         | 1 month           | Total axonal degeneration         |
| 4     | 3/M        | R    | TV falling on head     | 5        | 2         | 3 months          | Near-total axonal degeneration    |
| 5     | 67/M       | L    | Bicycle accident       | 5        | 1         | 1 month           | Total axonal degeneration         |
| 6     | 19/M       | R    | Traffic accident       | 6        | 3         | 1 month           | No voluntary MUP                  |
| 7     | 22/M       | R    | Traffic accident       | 6        | 6         | 2 months          | Total axonal degeneration         |
| 8     | 44/M       | L    | Traffic accident       | 6        | 3         | 1 month           | Total axonal degeneration         |
| 9     | 18/M       | R    | Traffic accident       | 6        | 3         | 1 month           | Total axonal degeneration         |
| 10    | 44/M       | L    | Traffic accident       | 5        | 2         | 3 months          | Near-total axonal degeneration    |
| 11    | 10/M       | L    | Iatrogenic             | 6        | 3         | 2 months          | Total axonal degeneration         |
| 12    | 43/M       | R    | Wood block falling on head | 6   | 2         | 1 month           | Total axonal degeneration         |
| 13    | 19/M       | R    | Traffic accident       | 6        | 2         | 1.5 months        | Near-total axonal degeneration    |

*P. no, Patient no; HB, House–Brackman; EMG, electromyography; M, male; Preop, preoperative; Postop, postoperative; R, right; L, left; MUP, motor unit potential.

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*Timing of facial nerve decompression after the traumatic insult.
harvested from the greater auricular nerve (GAN) to repair the nerve. Therefore, the left ear of this patient was excluded from the study. In the right ear of this patient, the incus was first removed in order to explore the geniculate ganglion, and the bone spur was then removed from the geniculate ganglion region. At the end of the operation, the incus was replaced in its original position so as to restore the hearing, by fixing with bone cement. In 1 patient (Patient 7), the facial nerve showed severe edema and damage in the mastoid segment near the stylomastoid foramen. Facial nerve decompression surgery was performed. However, functional recovery could not be achieved, and the patient had HB grade VI FNP after the first surgery. About 4 months after decompression, VII-XII anastomosis was performed with a sural nerve graft. The final HB grade of the patient after the latter operation was HB grade III. Nevertheless, the postoperative HB grade of the patient was regarded as grade VI, and the HB grade of the VII-XII anastomosis was not included. A 10-year-old boy (Patient 11) had undergone congenital aural atresia surgery in another hospital, had immediate FNP after surgery, but he had been treated with 1 mg/kg methylprednisolone. His family was admitted to our clinic 2 months after the first surgery. The boy was operated on after EMG and temporal bone HRCT evaluation. During surgery, traumatic injury near the stylomastoid foramen in the mastoid segment of the facial nerve was seen, and the mastoid segment of the facial nerve was decompressed, including the stylomastoid foramen.

RESULTS
The age of the 13 male patients ranged from 3 to 67 (mean age 28 ± 17.67). Patients’ demographic features and trauma types are shown in Table 1. Nine patients had FNP on the right side and 4 patients on the left side. Tympanic membrane and middle ear could not be examined for the boy who had undergone surgery for aural atresia in another hospital. Neurologic examinations, except for the facial nerve, were unremarkable in the remaining patients.

EMG Findings
All patients had total or near-total axonal degeneration and no voluntary motor unit potential on EMG records preoperatively (Table 1).

Temporal Bone Computed Tomography Examination
Five longitudinal, 1 transverse, and 6 mixed type fractures were observed on HRCT (Figures 1, 2, 3, and 4). These fracture lines were seen in the mastoid segment in 2 (17%), and in the perigeniculate region in 10 (83%) of the temporal bone HRCT scans. There were otic capsule-violating fractures in 4 temporal bones (33%) and otic capsule-sparing fractures in 8 temporal bones (67%). The otic capsule-violating fractures were transverse in 1 and mixed type in 3 patients (Table 2). In 1 patient who had undergone aural atresia surgery in another institution, there was a mastoid cavity, and the result of the temporal bone computed tomography (CT) examination showed no fracture line.

Facial Nerve Injury Sites
Injury of the facial nerve was seen at the geniculate region in 10 and at the mastoid segment in 3 patients who were related to 2 TBFs and one iatrogenic trauma.

Surgical Findings for Facial Nerve Paralysis
Small bone spicules in the fallopian canal were seen in 10 patients during FND. It was seen that there was edema in the affected nerve area of all patients. A totally transected facial nerve at tympanic segment of perigeniculate area was not encountered in any patient.
Table 2. Computed Tomography and Intraoperative Findings of the Patients

| Ear No | Type of Fracture | Affected Region | Intraoperative Findings and Surgical Procedures |
|--------|------------------|----------------|-----------------------------------------------|
| 1      | Mixed            | Mastoid        | Bone spur, GAN grafting                       |
| 2      | Mixed            | GG             | Bone spur, edema in nerve, intact ossicular chain |
| 3      | Longitudinal     | GG             | Bone spur, displacement of incus to attic, removed incus and interposed |
| 4      | Mixed            | GG             | Bone spur                                     |
| 5      | Longitudinal     | GG             | Removed ossicles                              |
| 6      | Mixed            | GG             | Bone spur                                     |
| 7      | Longitudinal     | Mastoid        | Severe edema and damage in mastoid segment, removed incus |
| 8      | Longitudinal     | GG             | Bone spur, edema in nerve, non-applicable fractured incus, removed incus, MSP |
| 9      | Mixed            | GG             | Bone spur, absent of long process of the incus, removed incus and interposed |
| 10     | Longitudinal     | GG             | Edema in nerve, fixed incus in its original place |
| 11     | Iatrogenic       | Mastoid        | Fusion anomalies of malleus – incus, bone spur, granulation tissue, removed incus, MSP |
| 12     | Transverse       | GG             | Bone spur, separation at incudostapedial joint, fixed incus in its original place |
| 13     | Mixed            | GG             | Bone spur, displacement of incus to middle ear, removed incus and interposed |

GG, geniculate ganglion; GAN, greater auricular nerve; MSP, malleo-stapediopexy.

Surgical findings of the patients are summarized in Table 2. No postoperative complications were seen.

Evaluation of the Facial Nerve Function
The HB grades were V in 5, and VI in 8 preoperative facial examinations. Since all patients had a history of being in ICU with mechanical ventilation, the time interval between the trauma and FNP and the initial FNP grade (complete or incomplete) after trauma could not be assessed. The mean preoperative HB grade score of patients was 5.61 ± 0.5; the scores were I in 1, II in 5, III in 6, and VI in 1, for facial examinations in the first-year postoperative control visits. The mean postoperative HB grade score of the patients was 2.7±1.2. Postoperative findings in 12 (92%) patients were referred to as good results, independent of the operation’s timing (Table 1).

Audiometric Examination
Postoperative hearing thresholds and closure of ABG were assessed in the control visits in the 12th month after FND. The patients’ audiometric results are summarized in Table 3.

Total sensorineural hearing loss was detected in 4 ears before surgery; thus, hearing-restoration surgery was not performed for these patients. Preoperatively, 8 ears had conductive hearing loss (CHL) or mixed hearing loss and one ear had normal hearing. Seven patients who had undergone hearing-restoration surgery had better PTA and ABG values compared to their preoperative hearing status, except for 1 patient (Patient 10, Figure 5). This patient had preoperative normal hearing and postoperative mild CHL. Mean ABG gain was 15.8dB for patients who had undergone hearing-restoration surgery (mean preoperative ABG: 33±15.9 dB, mean postoperative ABG: 17.2±8.68) (Table 3).

DISCUSSION
In the present study, we demonstrated that favorable facial nerve motor function could be maintained by transmastoid FND for patients with traumatic FNP even after 1-3 months of FNP. Decompression surgery between 1 and 3 months did not differ regarding facial nerve recovery according to the timing of the operation. Approximately 16 dB gain can be achieved by ossiculoplasty during transmastoid FND for patients with CHL or mixed HL. Ulug et al. presented a series of 11 patients with traumatic FNP; 63% of the patients had longitudinal type fracture, 37% had a mixed type,
Patients’ facial nerve functions could not be evaluated when they were in the ICU, since they were under general anesthesia and mechanical ventilation. In the late period, EMG records and HRCT findings can inform the surgeon about the decision of FND. In our study, the reason for delayed decompression for traumatic patients was also prolonged ICU stay. Patients’ facial nerve functions could not be evaluated when they were in the ICU, since they were under general anesthesia and mechanical ventilation; thus FND could not be performed early. Observation and conservative treatment in cases of traumatic FNP may be useful for trauma-induced FNP. Systemic steroid treatment is an effective option for the delayed-onset and incomplete traumatic FNP. Conservative treatment options can be effective for patients who have <90% facial nerve degeneration on ENoG within 3-14 days after trauma, absence of a distinct fracture line crossing the Fallopian canal on CT, and the presence of regeneration findings on EMG. However, FND may be needed for patients with immediate-onset and HB grade V or VI traumatic FNP. In our study, patients had HB grade V or VI FNP at first otolaryngologic examination, and they had a history of corticosteroid administration for brain injury during follow-up in the ICU. Additionally, their admission to our department was delayed by at least 1 month after the trauma. Therefore, these patients had already passed the observation and systemic corticosteroid treatment options when they admitted to our otorhinolaryngology clinic, and therefore, they underwent FND. There are many approaches for FND such as transmastoid, translabyrinthine, middle cranial fossa (MCF), and the combined approach, according to the area of the nerve injury and the hearing thresholds of the patients. If there is no serviceable hearing in the patient, the translabyrinthine approach may be an option for decompression. However, if there is favorable hearing, the transmastoid, MCF, or a combination of these 2 procedures can be employed in order to retain the hearing levels. There is still no consensus regarding the gold standard in surgical approaches for FND for temporal bone fractures in the literature. MCF, MCF combined with TMA, and isolated TMA have all been demonstrated to exhibit satisfactory facial nerve function outcomes after decompression surgery. Additionally, Ulug et al. emphasized that the labyrinth should be protected for cochlear implantation even if the patient has no serviceable hearing, so they offered that the MCF approach should be used instead of the translabyrinthine route for patients with total sensorineural hearing loss (TNSHL). The rationale of MCF approach for FND is that this technique promotes optimal access to the labyrinthine segment and the perigeniculate region. Although MCF is an extradural subtemporal route, it has serious complications such as cerebrospinal fluid leak, meningitis, as well as aphasia and seizures because of craniotomy and retraction of the temporal lobe. However, the mentioned complications are seen rarely with experienced surgeons, and permanent sequels are uncommon. As seen in our study, extralabyrinthine TMA can also provide access to the perigeniculate region with incus removal and interposition or refixation to the original position at the end of the decompression, without deteriorating the hearing levels and protecting the patient from the complications of craniotomy. Except in cases with otic capsule-violating fractures, most patients with TBFs have conductive or mixed HL. For these patients, TMA with wide anterior and posterior tympanotomy provides access to the middle ear during FND, and ossicular chain reconstruction for hearing improvement can be performed easily. Liu et al. demonstrated an average 15 dB improvement in air conduction hearing levels by ossiculoplasty during TMA for patients with traumatic FNP. Similarly in our study, we demonstrated a significant (average 15.8 dB) ABG closure for patients with preoperative conductive or mixed HL by the same surgical route. On the other hand, the isolated MCF approach cannot provide effective ABG closure and it needs a second look or combined surgery for hearing improvement for patients with conductive or mixed HL. It is important to mention that in our study, we did not see any case of totally transected facial nerve at the perigeniculate region. By TMA, we could successfully explore the perigeniculate region, and edema of the nerve or bone spur trauma could be easily handled by this route. However, for cases with transected facial nerve at the proximal part of the geniculate ganglion, the MCF approach or translabyrinthine approach (in cases of TNSHL) are more suitable surgical routes.
suggested that FND performed within 3 months of the traumatic insult could obtain satisfactory facial nerve function outcomes irrespective of the timing of the surgery.18 Our study results were similar, in that all patients were operated in 1 to 3 months of the paralysis, and all of them except for 1 patient recovered with favorable outcome regardless of the operation timing. Observation with conservative treatment options may also exhibit good recovery rates for most of the patients with delayed-onset traumatic FNP.25 On the other hand, patients with immediate-onset FNP, having no motor unit potentials on EMG and bone fracture lines involving the Fallopian canal, are candidates for decompression surgery since these patients may exhibit unsatisfactory facial nerve recovery outcomes and may recover with synkinesis sequel by waiting for spontaneous recovery.7,25,27 In our study, we could not classify the patients according to the delayed- or immediate-onset FNP, since they were under general anesthesia in the ICU and facial nerve functions could not be assessed immediately after the traumatic insult. Total or near-total axonal degeneration on EMG results, bone spurs or fracture lines crossing the fallopian canal on CT, and no spontaneous recovery despite at least 1 month’s period were the primary findings that indicated FND surgery in our study. Therefore, all patients underwent FND surgery. In summary, for the patients who have the aforementioned FND indications and have good health conditions, decompression may be a better treatment option. However, favorable results can also be obtained with delayed transmastoid decompressions.

CONCLUSION
Surgical treatment of FNP due to TBF can be successfully performed by TMA. The transmastoid route can be used safely by eliminating the risks of craniotomy and middle cranial fossa approach, and postoperative hearing results can be preserved even in patients with incus removal and replacement. This surgical route allows the restoration of the ossicular chain for patients with conductive or mixed HL while performing effective decompression of the facial nerve. Although early decompression is advocated, late decompression delayed by a period within 1 to 3 months can also result in satisfactory facial nerve function outcomes, especially for patients who were treated in the ICU for a long time. The transmastoid approach to traumatic FNP is an effective method that enables ossicular chain reconstruction in cases of trauma-induced CHL. Transmastoid FND prevents the risks of intracranial complications of the middle cranial fossa approach.

Delayed (between 1 and 3 months of the insult) FND can also lead to satisfactory facial nerve function outcomes.

Ethics Committee Approval: This study was approved by Mersin University review board (No:2019/315).

Informed Consent: Informed consent was obtained from all the patients themselves other than a male baby’s parents.

Peer Review: Externally peer-reviewed.

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