# Intraoperative monitoring of motor evoked potential for the facial nerve using a cranial peg-screw electrode and a "threshold-level" stimulation method

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Running title: Intraoperative facial MEPs in skull base surgery

**Abstract**

**Objective:** Transcranial motor evoked potential for the facial nerve (facial MEP) has been recognized as a good quantitative monitoring of facial nerve function in the skull base surgery. To improve the feasibility and safety of facial MEP monitoring, a peg-screw electrode and a "threshold level" method were investigated.

**Design:** From 2007 to 2009, intraoperative facial MEP monitoring with the peg-screw electrode and "threshold level" method was successfully achieved in 26 out of 29 patients who underwent surgery for the posterior fossa extraaxial tumor. The relationship between the change in the facial MEP threshold level and the postoperative function of the facial nerve was analyzed in 23 patients who had no facial palsy preoperatively.

**Results:** There were no complications associated with facial MEP monitoring. Nine patients having the stable facial MEP threshold had no facial palsy. 14 patients having the worsened-but-measurable facial MEP threshold had mild palsy at discharge. Two of three patients having the severely worsened-and-unmeasurable facial MEP threshold had severe facial palsy.

**Conclusions:** The change in the facial MEP was well correlated with the postoperative facial function. The peg-screw electrode and "threshold level" method are good options for facial MEP monitoring. (192 / 200 words)

**Key words:** intraoperative electrophysiological monitoring, facial nerve, motor evoked potential, skull base

## Introduction

Surgery of skull base tumors still poses some challenges owing to the difficult anatomy and intimate association with the cranial nerves. Postoperative cranial nerve palsy in the skull base surgery remains a significant clinical problem although various monitoring techniques have been used routinely. Facial nerve function is currently monitored during surgery using various electrophysiological methods. Among many electrophysiological monitorings for the facial nerve, transcranial motor evoked potential (MEP) for the facial nerve (facial MEP) has been recently recognized as a safe and valuable quantitative method for monitoring the inherent variability of facial nerve function.[1-4]

It has been difficult to measure MEP of the facial nerve compared to that of the extremities. Because stimulation point of the skull is near to the recording point of the face, high frequency multi-pulse transcranial stimulation will affect the facial electromyogram (EMG), which will cause difficulty in reading the MEP wave.[1-3] To decrease the current spread effect, a cranial peg-screw electrode and a "threshold level" stimulation method which have already been utilized to monitor intraoperative transcranial MEP were adopted for convenient measuring and monitoring of the facial MEP.[5-7] Our methods and results of faical MEP monitoring and its correlation with postoperative facial function are reported.

## Materials and Methods

From February 2007 to April 2009, consecutive 29 patients with extra-axial tumor in the posterior fossa requiring EMG monitoring for the facial nerve were treated at Shinshu University Hospital and its affiliated hospitals. Facial MEP was measured and monitored in these subjects. The majority of patients (n=18) underwent resection of vestibular schwannomas. 7 patients with petrous and clival meningiomas, 3 patients with jugular foramen neurinoma and one patient with trigeminal neurinoma were included.

### *MEP monitoring technique*

*MEB 2216 (Nihonkohden Co. Ltd., Tokyo, Japan) was used as an electrophysiological device. After induction of general anesthesia, the scalp corkscrew electrodes were placed at C3' and C4' which were 7 cm lateral from the midline on the line between Cz' (2 cm caudal from Cz) and midpoint of the zygomatic arch. The cranial peg-screw electrode was placed at the midpoint on the line mentioned above, and between C3' or C4' in the contralateral side and the imaginary sylvian fissure which is lined from the external angle of eyelid to 6 cm above the external auditory canal (Figure 1 and 2).* [7] *Ipsilateral side of scalp corkscrew electrode was for cathode, and each of contralateral anodal electrode* *was chosen when scalp corkscrew was selected for the MEP of upper extremity, and cranial peg-screw electrode was for the facial MEP. An anodal constant current stimulation (mA) was used for transcranial electrical stimulation. A 4- or 5-pulse stimulus train was used with each stimulus duration of 0.2 mS or 0.3 mS and an initial interstimulus interval (ISI) of 1.7 to 2.0 mS. Compound muscle potentials were recorded from a pair of the needle electrodes placed on the ipsilateral side of the face (m. frontalis, orbicularis oculi, orbicularis oris (o. oris)) and bilateral Abductor Pollicis Brevis (APB). Signals were amplified and filtered (20-2,000 Hz) before display.*

*General anesthesia was introduced by injection of a short-acting barbiturate or propofol and neuromuscular blocking agent to intubate the subject. Inhalational agents and neuromuscular blockade was avoided after intubation. The anesthesia was maintained by constant infusion of propofol (100-300 mg/kg/min). Narcosis (e.g., fentanyl, remifentanil) was also delivered by either constant infusion or intermittent bolus. In most cases, nitrous oxide (-50 %) was also given.*

*"Threshold-level" stimulation method was attempted to monitor the facial MEPs. This method has been proposed by Blair Calancie et. al.[5,6] A threshold response was any evoked muscle response that exceeded about 20 µV in peak-to-peak*

*amplitude, and which had appropriate response latency (e.g., latency to o. oris was about 15-20 mS and latency to APB was about 20-25 mS). To evaluate whether the response was evoked by the motor pathway, disappearance of the response was confirmed by the times of pulse stimulus train decreased in the same electric intensity (Figure 3). Baseline thresholds were established for all muscle groups being monitored, and determined at multiple times throughout the surgical procedure. The stimulus intensity was limited below 100 mA. The surgeon was notified whenever the "threshold-level" of facial MEP changed even "threshold-level" of the MEP of APB was equal.*

Other electrophysiological monitorings were also applied. Triggered compound muscle action potentials (tCMAP), 4 Hz of bipolar stimulation with 0.1 mA of electrical intensity and 0.1 mS of duration, were utilized for detecting the location of the facial nerve. Sounds of free running EMG of the face was made for continuous monitoring of facial function whenever the facial MEP was not recorded. Auditory brainstem response and cochlear nerve action potentials were measured for monitoring the hearing function.

All the patients well tolerated and had a good postoperative course. There were no complications associated with surgical procedures such as CSF leakage, brain injury, intracranial hemorrhage, and wound infection.

Intraoperative facial MEP was monitored by a "threshold level" method in 26 patients. In the initial 3 patients, facial MEP was unable to be recorded due to technical failure. The changing pattern of facial MEP was divided in three groups; unchanged group, worsened-but-measurable (less than 100 mA) group, and severely worsened and un-measurable (over 100 mA) group. Correlation between intraoperative facial MEP findings and postoperative facial function was analysed in 23 cases; remaining 3 patients, as they had facial palsy preoperatively, were excluded. Postoperative facial function was graded clinically using the House-Brackmann (H&B) grading system.[9] The facial function was examined at discharge and at least 6 months after operation. At discharge, 7 patients had H&B grade I facial palsy, 9 had grade II, 4 had grade III, and 2 had grade IV and V palsy, respectively. Mean follow-up period was 17 months. At follow-up, 19 patients had H&B grade I palsy, 2 had grade II, and 2 had grade IV and V palsy, respectively. Grade II facial palsy at discharge disappeared in all 9 patients. Two patients of grade III facial palsy at discharge remained grade II facial palsy after at least 6 months of follow-up.

**Results**

There were no complications associated with the placement of the electrodes and electrical stimulation such as skin injury, infection, skull fracture, and epi- or subdural hematoma. Facial MEP was recorded from the o. oris, because facial MEP was not sometimes recognized from frontalis and o. oculi. Facial MEP threshold-level fluctuated during microsurgery, even MEP of APB threshold-level was stable. Attenuation of facial MEP following compression and movement of the tumor were almost recovered soon after short interrupting manipulation. On the other hand, facial MEP sometimes suddenly attenuated during dissection of the facial nerve from the tumor. This type of attenuation was difficult to recover.

The individual change of facial MEP threshold level was shown in Figure 4. All patients in unchanged group had no postoperative facial palsy at postoperative period. All patients in worsened-but-measurable group had postoperative H&B grade II or III at discharge, and two patients in this group remained grade II at follow-up. Two of three patients in severely worsened and un-measurable group had over H&B grade IV.

## Discussion

**Problems of measuring the facial MEP:** Measuring MEP of the facial nerve is more difficult than measuring MEP of the extremities. Because stimulation point of the skull is near to the recording point of the face, high frequency multi-pulse transcranial stimulation will affect the facial EMG, which will cause difficulty in reading the MEP wave.[1-3] The peripheral seventh nerve is stimulated directly without conduction through the central motor pathway from the cortex. Further, baseline of facial EMG is distorted by condenser effect of the scalp and the skull. Facial EMG is frequently contaminated by temporalis muscle contraction by direct electrical stimulation. Although placing the stimulation electrode just above the related somatotopy of the face is effective for decreasing the stimulation current intensity, temporalis muscle just above the primary motor area of the face emphasizes the current spread effect. To avoid these problems of the current spread, scalp electrode for cathode on Cz not the ipisilateral C3' or C4' has been proposed.[1-3] However, bigger electric intensity to stimulate the central cortex may be necessary than that of conventional transcranial stimulation point.

**Merits of using peg-screw electrode and "threshold level" stimulation methods for facial MEP:** Concept of the current pathways for stimulation of peg-screw electrode was represented by Watanabe et al..[7] While much of the stimulus current spreads laterally through the scalp from the scalp electrodes because of the high resistance of the skull, the stimulus current passes through the skull more effectively from the peg-screw electrodes. The use of peg-screw electrodes can reduce the condenser effect of the skin, therefore reduces the current intensity. The peg-screw electrode can be placed just above the primary motor area of the face due to less contraction of the temporalis muscle. It means that the effect of current spread decreases.

MEP is monitored by the final-baseline ratio of amplitude in many institutes. On the other hand, “threshold level” stimulation method is another approach to monitor the MEP. Smaller electric intensity is adequate to stimulate the central cortex because the baseline amplitude of MEP is smaller compared with that of the conventional MEP monitoring. Smaller electric intensity can decrease the problems of the current spread effect. Further, threshold-level method may provide earlier warning of, and be more sensitive to, impending deterioration in the central motor conduction.[5]

Compared to conventional approach, facial MEP can be recorded conveniently and is judged easily. Convenient monitoring leads to easy routine use and easy judgment of waveform change. It also prevents misjudging of the waveform.

**Facial MEP with other intraoperative facial monitorings:** There are no doubts on evaluation of the intraoperative facial nerve function by electrophysiological monitoring improving postoperative facial nerve function preservation rate. Facial MEP monitoring is not independent from other facial nerve monitorings.

tCMAP, free running electromyography, and facial MEP are widely used for prediction of postoperative facial nerve function, because each of them has its merits and demerits. tCMAP is easily available and widely used in facial nerve preservation surgery; however, it is questionable whether tCMAP monitoring predicts the facial function or not. Recording tCMAP interrupts the surgical procedures. It is impossible to record the baseline of tCMAP before securing the route exit zone of the facial nerve. Unstable condition of a stimulation electrode is unreliable for quantitative tCMAP evaluation. Supramaximal stimulation for quantitative evaluation might cause electrical injury to the facial nerve. tCMAP might be used for facial nerve mapping. Although free running EMG signals is known as a sensitive monitoring to detect the damage of the facial nerve, it is still uncertain for quantitative analysis. Free running EMG should be used as an early worsening sign of the facial nerve function.

Facial MEP can be monitored throughout the operation without interrupting the surgical procedure. In facial MEP monitoring, recording and stimulation electrodes can be placed stably and do not disturb the operative field. These characteristics of the facial MEP lead to a high possibility of quantitative monitoring. Our results showed that the initial threshold level was stable in all patients of postoperative-no-facial-palsy group. This indicates that facial function was intact. However, our report has some limitations because of a small sample size and lack of control group, which limits the statistical analysis. A surgeon can perform the procedure near the facial nerve with confidence in the facial nerve function, even if the facial nerve at the route exit zone is not secured. Monitoring facial MEP can improve surgeon's confidence level, thus, lead to better surgical results.

## Conclusions

Intraoperative facial MEP was monitored using a peg-screw electrode and "threshold level" method. No attenuation of the facial MEP indicated no postoperative facial palsy and severe attenuation of facial MEP had a possibility of permanent severe facial palsy. Together with other electrophysiological monitorings, the facial MEP has an important role for preserving the facial nerve function in the skull base surgery.

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## Disclosure

The abstract of this paper was presented at the 21st Annual Meeting of Japanese Society for the Skull Base Surgery, and was recommended to submit to the journal of "Skull Base: an interdisciplinary approach" from the committee.

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**Figure legend:**

Figure 1: Illustration depicting the placement of stimulating scalp corkscrew electrode and cranial peg-screw electrode.

Figure 2: Upper left: a photo showing the scalp corkscrew electrode. Lower left: a photo showing the cranial peg-screw electrode. Right: a photo showing the scalp electrode and peg-screw electrode placed in their approximate position on the patient's head. After fixing the head position, each electrode is connected to the electrical stimulator.

Figure 3: The waveform of facial MEP. Stimulation time increased one by one with the same stimulation intensity, 5-train stimulation shows the response.

Figure 4: The individual data of the change in the facial MEP threshold level. Left: relationship with postoperative facial palsy at discharge. Right: relationship with postoperative facial palsy at latest follow up.

TABLE 1. The relationship between postoperative facial palsy at discharge and intraoperative facial MEP threshold level

| Facial palsy (Hause−Brackmann) | Number of cases | facial MEP threshold level (mA) on dural opening | | | facial MEP threshold level (mA) on dural closure | | | Worsening % | | |
|---|---|---|---|---|---|---|---|---|---|---|
| grade I | 7 | 55.1 | ± | 7.9 | 55.8 | ± | 8.2 | 1.3 | ± | 2.6 |
| grade II | 9 | 56.8 | ± | 13.9 | 68.7 | ± | 19.4 | 20.2 | ± | 14.2 |
| grade III | 4 | 57.2 | ± | 15.2 | 69 | ± | 21.8 | 19.9 | ± | 11.9 |
| grade IV,V | 2 | 51 | | | over 100 | | | over 100 | | |

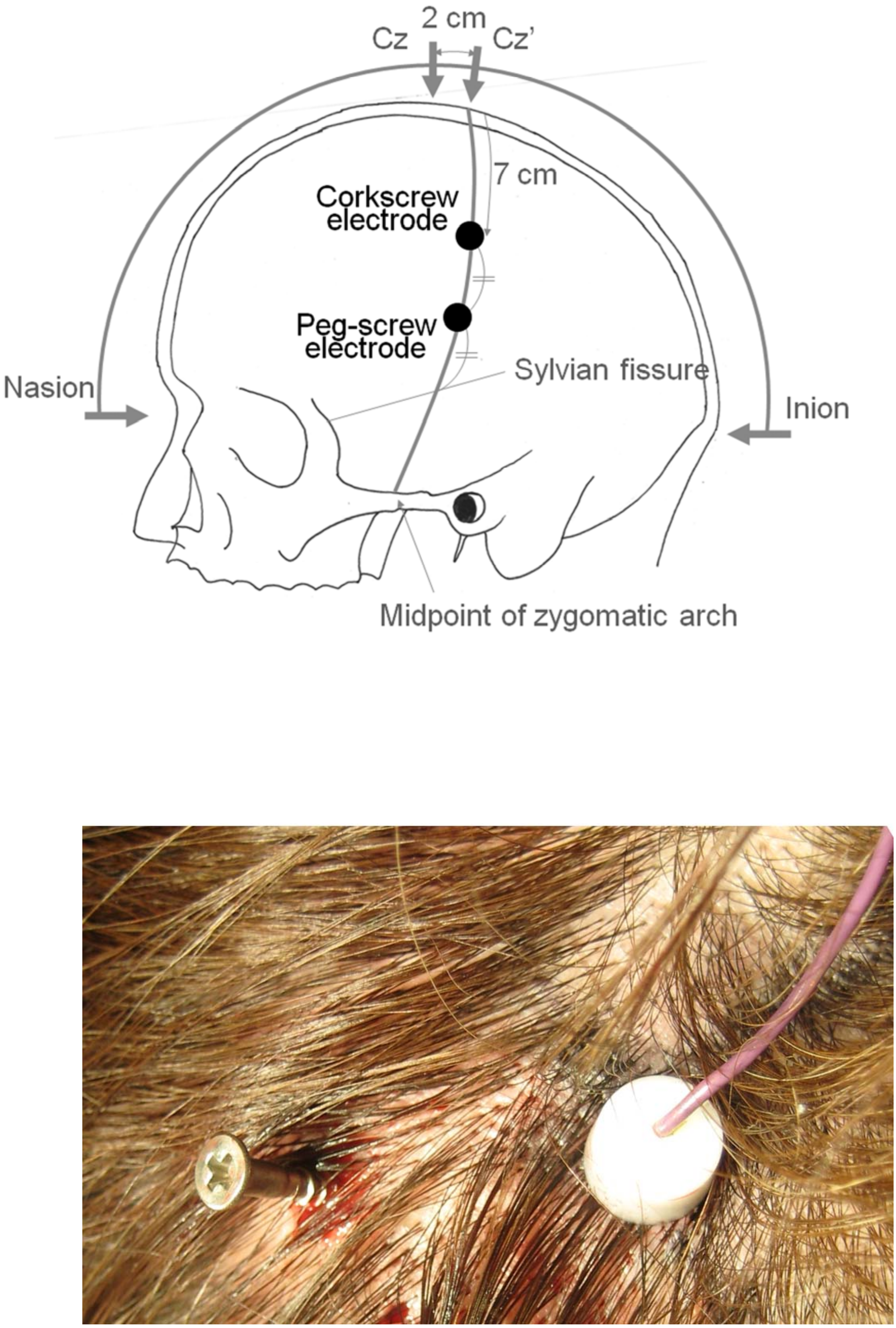
2 cm
Cz
Cz'
7 cm
Corkscrew electrode
Peg-screw electrode
Sylvian fissure
Nasion
Inion
Midpoint of zygomatic arch

Figure 1

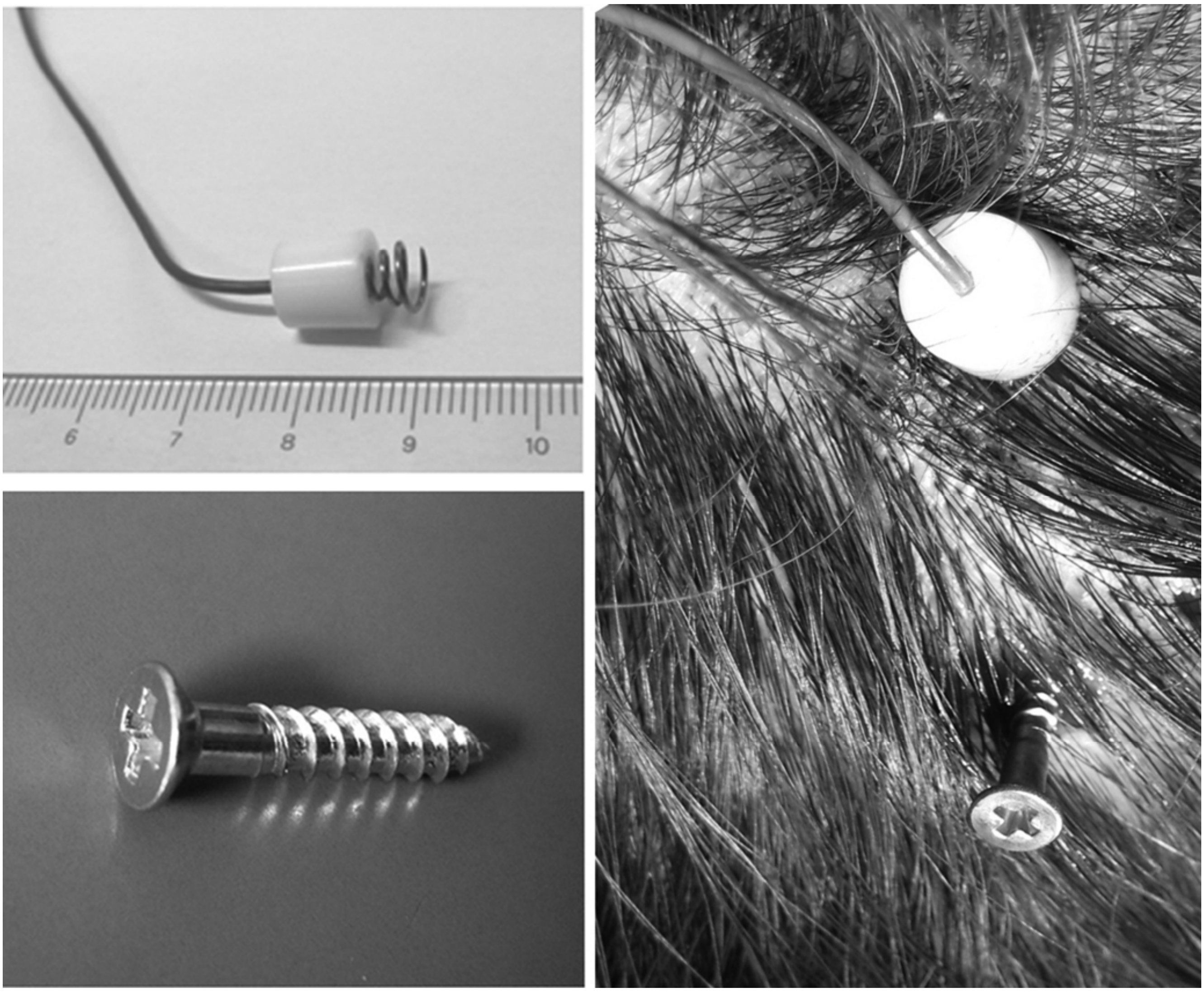


Figure 2

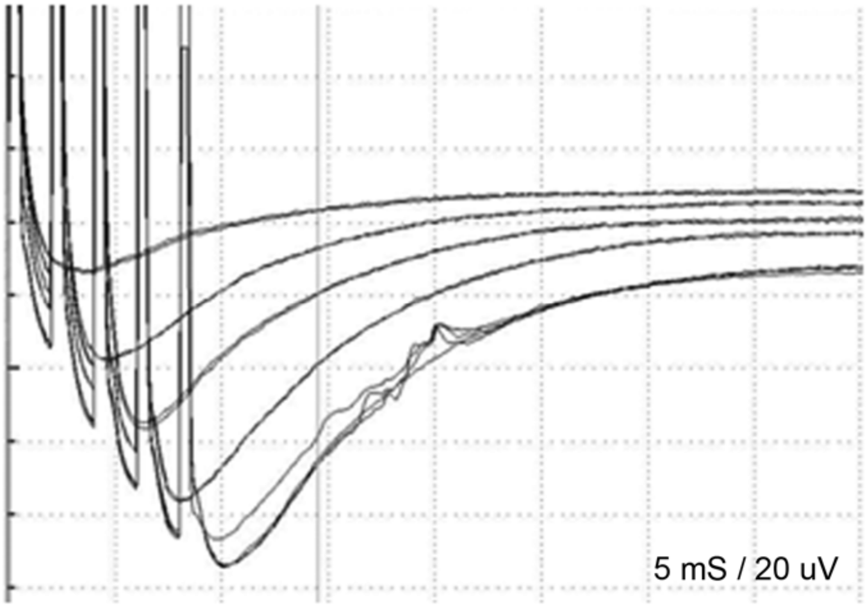


Figure 3

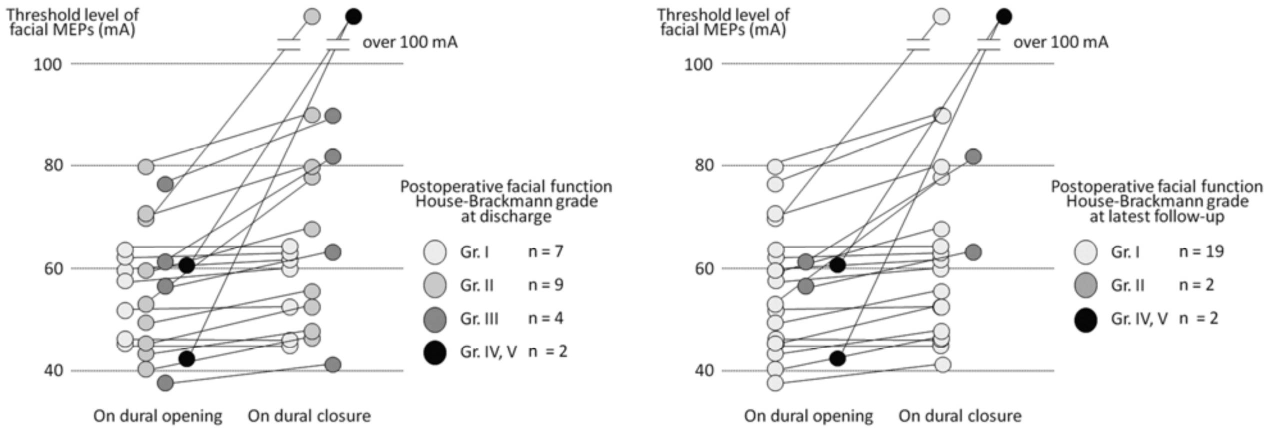


Figure 4