Microsurgical Skills Training With a New Tympanoplasty Model: Learning Curve and Motivational Impact

Marcus Neudert, Anne Kluge, Thomas Beleites, Max Kemper, and Thomas Zahnert

Technische Universität Dresden, Department of Otorhinolaryngology, Head and Neck Surgery, Dresden, Saxony, Germany

Objectives: To evaluate the microsurgical skills training on a tympanoplasty model with regard to the learning curve and the participants’ motivation for a surgical specialty.

Study Design: Randomized controlled prospective study.

Setting: Department of Otolaryngology, Head and Neck Surgery, Medical Campus Carl Gustav Carus at the Technische Universität Dresden, Germany.

Subjects: Thirty randomly chosen fifth-year medical students divided into 2 groups.

Interventions: Group 2 (n = 16) had to perform an ossicular and tympanic membrane reconstruction on a tympanoplasty model on Days 1, 7, 14, and 21 and Group 1 (n = 14) on Days 1 and 21, while observing the procedure at Days 7 and 14. Six otosurgeons served as gold standard. Attempts and time of prosthesis placement and time for tympanic membrane reconstruction were recorded. Tremor frequency and amplitude were obtained at the same time points. An adjusted study interest questionnaire was used to assess students’ motivation.

Results: Students in Group 2 showed a significant improvement in all reconstruction parameters over the study period compared with both, baseline measurement on first day and Group 1. However, the obtained learning curve did not reach the experts level. Tremor indices and students’ motivation showed no correlation with the reconstruction parameters, whereas the training itself had a positive impact on students’ interest in the surgical specialty.

Conclusion: Training with the tympanoplasty model is suitable to acquire first microsurgical motor skills in otolaryngology and to arouse students’ interest in the surgical field and otorhinolaryngology.

Key Words: Learning curve—Motivation—Tympanoplasty—Training model.

less or not suitable for acquiring motor skills in ossicular chain reconstruction. Moreover, most models are used to train a set of standardized procedures, but the evaluation of achieving success is limited because minimal acceptable scores are not established yet.

The aim of the present study was to investigate the ability of surgical novices to perform and improve motor skills as necessary in tympanoplasty. The influences of students’ study interest assessed by a validated questionnaire and hand steadiness assessed by tremor measurements on their reconstruction success were evaluated. Furthermore, the impact of training on the students’ interest in the surgical field in general and otorhinolaryngology (ORL) in detail was investigated.

MATERIALS AND METHODS

Study Design

Study Population and Setting

To assure a comparable level of previous experience and knowledge in microsurgical skills, final-year medical students were chosen to provide a homogenous subject population. The study was carried out at the Department of Otolaryngology, Head and Neck Surgery, medical campus Carl Gustav Carus at the Technische Universität Dresden, Germany.

Novices

Thirty of 211 randomly chosen fifth year medical students, who were completing their 1-week otolaryngology internship within the same educational semester were included in the study. Their study participation was optional and had no impact on their internship grading. They were randomly divided into 2 groups (n = 14 and 16); mean age was 24.3 ± 2.71 years, and sexes were distributed equally (male/female; Group 1 = 6/8 and Group 2 = 8/8).

On Day 1, both groups achieved a profound introduction on practical issues of tympanoplasty (30-min lecture), followed by a 4-step approach in teaching the essential practical steps in placing a partial ossicular replacement prosthesis on the stapes head with subsequent reconstruction of the tympanic membrane (according to Walker and Peyton [6]). From Day 7 onward, Group 2 (trainees) repeated the whole procedure of tympanoplasty on Days 7, 14, and 21, whereas Group 1 (observers) was observing the expert again, without any practical recapitulation of the acquired motor skills. On Day 28, all students had to show their practical performance again by executing the learned maneuvers.

Experts

Six experienced otosurgeons, all affiliated with the Department of Otorhinolaryngology, Head and Neck surgery, Dresden, who had at least 8 years of practical experience in middle ear surgery served as the reference group (gold standard).

The experimental protocol is shown in Figure 1.

Assessment Criteria

Tremor Measurement

The tremor measurement technique was described previously (7). In brief, using a preparation needle, a pivot-mounted stapes had to be kept in an upright position against a predefined loading mass for 12 seconds. The stapes head displacement was measured by laser interferometry with a detection rate of 164 Hz using a laser Doppler vibrometer (OFV 302/301; Polytec, Waldbronn, Germany). Measured data were recorded at a computerized workstation (DasyLab 3.5; DATALOG, Mönchengladbach, Germany). Tremor frequency (Hz) and amplitude (µm) were determined to describe the ability of keeping the marked position throughout the measured sample and hence assess the subjects’ fine motor skills.

Middle Ear Reconstruction on the Dresden Tympanoplasty Model

A simplified tympanoplasty model for microsurgical skills training was used for this study. The outer ear canal and the tympanic cavity are simulated by plastic material components with real-size stapes model placed on a soft plastic pad (imitating the annular ligament flexibility) in projection of the upper posterior tympanic membrane quadrant. The tympanoplasty model and the reconstruction steps are shown in Figure 2, A–D.

The reconstruction was performed as follows: after focusing the stapes in the Dresden tympanoplasty model (DTM) with an

![Experimental protocol of the study.](image)
operation microscope, the participants had to pick up a 2.5-mm titanium clip prosthesis (Kurz Co., Dusslingen, Germany) and place it on the stapes head. After this, the tympanic membrane had to be reconstructed by thin slices of sheep ear cartilage. For all procedures, standardized sets of instruments and cartilage were provided. The reconstruction parameters to assess the individual’s performance are summarized in Table 1.

### Students’ Motivation

The study interest questionnaire, modified according to Schiefele et al. (8), assesses emotional, value-related, intrinsic motivational orientation, extraversion, use of learning strategies, and achievement, among others. An additional 5 items were referring to the self-evaluation and the benefit of the tympanoplasty training regarding decision making for a (micro-)surgical specialty (Table 2). Item scores were expressed in German school marks 1 (fully applicable) to 5 (not applicable). The questionnaire was completed by all novices at Day 28.

### Statistical Analyses

Statistical analyses were done in cooperation with the Institute of Statistics, Technische Universität Dresden, Germany, and performed by means of a SPSS software package (18th edition; IBM, Ehningen, Germany). For comparison and evaluation of differences between 2 groups, Mann-Whitney $U$ test was used, whereas rank variance analyses were used for comparison and evaluation of differences of more than 2 groups. Multiple linear regressions for prediction of one of several parameters were used for discrimination and correlation of binary data with the total number of scores. All descriptive data are expressed as mean ± standard deviation, and a $p$ value of less than 0.05 was considered significant.

### RESULTS

**Middle Ear Reconstruction in the DTM**

Reconstruction parameters (Table 1) were recorded at all points in time. The number of attempts until proper placement of the prosthesis on the stapes head and the tympanic membrane are summarized in Table 1.

<table>
<thead>
<tr>
<th>Assessed criteria</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Attempts needed to place the prosthesis on the stapes head</td>
<td>Number</td>
</tr>
<tr>
<td>2. No. of needed prostheses</td>
<td>Number</td>
</tr>
<tr>
<td>3. Time until proper placement of prosthesis</td>
<td>Time (seconds)</td>
</tr>
<tr>
<td>4. Stapes defect</td>
<td>Yes/no</td>
</tr>
<tr>
<td>5. Time for tympanic membrane reconstruction</td>
<td>Time (seconds)</td>
</tr>
<tr>
<td>6. Integrity of reconstructed tympanic membrane</td>
<td>Intact/remaining defect</td>
</tr>
</tbody>
</table>

Once the prosthesis was picked up, every loss inside or outside the Dresden tympanoplasty model was counted until proper placement of the prosthesis. If the titanium clips were bent too much upon ineffective manipulations, a new prosthesis was provided. Time was taken after proper prosthesis placement, and the stapes integrity was evaluated. Hereafter, the tympanic membrane was reconstructed by thin slices of cartilage, and the required time was recorded. Finally, the tympanic membrane integrity was evaluated.
respective time are shown in Figure 3, A and B. At Day 1 the novices needed 3.22 ± 1.1 attempts in Group 1 and 3.18 ± 1.78 in Group 2. By Day 7, the students in Group 2 significantly reduced the attempts for prosthesis placement down to 2.12 ± 0.99 (p < 0.05). A further reduction for the trainees (Group 2) was observed in the following intervals down to 1.31 ± 0.48 on Day 28 (p < 0.001 versus Day 1). The observing participants, who were performing the procedure at Day 28 for the second time, needed 2.89 ± 2.03 attempts, which was not significantly lower than on Day 1 but significantly more when compared with the trainees (p < 0.001; Fig. 3A).

When the respective time for prosthesis placement was captured, on Day 1, students in Group 1 needed 183 ± 54 seconds, and those in Group 2 needed 197 ± 88 seconds. Interestingly, on Day 7, Group 2 needed an almost similar amount of time of 206 ± 122 seconds. The first improvement was seen on Day 14 with 139 ± 72 seconds (p < 0.05).

TABLE 2. Additional questions on students’ interest in the (micro)surgical specialty

<table>
<thead>
<tr>
<th>Item</th>
<th>Fully applicable</th>
<th>Not applicable</th>
<th>Group 1 (Observers)</th>
<th>Group 2 (Trainees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 I was interested in ORL even before the ORL internship.</td>
<td>+ (1)</td>
<td>- (5)</td>
<td>2.56 ± 1.24</td>
<td>2.50 ± 1.15</td>
</tr>
<tr>
<td>2 The training with the DTM had a positive impact on my decision for a microsurgical specialty.</td>
<td>+/-(2)</td>
<td></td>
<td>2.22 ± 0.67</td>
<td>1.75 ± 0.58*</td>
</tr>
<tr>
<td>3 After working with the DTM, a microsurgical specialty comes into consideration.</td>
<td></td>
<td></td>
<td>2.78 ± 1.20</td>
<td>1.94 ± 0.68*</td>
</tr>
<tr>
<td>4 The DTM was useful to obtain first experience with microsurgical procedures.</td>
<td></td>
<td></td>
<td>1.33 ± 0.50</td>
<td>1.56 ± 0.73</td>
</tr>
<tr>
<td>5 I enjoyed the training with the DTM.</td>
<td>+/- (-3)</td>
<td></td>
<td>2.23 ± 1.09</td>
<td>1.50 ± 0.63*</td>
</tr>
</tbody>
</table>

DTM indicates Dresden tympanoplasty model; ORL, otorhinolaryngology.
*p < 0.05.

FIG. 3. Reconstruction results on the DTM. A, Number of attempts for final prosthesis placement. B, Time until final prosthesis placement. C, Time for tympanic membrane reconstruction. D, Percentage of participants who achieved a complete tympanic membrane reconstruction. *p < 0.05; **p < 0.01; ***p < 0.001 versus Day 1. #p < 0.05; ##p < 0.01; ###p < 0.001 versus Group 1 (controls). +++p < 0.001 versus both novices’ groups.
At Day 28, the trainees (Group 2) were significantly faster compared with their baseline measurement (Day 1) and their observing colleagues (Group 1) as shown in Figure 3B.

The period for tympanic membrane reconstruction on Day 1 was nearly similar, with 322 ± 168 seconds in Group 1 and 392 ± 132 seconds in Group 2. Again, a reduction in time was observed over the training interval down to 145 ± 54 seconds in the trainee group, which was significantly faster compared with Day 1 \( (p < 0.05) \) and to the reconstruction time in Group 1 with 249 ± 139 seconds \( (p < 0.001; \text{Fig. 3C}) \).

At Day 1, students in both groups achieved similar tympanic membrane reconstruction results. Fifty-six percent of students in Group 1 and 65% in Group 2 achieved a complete closure of the tympanic membrane. In Group 2, the percentage constantly increased up to 100% for the complete reconstruction on Day 21. This was significantly better compared with both their initial reconstruction result on Day 1 and the result of Group 1 (67% on Day 21; Fig. 3D).

The experts set the gold standard, with 16 ± 2.8 seconds for prosthesis placement in the first attempt and 56 ± 12.6 seconds for complete tympanic membrane reconstruction.

**Tremor Measurements**

On Day 1, the mean single handed tremor frequency was 7.69 ± 1.2 Hz in Group 1 and 7.81 ± 1.73 Hz in Group 2 \( (p = 0.8214) \). The absolute tremor amplitude on Day 1 was 60.0 ± 10.8 μm in Group 1 and 63.4 ± 13.7 μm in Group 2. There were no significant changes in tremor frequency and amplitude in both groups compared with respective baseline measurements on Day 1 or between both groups on Day 28. This effect also was observed when tremor frequency and amplitude were measured for double handed use (data not shown).

**Study Interest Questionnaire**

There were no significant changes between the 2 groups; neither in the single items scores nor in the score sum on Schiefele’s study interest questionnaire. The additional 5 items referred to the benefit of the DTM training in respect to motivation for surgical subjects and further career decision (Table 2). Students of Group 2 (trainees) reached statistically lower scores in the Items 2 (1.75 ± 0.58 trainees versus 2.22 ± 0.67 controls; \( p < 0.05 \)), 3 (1.94 ± 0.68 trainees versus 2.78 ± 1.20 controls; \( p < 0.05 \)), and 5 (1.50 ± 0.63 trainees versus 2.22 ± 1.09 controls; \( p < 0.05 \)), indicating them as rather more applicable than in Group 1 (observers). Items 1 and 4 were not significantly different between both groups (Table 2).

**Performance in Middle Ear Reconstruction Considering Tremor and Study Interest**

A prediction of the reconstruction parameters with the DTM could not be confirmed for the questionnaire items. Neither single-item analyses nor summation of subtest categories or total score sum correlated with an increased success in the middle ear reconstruction. In addition, the tremor measurement results regarding frequency and amplitude as parameters for hand steadiness had no influence on the reconstruction results. Success of middle ear reconstruction in this model was not correlated to a low tremor amplitude or frequency in the student’s groups.

**DISCUSSION**

Practical experience is one of the most important factors to motivate students and arouse their interest in the surgical field. In otolaryngology, microsurgical skills as needed in middle ear surgery are not taught at all in medical school and traditionally late during residency. On one hand, a profound training of these skills in medical schools seems not to be necessary and effective in the light of the considerably small number of students who finally specialize in otolaryngology. On the other hand, an adequate insight into specialty-related skills would provide a basis for further decision making and could evoke an unknown desire for that specialty.

The DTM represents an effective tool to impart first microsurgical motor skills as needed in otolaryngology. In this study, thirty 5-year medical students without any microsurgical experience or specialty-related skills performed the basic steps of ossicular chain and tympanic membrane reconstruction. After 21 days and 3-times repetition of the procedure, the trainees were able to place a partial prosthesis on the stapes within 65 ± 37 seconds and reconstruct the tympanic membrane within 145 ± 54 seconds. This is indeed significantly slower compared with the gold standard set by experienced otosurgeons but, nevertheless, a remarkable and significantly better result in contrast to their nontrained, mainly observing colleagues. This training effect was seen throughout all assessed reconstruction parameters indicating a considerable learning curve for all performed maneuvers over the study period. A beneficial effect of observing an expert doing the reconstruction for the individual novices performance could not be shown because the results of Group 1 were not statistically better at study termination than on Day 1. Interestingly, the number of attempts for prosthesis placement was already significantly lower in the trainees group at their second training unit on Day 7. This decrease could not be detected for the observers group, who needed the same number of attempts on their second try after 21 days as on the first day. Although this effect was not seen in the other parameters, the time interval of 21 days between the training units is obviously too big as to produce an increasable starting point to expand this particular motor skills capacity. Further studies have to clarify if shorter training ranges or maybe additional repetitions in 1 day have an additional benefit on the learning curve.

For the ear as a sense organ, successful middle ear reconstruction becomes manifest not only in fast prosthesis placement and tympanic membrane reconstruction but also in a satisfactory patients’ hearing outcome. Reconstruction factors that influence the postoperative air-bone gap and the intraoperative noise and trauma exposure...
were not evaluated in this study. Naturally, the expert’s reconstruction is characterized by both a time-efficient performance and the best possible audiologic outcome for the patient. Further studies on the improved active DTM with a biofeedback mechanism (9) could provide further parameters to assess the acoustical reconstruction quality. In addition, the long-term effect and transferability of the acquired microsurgical motor skills remain unclear. Studies with the DTM in combination with other microsurgical training models have to show whether obtained skills with the DTM lead to better results and a steeper learning curve in other related skills, for example, microvascular anastomosis.

Hand steadiness and instrument stability are critical factors for microsurgery. Measurement of tremor frequency and amplitude in an otologic surgery setup has shown to be influenced by numerous factors, for example, caffeine intake and food abstinence, previous physical exercise, and training (7). Tremor frequency and amplitude (single and both handed) did not prove to have a predictive value for the reconstruction performance in our study. Novices (observers and trainees) had comparable results in the tremor measurements throughout the study and were not statistically different from the expert group. Also, a tendency toward smaller tremor results in the otsurgeons’ group was observed, the difference did not reach significance level. Our results do not indicate that the success of first microsurgical skills acquisition depends on the measured tremor indices in this model.

Additionally, the students’ study interest and their intrinsic motivation had no impact on their practical performance on the DTM. In a different study, some questions of Schiefele’s study interest questionnaire showed a prediction for positive written test results and high scores in a clinical practical examination in neurology and otolaryngology (10). The practical examination contained basic clinical examinations that were assessed in a standardized setup. The high level of specialty-related motor skills and/or the rather broad orientation of the questionnaire might be one reason for the absence of any prediction or correlation in our study.

Nevertheless, all students enjoyed the skills training with the DTM. Focusing on the 5 additional items, students of Group 2 (trainees) assessed the continuous training with DTM as a positive factor for their general career decision toward the surgical field. The detailed query on the impact of the DTM training on the decision for a microsurgical specialization showed a higher acceptance in the trainees group. Although both groups evaluated the DTM training as a useful tool to get first insights into the microsurgical field, Group 2 enjoyed their training significantly more than their mainly observing colleagues in Group 1. Because all participants were randomly chosen out of the fifth year medical students, a bias toward extremely interested students is unlikely. This also is supported by the similar results when asking for the general interest in ORL previous to the ORL internship (2.50 ± 1.15 trainees versus 2.56 ± 1.24 controls; $p = 0.301$). Although the sustainability and career consequences of the training could not be proven in this study, the results show a positive effect on the interest in ORL and in a microsurgical specialty in general. In light of increasingly hostile working conditions in surgical disciplines, increasing burnout rates in young surgeons and declining numbers of surgical entrants (11), the teaching of motor skills early in the educational track seems to have a broad influence on further decisions (12). Given that, training with the DTM also is of great value in residents’ education. Other existing training models for middle ear surgery focus mainly on the drilling part (mastoidectomy) of the procedure and lack the ability of ossicular reconstruction. Although temporal bone preparation is essential for residents before performing middle ear surgery in the operating room, additional and explicit training in ossicular chain and tympanic membrane is desirable. Two other simplified and inexpensive models for stapesplasty training (13,14) provide an economical method for acquiring microsurgical skills but are limited to the sole placement of a stapes piston, which additionally is not the first middle ear operation performed by surgical novices.

**CONCLUSION**

Training with the DTM is suitable to acquire first microsurgical motor skills in ORL. Its inexpensive production, the easy storage, and nevertheless, the good anatomic analogy to the real middle ear in terms of stapes mobility and location in the tympanic cavity make it a useful tool in students’ and residents’ education. It is suited to arouse students’ interest in surgical disciplines and ORL.

**Acknowledgments:** The authors thank Dr. med. Dipl.-Ing. Christoph Bethge for his assistance in the experimental realization of the study, Dipl.-Math. Eberhard Kuhlisch for statistical analyses, and Toni Sander for supplying linguistic support. The authors also thank Kristijonas Dutke for providing Figure 2 of the Dresden tympanoplasty model.

**REFERENCES**


*Otology & Neurotology, Vol. 33, No. 3, 2012*


