# Active olfactory training for the treatment of smelling disorders

Franca Fleiner, MD; Larissa Lau, BS; Önder Göktas, MD


## Abstract

*Olfactory function appears to be influenced by repeated odor stimulation. We conducted a nonrandomized, nonblinded, retrospective study of the impact of an 8-month period of olfactory training in patients with olfactory dysfunction. Our study population was made up of 46 adults—14 men and 32 women (mean age: 59.17 ± 13.25 yr)—with olfactory dysfunction of different etiologies (sinonasal: n = 15; post–upper-respiratory-tract infection [URTI]: n = 16; post-traumatic: n = 7; and idiopathic: n = 8). All patients had been previously treated without success with systemic or topical corticosteroids. For their training, patients exposed themselves to four different odors twice a day. Olfactory function was evaluated at baseline and again at 4 and 8 months, and results were quantified in the form of each patient's TDI (threshold, discrimination, and identification) score. Of the 46 patients, 28 had undergone olfactory training only, while the remaining 18 had received topical corticosteroids in addition to training. At study's end, the mean overall TDI score in the entire group increased by 4.09 points over baseline—a statistically significant increase (p = 0.01); this increase was mainly attributable to improvement in the* identification *component of the TDI, which increased by 2.51 points (p = 0.02). Among the 18 patients who received a topical corticosteroid in addition to training, the mean TDI increased by 6.83 points (p = 0.001), primarily because of improvements in the* discrimination *and* identification *components. The 28 patients who underwent olfactory training alone experienced a mean increase in the* identification *component of only 2.20 points (p = 0.14) after 8 months. Olfactory function in the post-URTI patients increased significantly at 4 months. We conclude that olfactory* discrimination *and* identification *can be enhanced by the addition of a topical corticosteroid to a program of defined, daily, short-term exposure to olfactory training.*


## Introduction

So far, the therapeutic options available for the treatment of olfactory dysfunction have been disappointing.[1] Therefore, treatment modifications and enhancements ought to be investigated. It is well known that olfactory receptor cells and the granular cells of the olfactory bulb can regenerate. The olfactory system is therefore almost certain to retain, improve, or regain its efficiency with daily exposure to odors.[2,3]

The olfactory epithelium is unique in that it maintains a lifelong ability to regenerate. Remarkably, the associated central neurons of the olfactory system are also able to regenerate. In the rodent, the olfactory bulb receives an estimated several thousand newly generated interneurons per day throughout the animal's life.[4] Recently, proof has been obtained that humans also have a rostral migratory stream that delivers interneurons to the olfactory bulb.[5] Cells from the subventricular zone constantly migrate to the olfactory bulb and differentiate into interneurons in the periglomerular zone and the granule cell zone of the bulb.[6]

In rodents, the typical lifespan of an olfactory receptor neuron is 30 to 60 days, but some live as long as a year. The mitotic activity of the neuronal cell line and differentiation from precursor cell populations have been proven and might be assumed to influence rehabilitation of the olfactory function after viral infection or trauma.

Long-term exposure to a wide range of odors increases the survival of newly generated interneurons[7] and transiently improves odor memory,[8] suggesting a potential role for adult neurogenesis in olfactory memory. Mouret et al found that olfactory training based on repeated stimulation by odors promoted the survival of imma-

From the ENT Department, Charité University of Medicine, Berlin, Germany.
Corresponding author: Önder Göktas, MD, ENT Department, Charité Campus Mitte, Universitätsmedizin Berlin, Chariteplatz 1, 10117 Berlin, Germany. Email: oender.goektas@charite.de
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ture new neurons and the elimination of more mature neurons; they reported successive periods of no effect, increased survival, decreased survival, and no change with regard to the maturation of newborn interneurons.[9]

It is olfactory learning rather than the mere exposure to odorants that changes olfactory bulb neurogenesis. Alonso et al[10] found that more 30-day-old newborn interneurons survived in the olfactory bulb of mice that had learned to discriminate between two odorants, whereas Mandairon et al[11] reported the opposite effect in 45-day-old newborn granular cells, indicating that the major impact of olfactory learning results from changes in survival rate. The findings of these studies might have important implications for elderly patients, in whom the plasticity and turnover of cells decreases rapidly.

The spontaneous recovery of olfactory function is possible.[12] An in-depth analysis of the efficacy of olfactory training using special odorants in a bottle and a standard Sniffin' Sticks test battery has been described by Hummel et al.[13] In that study, olfactory function in 40 patients who underwent short-term (12 wk) olfactory training was compared with that of 16 patients who did not receive any intervention. Different odor thresholds improved significantly in the training group, and 10 of 36 evaluable patients (27.8%) at study's end exhibited a clinically relevant improvement of at least 6 points in the TDI (threshold, discrimination, and identification) score. Training appeared to be especially helpful for patients whose olfactory dysfunction occurred secondary to an upper-respiratory-tract infection (URTI).

In this article, we describe the results of our study of the effect of daily olfactory training in improving olfactory dysfunction, including the influence of the addition of topical corticosteroid treatment, etiology, the duration of the dysfunction, the degree of dysfunction, age, and sex.

## Patients and methods

***Patients.*** For this nonrandomized, nonblinded, retrospective study, we analyzed the records of patients who had been treated for olfactory dysfunction of different etiologies and duration at the Consultation Service for Olfactory Disorders in the ENT Department at Charité University in Berlin from January 2007 through February 2009. These patients had been selected for olfactory training following unsuccessful medical treatment with a systemic or topical corticosteroid. Every patient had been interviewed and examined by an otolaryngologist. The examination included an inspection of the olfactory cleft.

To be considered for study eligibility, patients had to be aged 18 years or older. Exclusion criteria included pregnancy, current lactation, the presence of a malignant tumor, and a history of treatment for a malignant tumor (i.e., radiotherapy and/or chemotherapy).

A total of 58 patients met our initial eligibility requirements. Of these, 12 had to be dropped from the study—10 because they had been lost to follow-up, 1 for concomitantly taking both a systemic and topical steroid, and 1 who declined to comply with the testing protocol. Thus, we were left with a total of 46 patients—14 men and 32 women (mean age: 59.17 ± 13.25 yr).

The etiology of olfactory dysfunction among this group was distributed as follows: sinonasal (n = 15), post-URTI (n = 16), post-traumatic (n = 7), and idiopathic (n = 8). The median duration of symptoms was 21 months (range: 10.5 to 36).

We divided the patient population into two groups on the basis of adjunctive treatment. One group had received olfactory training only (training-only group), and the other group had augmented their training with the application of a topical corticosteroid (steroid group).

*Training-only group.* The training-only group was made up of 28 patients—10 men and 18 women (mean age: 58.89 ± 14.22 yr). The distribution of their etiologies was as follows: sinonasal (n = 10), post-URTI (n = 9), post-traumatic (n = 4), and idiopathic (n = 5). The median duration of their olfactory dysfunction was 21 months (range: 14 to 40).

*Steroid group.* The 18 patients in the steroid group included 4 men and 14 women (mean age: 59.61 ± 11.97 yr). Their etiologies were distributed as follows: sinonasal (n = 5), post-URTI (n = 7), post-traumatic (n = 3), and idiopathic (n = 3). The median duration of their olfactory dysfunction was 17 months (range: 9.25 to 36).

There were no statistically significant differences between the two groups in terms of age ($p = 0.86$), sex ($p = 0.51$), and duration of olfactory dysfunction ($p = 0.28$). Likewise, when the entire group was analyzed according to etiology, there were no significant differences in the use of a topical corticosteroid ($p = 0.97$), the duration of the olfactory disorder ($p = 0.69$), age ($p = 0.42$), or sex ($p = 0.58$).

On nasal endoscopy, the olfactory cleft could be identified in all 46 patients; it was visible bilaterally in 39 patients and unilaterally in 7.

***Methods.*** For daily active olfactory training, patients were provided with substances that emitted a variety of odors, including rose, orange, citrus, peppermint, raspberry, chocolate, vanilla, cinnamon, and leather. The odoriferous substances had been mixed by an assistant medical technician, and each odorant was provided to

patients in similar brown glass receptacles labeled with the name of the specific odor. Each substance was made up of 9 ml of pure ethanol and 1 ml of fragrance oil (Frey + Lau; Henstedt-Ulzburg, Germany).

Each patient received four different odors and was instructed on how to use them. Twice a day, the patients were to open a receptacle, sniff it for 10 seconds, close the receptacle, and move to the next odor until all four had been sniffed. Thus, the total amount of time spent on this training was less than 5 minutes per day. Patients were informed that they could expect no risks or side effects from training or from subsequent testing.

***Endpoints.*** The primary endpoint was the change in olfactory function at 4 and 8 months compared with baseline as measured by the standardized TDI scoring system recommended by the Olfactology and Gustology Working Group of the German Society of Otorhinolaryngology, Head and Neck Surgery. TDI scores are subjective quantifications of olfactory *threshold, discrimination,* and *identification* during exposure to 16 odorous markers that make up the Sniffin' Sticks test battery.[14,15]

To obtain a TDI measurement, the examiner removes the cap of the pen-like device that contains a particular odor and places the tip of the device approximately 2 cm in front of the nostrils for 3 seconds. In our study, TDI scores for each patient were measured by the same person, who was experienced in administering these tests.

The TDI score is a reliable *(r* = 0.72) and validated tool that accurately reflects olfactory function.[16] In general, a score of 15 or less indicates anosmia, a score of 15.5 to 30 indicates hyposmia, and a score of 30.5 or higher indicates normosmia. A change of at least 6 points in a particular TDI score is accepted as evidence of subjective clinical improvement or deterioration of the olfactory function of a given patient.[17]

Other endpoints included an assessment of variables that might or might not have been associated with therapy efficacy: etiology, the duration of dysfunction, the degree of dysfunction (i.e., anosmia or hyposmia), age, and sex.

There were no statistically significant differences between the training-only group and the steroid group in baseline TDI score *(p* = 0.25) or the prevalence of anosmia and hyposmia *(p* = 0.37). Likewise, when patients were classified according to etiology, there were no significant differences in baseline TDI score *(p* = 0.34) or the prevalence of anosmia and hyposmia *(p* = 0.40).

In addition to the 4- and 8-month evaluation visits, all patients returned at 2-month intervals for informal follow-up. At these encounters, they were asked about any inconvenience or difficulty they might have experienced in complying with their training regimen and in reacting to any side effects.

**Table. Selected characteristics of the study patients and their**

| | All patients (N = 46) | Training-only group (n = 28) |
|---|---|---|
| Age, yr, mean ± SD | 59.17 ± 13.25 | 58.89 ± 14.22 |
| Sex, n (%) | | |
| Men | 4 (30.4) | 10 (35.7) |
| Women | 32 (69.6) | 18 (64.3) |
| Median duration, mo | 21 | 21 |
| Range | 10.5 to 36 | 14 to 40 |
| Steroid group, n (%) | 18 (39.1) | — |
| Degree of dysfunction, n (%) | | |
| Anosmia | 23 (50.0) | 12 (42.9) |
| Hyposmia | 23 (50.0) | 16 (57.1) |
| TDI-0 | 15.02 ± 9.01 | 16.27 ± 9.01 |
| T-0 | 2.52 ± 2.51 | 2.95 ± 2.76 |
| D-0 | 6.66 ± 4.06 | 7.27 ± 3.95 |
| I-0 | 5.85 ± 3.88 | 6.07 ± 3.77 |
| TDI-1 | 16.95 ± 9.08 | 18.28 ± 8.76 |
| T-1 | 2.70 ± 2.62 | 2.58 ± 1.99 |
| D-1 | 7.27 ± 4.07 | 8.45 ± 3.79 |
| I-1 | 6.97 ± 3.85 | 7.25 ± 3.99 |
| TDI-2 | 19.11 ± 7.09 | 18.32 ± 8.48 |
| T-2 | 2.43 ± 2.13 | 2.77 ± 2.44 |
| D-2 | 8.32 ± 2.97 | 7.27 ± 3.17 |
| I-2 | 8.36 ± 3.33 | 8.27 ± 3.82 |

** TDI scores, followed by a breakdown of their individual components, are shown at*

*† Data that are not of normal distribution are expressed as a median with first- and*

***Statistical analysis.*** Statistical analysis was performed with the Statistical Package for the Social Sciences software (v. 16.0; SPSS; Chicago). For numeric data, the Wilcoxon test was used for dependent samples and the Mann-Whitney *U* test and the Kruskal-Wallis test were used for independent data. For variables according to a Gaussian distribution, the *t* test was used. For categorical data, the chi-square test was applied. Correlations were assessed by means of bivariate regression analysis. In cases of a Gaussian distribution, the data are presented as a mean with standard deviation (mean ± SD). When data are not of normal distribution, they are expressed as a median with first- and third-quartile values. A dif-

**TDI scores* according to treatment and etiology**

| | Etiology | | | |
|---|---|---|---|---|
| **Steroid group (n = 18)** | **Sinonasal (n = 15)** | **Post-URTI (n = 16)** | **Post-traumatic (n = 7)** | **Idiopathic (n = 8)** |
| 59.61 ± 11.97 | 58.53 ± 13.78 | 62.19 ± 10.43 | 51.29 ± 17.13 | 61.25 ± 13.23 |
| 4 (22.2) | 4 (26.7) | 2 (12.5) | 3 (42.9) | 5 (62.5) |
| 14 (77.8) | 11 (73.3) | 14 (87.5) | 4 (57.1) | 3 (37.5) |
| 17 | 21.5 | 18 | 23 | 25 |
| 9.25 to 36 | 10 to 37 | 10.25 to 30.75 | 7 to 120 | 15.75 to 153 |
| — | 5 (33.3) | 7 (43.8) | 3 (42.9) | 3 (37.5) |
| 11 (61.1) | 5 (33.3) | 9 (56.2) | 5 (71.4) | 4 (50.0) |
| 7 (38.9) | 10 (66.7) | 7 (43.8) | 2 (28.6) | 4 (50.0) |
| 13.08 ± 8.92 | 17.37 ± 10.71 | 15.56 ± 6.90 | 9.93 ± 8.19 | 14.00 ± 9.67 |
| 1.86 ± 1.97 | 3.30 ± 2.95 | 2.44 ± 2.44 | 1.79 ± 2.08 | 1.88 ± 2.10 |
| 5.72 ± 4.16 | 6.87 ± 4.47 | 7.25 ± 3.07 | 5.00 ± 4.36 | 6.56 ± 5.10 |
| 5.50 ± 4.13 | 7.20 ± 4.68 | 5.88 ± 3.05 | 3.14 ± 2.91 | 5.63 ± 3.81 |
| 15.38 ± 9.47 | 18.39 ± 10.72 | 20.83 ± 5.86 | 11.00 ± 8.95 | 12.20 ± 6.38 |
| 2.85 ± 3.28 | 3.31 ± 3.18 | 3.00 ± 2.59 | 2.29 ± 2.27 | 1.00 (1 to 1)† |
| 5.88 ± 4.04 | 7.46 ± 4.37 | 9.33 ± 2.27 | 4.86 ± 4.02 | 5.20 ± 4.97 |
| 6.65 ± 3.77 | 7.62 ± 4.79 | 8.50 ± 2.35 | 3.86 ± 3.72 | 6.00 ± 1.58 |
| 19.91 ± 5.68 | 19.21 ± 9.89 | 19.20 ± 4.87 | 13.00 (13 to 13)† | 20.25 ± 8.42 |
| 2.09 ± 1.81 | 3.07 ± 2.42 | 2.10 ± 1.73 | 1.00 (1 to 1)† | 2.50 ± 3.00 |
| 9.36 ± 2.46 | 7.57 ± 4.12 | 8.50 ± 2.59 | 7.00 (7 to 7)† | 9.50 ± 1.91 |
| 8.46 ± 2.94 | 8.57 ± 4.69 | 8.60 ± 1.90 | 5.00 (5 to 5)† | 8.25 ± 4.35 |

*baseline (TDI-0), 4 months (TDI-1), and 8 months (TDI-2), and are expressed as a mean ± the standard deviation except where noted by the † symbol.*

*third-quartile values.*

ference was considered to be statistically significant at a $p$ value of <0.05.

## Results

***Overall findings.*** Among the group as a whole, the mean baseline TDI score was 15.02 ± 9.01 (table). The mean score improved slightly to 16.95 ± 9.08 at 4 months ($p$ = 0.10) and then to 19.11 ± 7.09 at 8 months (figure 1). The increase of 4.09 between baseline and 8 months was statistically significant ($p$ = 0.01); however, since the increase was less than 6 points, it was not considered to be clinically relevant.

When the three components of the TDI score were analyzed individually, the only statistically significant difference over baseline was seen in the *identification* component, which rose from 5.85 ± 3.88 at baseline to 6.97 ± 3.85 at 4 months ($p$ = 0.02) and to 8.36 ± 3.33 ($p$ = 0.004) at 8 months. Still, the increase in absolute value was only 2.51 points, which was far below the threshold for clinical relevance of 6 points. The changes in the *threshold* and *discrimination* components were not statistically significant at 4 and 8 months.

***Training-only group.*** The mean TDI score among the 28 patients who did not use a topical steroid was 16.27 ± 9.01 at baseline (figure 2). It rose to a statistically nonsignificant level of 18.28 ± 8.76 at 4 months ($p$ = 0.39) and then remained stable at 18.32 ± 8.48 ($p$ = 0.96) at 8 months.

The mean score for the *identification* component increased from 6.07 ± 3.77 at baseline to 7.25 ± 3.99 at 4 months ($p$ = 0.06) and to 8.27 ± 3.82 at 8 months ($p$ = 0.14); the significant improvement noted at 4 months

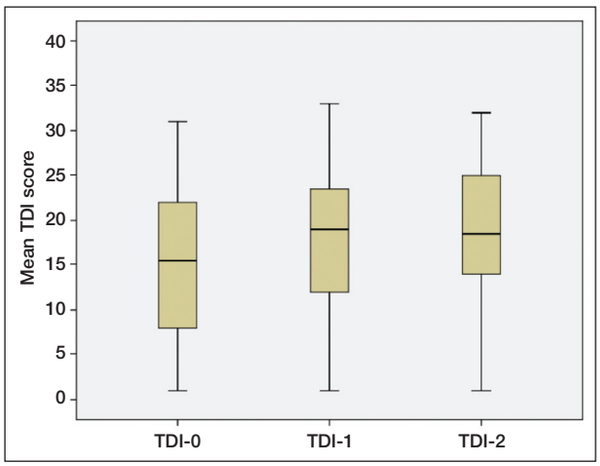


*Figure 1. Among the entire group, the mean TDI score increased from 15.02 ± 9.01 at baseline (TDI-0) to 16.95 ± 9.08 at 4 months (TDI-1) to 19.11 ± 7.09 at 8 months (TDI-2). The difference between TDI-0 and TDI-1 was not statistically significant* (p = *0.10). The difference of 4.09 points between TDI-0 and TDI-2 was statistically significant* (p = *0.01) but not clinically relevant. The horizontal line in the middle of each box indicates the median score; the top and bottom of each box represent the 75th and 25th percentiles, respectively; and the whiskers above and below the boxes demarcate the 90th and 10th percentiles, respectively.*

was not maintained at 8 months. No significant changes were seen in the mean scores for the *threshold* and *discrimination* components at 4 and 8 months.

***Steroid group.*** The 18 patients who applied a topical steroid during olfactory training had a mean TDI score of 13.08 ± 8.92 at baseline (table; figure 2). Their mean score increased to 15.38 ± 9.47 at 4 months ($p = 0.17$) and to 19.91 ± 5.68 at 8 months ($p = 0.001$). The increase of 6.83 from baseline to 8 months was not only statistically significant, but also clinically relevant.

When the individual components were analyzed, significant differences were seen between baseline and 8-month scores in the *discrimination* component (from 5.72 ± 4.16 to 9.36 ± 2.46; $p = 0.02$) and the *identification* component (from 5.50 ± 4.13 to 8.46 ± 2.94; $p = 0.02$). Neither of these improvements was clinically significant. There was no significant change in the mean *threshold* scores.

***Etiology.*** When TDI scores were analyzed according to etiology, no statistically significant changes were seen in the sinonasal, post-traumatic, and idiopathic categories. On the other hand, patients in the post-URTI category experienced a statistically significant increase in mean TDI score from 15.56 ± 6.90 at baseline to 20.83 ± 5.86 at 4 months ($p = 0.02$); no further improvement occurred thereafter.

In addition, the *identification* component scores in the post-URTI category were significantly higher than baseline at both follow-up evaluations, rising from 5.88 ± 3.05 initially to 8.50 ± 2.35 at 4 months ($p = 0.02$) to 8.60 ± 1.90 at 8 months ($p = 0.02$). Neither the *threshold* nor *discrimination* values changed significantly in the post-URTI category. No significant changes in individual component values were seen in the sinonasal, post-traumatic, and idiopathic categories.

***Clinical relevance.*** Clinically relevant increases of 6 points or more in TDI and individual component scores were analyzed according to treatment group:

*Training-only group.* Only 3 of the 28 patients in the training-only group (10.7%) experienced a clinically relevant (although statistically nonsignificant) increase in TDI score of at least 6 points at the 4-month assessment. These 3 patients included 1 in the sinonasal category who improved from hyposmic to normosmic, 1 in the post-URTI category who improved from anosmic to hyposmic, and 1 in the post-traumatic category who remained anosmic. No further improvements were seen at 8 months.

*Steroid group.* A similar proportion of patients in the steroid group—2 of 18 (11.1%)—experienced a clinically relevant improvement at 4 months; 1 patient in the post-URTI category improved from hyposmic to normosmic, and 1 patient in the idiopathic category improved from anosmic to hyposmic. At 8 months, 4 other patients experienced an increase of at least 6 points; these included 1 patient in the sinonasal category who remained anosmic and 3 in the post-URTI category, 2 who improved from anosmic to hyposmic and 1 who remained hyposmic.

***Duration of olfactory dysfunction.*** As a group, patients whose olfactory dysfunction had been present for more than 2 years (n = 19) did not experience any improvement. In fact, their mean TDI score actually decreased by 0.75 ± 1.06 points ($p = 0.05$).

Among those patients whose olfactory dysfunction had been present for less than 2 years (n = 27), the mean TDI score improved by 2.07 ± 5.32 points at 4 months. The greatest improvement was seen in the post-URTI category: an increase of 4.60 ± 4.55 points.

***Degree of dysfunction.*** In the patients with baseline anosmia (n = 23), the mean TDI score increased by 2.97 ± 3.82 points at 4 months. Those with baseline hyposmia (n = 23) experienced no improvement.

When analyzed according to etiology, the patients in the post-URTI category again experienced the best results, and their TDI score increased significantly ($p =$

0.02). The mean TDI scores at 4 months rose by 5.00 ± 4.43 points in the 9 patients with baseline anosmia and by 2.42 ± 4.84 points in the 7 patients with hyposmia; the difference between these two groups was not significant ($p = 0.17$).

***Age and sex.*** No association was found between changes in olfactory function and either age or sex at 4 or 8 months.

***Adverse effects.*** None of the participants reported adverse effects or unexpected events throughout the course of the investigation.

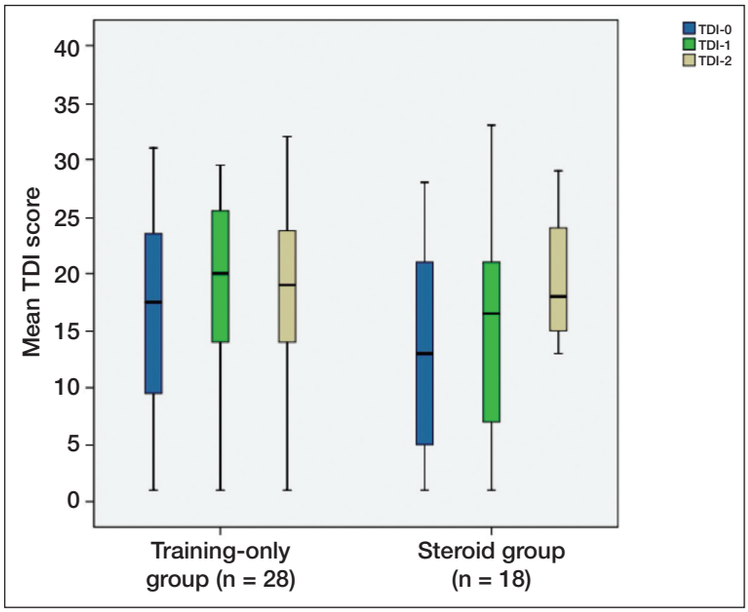


*Figure 2. Box plots show a comparison of the mean TDI scores in the training-only group and the steroid group at baseline (TDI-0), 4 months (TDI-1), and 8 months (TDI-2). The only statistically significant difference was between the TDI-0 and TDI-2 scores in the steroid group (p = 0.001); this difference of 6.83 points was also clinically relevant. The horizontal line in the middle of each box indicates the median score; the top and bottom of each box represent the 75th and 25th percentiles, respectively; and the whiskers above and below the boxes demarcate the 90th and 10th percentiles, respectively.*

## Discussion

This investigation revealed the following major findings:

- Patients who did not use adjunctive steroid therapy during their training experienced a slight, nonsignificant increase at 4 months that was maintained at 8 months. This improvement was primarily attributable to a progressive increase in the *identification* component.
- Patients who administered topical corticosteroids while undergoing olfactory training experienced a statistically significant and clinically relevant improvement in their mean TDI score at 8 months. This improvement was primarily attributable to progressive improvements in the *discrimination* and *identification* components of the total score.
- Three of the 28 training-only patients (10.7%) experienced a clinically relevant (although statistically nonsignificant) increase of at least 6 points in their TDI score at the 4-month assessment. We were surprised that these improvements occurred not only in a patient with olfactory loss post-URTI, but also in 1 patient in the sinonasal category and 1 in the post-traumatic category.
- In the steroid group, a clinically relevant increase in TDI score at 4 months was seen in a similar proportion of patients—2 of 18 (11.1%). At 8 months, 4 more of these patients reached the clinically relevant threshold, bringing the total to 6 of 18 (33.3%), including 4 patients with post-URTI olfactory disorder.
- The 9 patients in the post-URTI category who had baseline anosmia exhibited a statistically significant improvement in mean TDI score of 5.00 points after 4 months. The 7 hyposmic patients experienced an improvement of only 2.42 points at 4 months.

Hummel et al first reported the effect of olfactory training on olfactory disorders in 2009; the duration of that training was 3 months.[13] Like Hummel et al, we presume that repeated short-term exposure to odors may result in an increased growth of olfactory receptor neurons and an increased expression of olfactory receptors. The improvements in olfactory function in our study were not as good as those reported by Hummel et al.[13]

Moreover, based on the results of our longer study, it does not seem possible to improve olfactory function beyond a certain level with a longer duration of training. Our training-only group did not show any further improvement after 4 months, whereas patients who used the topical corticosteroid showed continual improvement during the entire course of 8 months.

Our study differed from that of Hummel et al[13] in that we included some patients whose olfactory disorder was of a sinonasal origin. The addition of the topical corticosteroid could explain the improvement in these patients.

The greatest benefit of training was observed in those patients in the post-URTI category, regardless of steroid status. This finding might also be attributable to the fact that 11 to 66% of such patients recover their olfactory function spontaneously.[12] In our investigation, we were

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of this entity, surgical risk and cosmetic result must be taken into account when contemplating correction of the deformity. However, the classic radiologic appearance of this tumor may not always be evident, and the tumor may mimic other more common or aggressive cranial tumors. Partial resection is recommended as an initial intervention followed by active surveillance for tumor recurrence.

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unable to determine spontaneous recovery because we did not have a control group of untreated patients. Moreover, without an untreated control group, one cannot definitively determine whether changes in TDI scores were attributable to olfactory training or to improved testing skills.

Finally, another difference between our findings and those of Hummel et al[13] was that we frequently saw improvements in the *identification* component of the TDI score while they found improvements in the *threshold* component, which we did not. This conflicting finding remains to be resolved by further investigations.

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