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Taste-strip gustometry in cochlear implanted patients

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Abstract

Objective: Investigation of the gustatory function in a large cohort of cochlear implanted patients using lateralized taste-strip tests.

Patients and Methods: One hundred and seven unilaterally or bilaterally profoundly hearing impaired or deaf patients who received cochlear implants (n = 113) were included in this study. Data on gustometry, subjective gustatory dysfunction, and the detailed surgical procedure were acquired retrospectively. Gustatory function, assessed using lateralized taste-strip tests, was performed the day before, 3 days after cochlear implantation, and on the day of the initial CI adjustment (39 days ±7.3 SD).

Results: Averaged taste-strip scores of the cohort declined significantly from preoperatively 12.3 [11.8; 12.7] (mean [95% confidence intervals]) to 10.5 [9.7; 11.2] on the implanted side about 6 weeks after surgery. Patients with intraoperatively exposed and rerouted, or a severed, chorda tympani nerve (CTN) showed significantly reduced unilateral postoperative scores (10.1 [8.8; 11.4] and 9.3 [8.1; 10.5], respectively), when compared to not exposing or to leaving a bony layer over the CTN. Total taste-strip test scores showed a significant decline 6 weeks postoperatively in CI-patients expressing a subjective gustatory dysfunction (from 23.6 [21.4; 25.8] to 17.5 [14.2; 20.8]), as opposed to patients with a documented subjectively normal taste.

Conclusion: We consider postoperative gustatory dysfunction as a relevant side effect post cochlear implantation, at least within the first month. Taste-strip based gustometry is a suitable diagnostic tool to assess taste function in CI patients and is recommended to be performed routinely.

Level of Evidence: 3, retrospective, nonrandomized follow-up study.

KEYWORDS
cochlea implant, dysgeusia, ear surgery, gustometry, gustatory function, hypogeusia, sense of taste, taste strips

Dirk Beutner and Julia Vent contributed equally to this work.

1 | INTRODUCTION

In recent decades, cochlear implants (CI), as the therapy of choice in patients with uni- or bilateral profound hearing loss and deafness, have become increasingly frequent.[1] The most common surgical approach to expose the base of the cochlea for electrode insertion is a mastoidectomy, followed by a posterior tympanotomy, a triangular access to the middle ear framed by the facial nerve, the fossa incudes, and the chorda tympani nerve (CTN).[2] In addition to general visceral efferent nerve fibers to the submandibular and sublingual gland, the CTN carries special visceral afferent fibers from papillae of the anterior two-thirds of the tongue. Thus, iatrogenic injury during cochlear implantation is assumed to lead to gustatory dysfunction.[3-7] The resulting impaired sense of taste induces changed dietary habits, weight loss, and other consequences associated with a reduced quality of life.[8,9]

Studies of gustatory function after cochlear implantation are few and pronouncedly heterogeneous in their results, reporting subjective taste disturbance in between 5% and 45% of CI patients after surgery.[3,4,6,7,10] The accuracy of self-ratings and questionnaires regarding gustatory function is rather low,[11] and instead the lateralized taste-strip test provides a validated instrument to determine taste sensation in the anterior two-thirds of the tongue.[12,13] Studies that have used taste strips after cochlear implantation have recorded very heterogeneous results, ranging from decreased bi- as well as unilateral (only on the implanted side) to unchanged scores; this may derive from the studies' rather small sample sizes.[3,5,10]

With this background, the current study aimed to investigate short-term changes in gustatory function after cochlear implantation in a large cohort of 107 patients (113 cochlear implantations) using lateralized taste strips, approximately 6 weeks after surgery. Furthermore, the study intended to assess gustatory function with regard to the intraoperative handling of the CTN, as well as different methods of electrode insertion.

2 | MATERIALS AND METHODS

2.1 | Patients and study design

This study was designed as a retrospective evaluation of the gustatory function of CI-patients in the period from January 2009 to December 2012 at the Department of Otolaryngology of the University of Cologne Medical Center. Informed consent on retrospective medical data analysis was available and no objections to this project were expressed by the Ethics Committee at the University of Cologne (ID: 20-1708).

In total, 107 patients suffering from profound hearing loss or deafness were included in this study. Baseline characteristics of the study cohort are listed in Table 1. Patients who underwent ear surgery prior to cochlear implantation were excluded from the study, while inclusion criteria were deliberately wide to obtain a heterogeneous cohort. Quantitative bilateral assessment of the gustatory function with *taste strips*,[13] was routinely performed on the preoperative day, 3 days post-surgery, as well as on the day of the initial CI-adjustment (on average 39.4 days ±7.3 SD).

TABLE 1 Baseline characteristics

Patient cohort		
Total	***n*** **= 107**	**(100%)**
Gender		
Female	59	(55.1)
Male	48	(44.9)
Cochlear implantation		
Unilateral left	50	(46.7)
Unilateral right	51	(47.7)
Bilateral	6	(5.6)
Mean age (at implantation)	43.3 years	7.4-87.0 years
Electrode insertion	*n* = 113	(100%)
Round window	98	(86.7)
Cochleostomy	15	(13.3)

2.2 | Cochlear implant surgery

All patients underwent cochlear implantation through a mastoidectomy and a subsequent posterior tympanotomy, performed by six different, senior neurootologists. Through retrospective review of the operation report, the intraoperative handling of the tympanic chord was assigned to four categories: "not exposed," "exposed with," and "exposed without bony coverage," as well as "severed." The CI electrode was inserted either via the round window or via an anterior and inferior cochleostomy.

2.3 | Gustometry

Lateralized gustometry in study patients was performed using taste strips, a psychophysical chemical taste test, as described by Mueller et al.[13] Patients were asked not to eat, drink, smoke, or brush their teeth from 1 hour prior to testing, and to rinse their mouth with water between the application of two different taste strips. Four different tastants (*sweet*: sucrose, *sour*: citric acid, *bitter*: quinine hydrochloride, and *salty*: sodium chloride) in four different concentrations were presented by placing tastant-impregnated paper strips alternating to each side of the tongue (anterior two-thirds) in a pseudo-randomized manner. Patients were asked to identify the taste in a forced-choice-test manner, resulting in a maximal test score of 16 per side (max. 32 in total). On a single-patient level, a reduction in the postoperative total taste score was considered clinically relevant if it decreased by more than 1.282 standard deviations (threshold to the 10th percentile) of the preoperative averaged scores, amounting to between 5 and 6 score points.

2.4 | Statistical analysis

The open-source statistic software "R" (packages: Hmisc, ggplot2, ggpubr, fitdistrplus, lme4, emmeans) was employed for statistical and graphical analysis, and statistical analysis was supported by the Institute of Medical Statistics at the University of Göttingen. Data fitted a normal distribution best in a goodness-of-fit test computing Kolmogorov-Smirnov, Cramer-von Mises, and Anderson-Darling statistics. A linear mixed-effects model analysis was performed, since not all data sets of patients were complete. Data was normalized before computing the model. CI-surgeries, influenced by the time point of taste testing and the implanted side, were set as random factor. Residuals of the model were tested for normality by Kolmogorov-Smirnov-Statistics. Likelihood ratio tests served to examine differences in various levels of the fixed factors. Tukey's test was subsequently used for pairwise contrast analysis. Correlational analysis was performed applying Pearson's statistics to the data sets. Alpha levels were set at .05 (*), .01 (**), and .001 (***).

3 | RESULTS

The preoperative total taste-strip test score (TTS) of the study cohort ($n = 107$, 113 cochlear implants) averaged 24.3 [23.5; 25.1] (mean [95% confidence intervals]) and showed a negative correlation with age ($r = -.30$, $P = .001$). In addition, a significant (unpaired *t*-test, $P < .001$) preoperative difference between male (22.4 [21.2; 23.7]) and female (25.9 [25.0; 26.8]) patients was found. According to normative values for taste-strip tests,[12] 10 patients (9.3%) of the cohort preoperatively exhibited an impaired taste function. Of the 113 cochlear implantations, in addition to the preoperative test (day −1), immediate postoperative taste-strip tests (day 3) were available from 83 patients. The second postoperative test (day 39.4 ± 7.3 SD) was available in 78 cases; taste strips were applied at both postoperative time points to 48 patients.

3.1 | Gustatory function

Total TTS at different points in time were found to be significantly different within the whole cohort ($\chi^2[2] = 9.22$, $P = .009$). In the second postoperative test, the post hoc pairwise comparison revealed a significant decrease of the averaged total TTS to 21.9 ([20.7; 23.1], $P = .003$) (Figure 1A). An influence of the interacting factor *operated side* also turned out to be significant ($\chi^2[5] = 43.93$, $P < .001$). On the implanted side, averaged TTS decreased significantly from 12.3 [11.6; 12.5] preoperatively to 11.0 ([10.3; 11.7], $P < .001$) in the immediate, and to 10.5 ([9.7; 11.2], $P < .001$) in the later postoperative test (Figure 1A). The taste strip test results are listed in detail in Table S1.

With regard to individual tastants (max. score of 4 points per side), TTS for *salty* showed the strongest divergence ($\chi^2[5] = 41.38$, $P < .001$), from 3.0 [2.8; 3.2] preoperatively to 2.4 ([2.2; 2.6], $P < .001$) in the first, and 2.4 ([2.1; 2.6], $P < .001$) in the second postoperative test. Furthermore, lateralized TTS for the tastants *sweet* ($\chi^2[5] = 42.02$, $P < .001$) and *bitter* ($\chi^2[5] = 16.44$, $P = .006$) changed markedly postoperatively, with a significant decline predominantly in the second postoperative taste test on the implanted side from 3.5 [3.3; 3.6] to 3.0 ([2.8; 3.3], $P < .001$) and from 3.3 [3.1; 3.5] to 2.9 ([2.6; 3.1], $P = .009$), respectively, while no significant divergences were found for the tastant *sour* ($\chi^2[5] = 9.7$, $P = .08$). More detailed data is presented in Table S1.

Neither the factor *method of electrode insertion* (round window insertion and cochleostomy), nor *actual side of implantation* (left and right) showed any significant impact on the total ($\chi^2[3] = 0.08$,

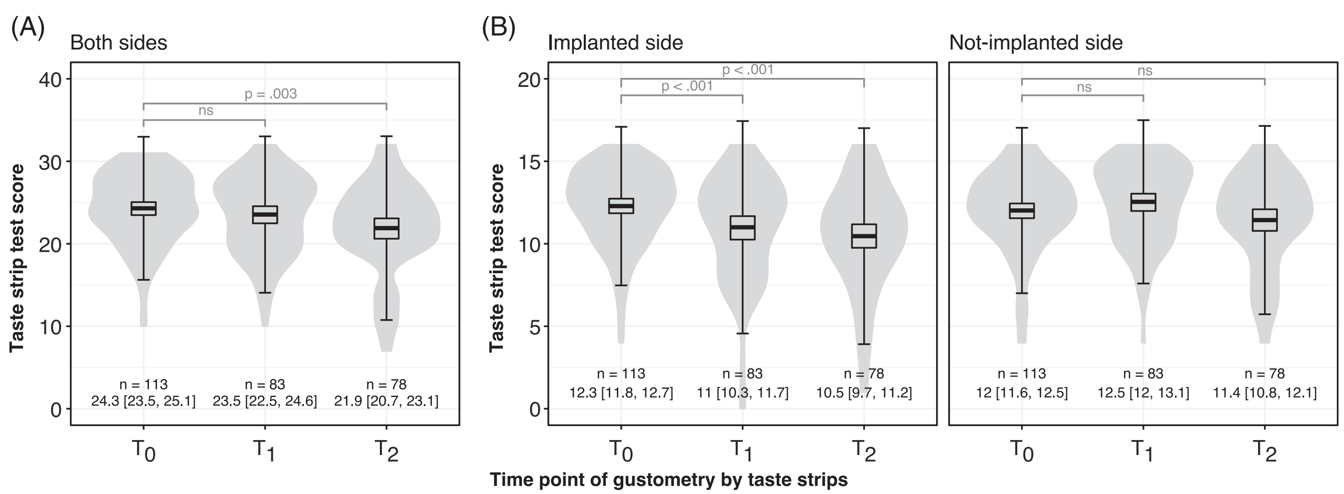

FIGURE 1 Taste-strip test scores of the cohort prior to and after cochlear implantation. Mean total, A, and mean lateralized taste-strip test scores, B, depicted as crossbars with 95% confidence intervals and corresponding SDs as error bars at three different time points (T_0 = day −1, preoperative; T_1 = day 3, first postoperative; T_2 = day 39.4 ± 7.3 SD, second postoperative). The background violin plots (gray) indicate the distribution of taste-strip test scores within the cohort. The actual number (n) as well as the mean and 95% confidence intervals are given at the bottom of each plot

P = .99 and $\chi^2[3]$ = 5.48, P = .14, respectively) as well as on the lateralized postoperative taste strip scores ($\chi^2[6]$ = 2.53, P = .87 and $\chi^2[6]$ = 7.06, P = .32, respectively). A reduction of postoperative taste scores on the implanted side, as demonstrated by data from the entire cohort, is reflected in the individual subgroups addressed above, as detailed in Table S1.

The handling of the CTN during cochlear implantation significantly affected postoperative bilateral ($\chi^2[9]$ = 18.12, P = .034) as well as unilateral TTS ($\chi^2[18]$ = 29.68, P = .041). While not exposing the CTN, as well as exposure with retaining a bony layer over the nerve did not lead to a decline in scores, full exposure of the CTN induced a significant reduction from 13.2 [12.1; 14.2] preoperatively to 9.3 ([7.6; 10.9], P < .001) in the immediate postoperative test on the implanted side (Figure 2A). Within the subgroup of patients with an intraoperatively severed tympanic chord (preoperative TTS on the implanted side: 12.5 [11.6; 13.3]), both postoperative tests revealed a significant decline to 10.1 ([8.8; 11.3], P < .001) for the first and 9.3 ([8.1; 10.6], P = .001) for the later test, respectively (Figure 2A). The proportion of patients showing a reduced TTS considered as clinically relevant was highest in this subgroup, with 22.7% (5 of 22) showing an immediate and 46.7% (7 of 15) a later postoperative loss (Figure 2B).

In comparison to patients not reporting any change in taste, patients expressing postoperative taste impairment revealed highly significant differences ($\chi^2[5]$ = 24.13, P < .001) regarding total TTS. The averaged total TTS of patients reporting postoperative taste disturbance decreased significantly from 24.2 [22.2; 26.2] to 20.1 ([17.4; 22.8], n = 15, P = .024) in the first, and from 23.6 [21.4; 25.8] to 17.5

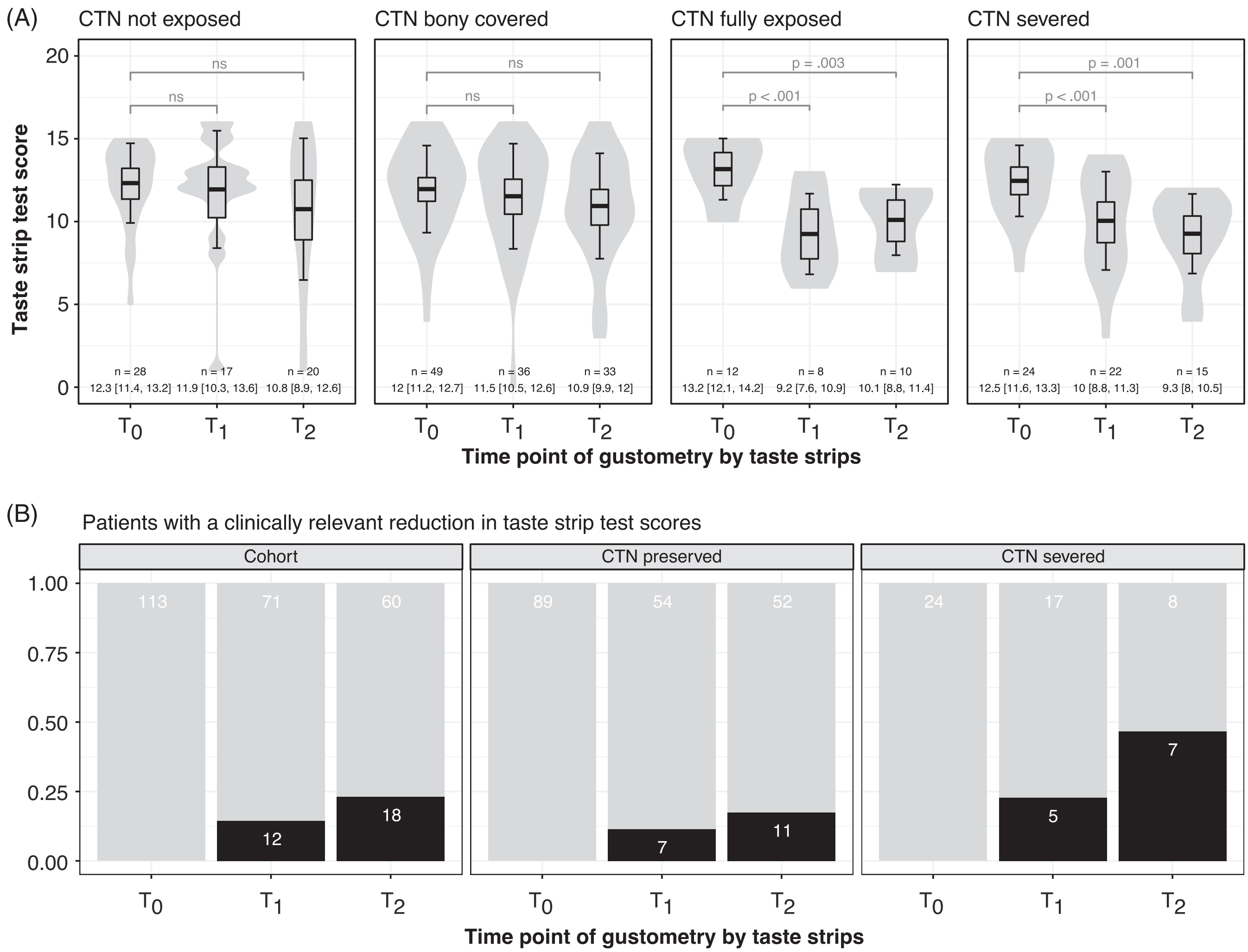

FIGURE 2 Analysis of gustometry regarding different intraoperative handling of the chorda tympani nerve (CTN). A, Lateralized taste-strip test scores for patients with intraoperatively not exposed CTN (left), exposed but bony covered CTN (middle left), fully exposed and partially rerouted CTN (middle right), as well as severed CTN (right). The means are depicted as crossbars with 95% confidence intervals and corresponding SDs as error bars at three different time points (T_0 = day −1, preoperative; T_1 = day 3, first postoperative; T_2 = day 39.4 ± 7.3 SD, second postoperative). The background violin plots (gray) indicate the distribution of taste-strip test scores within the cohort. The actual number (n) as well as the mean and 95% confidence intervals are given at the bottom of each plot. B, Number of patients with a reduction in taste-strip test scores considered as clinically relevant (decrease >1.282 SD, threshold to the 10th percentile) analyzed for the whole cohort (left), for patients with intraoperatively intact CTN (middle), as well as for a severed CTN (right)

TABLE 2 Taste strip test scores of bilateral cochlear implanted patients

Patient	First cochlear implant, ipsilateral side		Time in between (months)	Second cochlea implant, contralateral side
	Preop. TTS	Second postop. TTS		Preop. TTS
9	10	8	7.9	12
39	15	1	19.7	16
71	15	11	5.9	12
82	14	*NA*	6.6	13
83	11	7	9.6	4
113	13	13	8.3	14
Mean [95% CI]	13 [11.3; 14.7]	8 [4.0; 12.0]	9.7 ± 5.1 SD	11.8 [8.5; 15.1]

Abbreviations: CI, confidence interval; NA, not available; SD, standard deviation; TTS, taste test score.

([14.2; 20.8], $n = 16$, $P = .006$) in the second test. Patients with documented subjectively normal taste function showed an almost unchanged postoperative total TTS with 24.1 ([22.2; 26.1], $n = 22$, $P = .842$) in the first and 23.0 ([21.5; 24.5], $n = 36$, $P = .51$) in the second test, in comparison to a preoperative score of 23.7 [22.4; 25.0] and 23.7 [21.5; 24.5], respectively.

3.2 | Bilaterally cochlear implanted patients

Only 6 out of 107 patients had received a CI bilaterally, therefore providing long-term information (Table 2). Due to the small sample size, no further statistical analysis was performed. The averaged TTS on the side of the first cochlear implantation was 13 [11.3; 14.7], and declined to 8 [4.0; 12.0] in the second postoperative test. With a mean of 9.7 months (± 5.1 SD) between surgeries, most TTS of bilaterally implanted patients recovered to the initial level, on average 11.8 [8.5; 15.1] on the side of the first CI, before the second CI-surgery on the contralateral side. In two of these patients, the CTN was not exposed, in two others, a thin bony layer was left covering the CTN, and in the remaining two patients the CTN was severed.

4 | DISCUSSION

The present study aimed to clarify the currently inconsistent study situation on dysgeusia after cochlear implantation, with, to our knowledge, one of the largest patient cohorts analyzed so far. The results demonstrated a significant postoperative reduction in taste-strip test scores on the implanted side, without recovery during the first 6 weeks after surgery. Conversely, taste-test scores decreased on the cohort level. Moreover, results of this study indicated a critical influence of different intraoperative treatment of the chorda tympani nerve (CTN) on taste-strip test scores, and that a subjective impression of postoperative dysgeusia was manifest in a significant decrease in postoperative scores.

With regards to Landis et al., who determined normative values for taste-strip gustometry on 537 healthy subjects, the present study cohort showed comparable preoperative scores, similar significant differences between sexes, and a negative correlation of test scores with age, indicating a representative study cohort.[12] It involved 9.3% (10 of 107) of CI-candidates with taste-strip determined hypogeusia, which is in the range of population-based studies (5%-20%).[14-16] In the current study, the preoperative total TTS amounted to 24.3 [23.5; 25.1], and was therefore not reduced as reported for CI-candidates.[3,5,10] The total TTS of the cohort decreased significantly in the second test taken approximately 6 weeks postoperatively. This result concurs with findings of Walliczek et al,[5] who detected a significant reduction in TTS 4 weeks after cochlear implantation. Furthermore, we found a significantly reduced TTS in both postoperative tests on the implanted side, which is in accordance with a study of Mueller et al.,[3] who performed taste-strip tests 4 days and 18 months after cochlear implantation. Wager et al.[6] and Jeppesen et al.,[10] both investigating gustatory function in CI patients, observed no postoperative changes, but conducted their studies in rather small groups of 20 and 13 subjects, respectively.

Broken down to the single patient level, however, 14.5% and 23.1% showed a clinically relevant reduction in gustatory function in the first and second postoperative taste tests, respectively. Walliczek et al.[5] performed a similar evaluation of postoperative changes in taste-strip scores of CI-patients by arbitrarily assuming 6 points as clinically relevant, and found 9.8% of their study population affected 4 weeks after surgery. The difference to the present numbers may arise from the much lower baseline of preoperative TTS in their study cohort (19.7 ± 5.9 SD). Therefore, and due to the larger sample of the present study, we consider that 20% is a more realistic approximation of gustatorily impaired patients after cochlear implantation. Other published data on postoperative gustatory dysfunction in CI-patients—mainly assessed by patient's self-ratings—varied considerably, between 5% and 45%.[3,4,6,7,10]

CI-patients of the present study who expressed a disturbance in taste sensation, exhibited a significantly higher decrease from preoperative to postoperative total TTS as compared to patients who explicitly did not. Despite the retrospective study design, the missing qualitative subjective aspect, and the fact that existing symptoms are probably more often documented in patient's records than missing symptoms, we nonetheless consider that taste-strip gustometry does reflect the subjective gustatory impression in CI-patients.

Jeppesen et al.[10] reported a proportion of 23% with subjective changes in taste sensation 4 to 8 weeks after cochlear implantation, but observed no significant changes in postoperative TTS in their rather small study population of 13 patients. Mueller et al.[13] found taste-strip measured gustatory dysfunction in 6 subjects (25%), which was not reflected in a subjective visual analogue scale (VAS) analysis of their cohort. Guder et al.[17] found a significant correlation between postoperatively reduced TTS on the side of intervention, and decreased VAS-based self-ratings in 17 patients who underwent stapes surgery with minor intraoperative manipulation of the tympanic chord. Another study by Mueller et al.[18] investigating alterations in gustatory function after middle-ear surgery, described a significant postoperative reduction in TTS in 17 patients with major surgical manipulation of the CTN. The study situation is thus inconsistent, but the latter results suggest that subjective taste disorders are reflected by strip-test results, as depicted for CI-patients in the present study.

The present cohort provides a number large enough to draw relevant conclusions regarding different intraoperative handling of the chorda tympani nerve (CTN) and any resulting effects on gustatory function in CI-patients. An intraoperatively preserved, but fully exposed, CTN (to some extent rerouted), as well as a severed CTN showed a significant decline in TTS both immediately and approximately 6 weeks after cochlear implantation. By contrast, in the subgroups of patients with intraoperatively preserved but not exposed CTN, or CTN exposed but covered by bone, no decrease of postoperative taste scores was observed. The proportion of patients with reduced TTS considered as clinically relevant was highest in the second postoperative test, with 46.7% in the CTN severed subgroup, in comparison to 17.5% in patients with preserved CTN. Taken together, this indicates an expected correlation between the extent of CTN manipulation and postoperative gustatory function.

Most studies investigating the sense of taste in CI-patients either made no statement regarding the intraoperative CTN treatment, or simply reported individual cases with an injured CTN, mostly due to the limited sample size.[3,5-7,10] Supporting the presented results, a study by Lloyd et al. on 96 CI-patients, surveying self-ratings of pre- and postoperative gustatory function, found a significantly higher amount of postoperative taste disturbance in patients with severed (86%) than with preserved CTN (50%).[4]

The present study also aimed to examine gustatory function with regard to different methods of electrode insertion during cochlear implantation, hypothesizing that electrode insertion via cochleostomy leads to a higher rate of gustatory dysfunction, because the posterior tympanotomy has to be extended anteriorly and inferiorly into the area of the CTN. Here, mechanisms additional to the mere degree of exposure must be considered with regard to CTN injury, such as heat generation by drilling. The second postoperative taste scores did indeed show a strong reduction in patients who underwent a cochleostomy. Unfortunately, this subgroup was small ($n = 9$) and the data are therefore inconclusive, but this approach can be assumed to produce worse results on a larger scale.

One limitation of the present study is the lack of extended long-term data. In 6 patients implanted bilaterally during the study period, preoperative TTS of the second CI—performed approximately 10 months after the first surgery—revealed a recovery of TTS to the initial level, although postoperative averaged TTS decreased strongly after the first cochlear implantation. Though in contrast to Mueller et al.,[19] who observed significantly decreased TTS on the side of intervention after 18 months, most studies investigating gustatory function after ear surgery in non-inflammatory diseases observed high subjective recovery rates from 61% to 79%, even in cases of a severed CTN. Several recovery mechanisms with regard to the extent of CTN-injury—recovery from neuropraxia, neural outgrowth in axonotmetic nerves, and recovery of a severed CTN, as well as contralateral neuronal ingrowths—have been proposed in this context.[20-22] Further studies with larger patient numbers and in the long term should provide clarification on the permanence of gustatory dysfunction in CI-patients.

5 | CONCLUSION

The present study helps to classify results of taste-strip based gustometry performed in CI-patients, as the literature data on gustatory function after cochlear implantation varies considerably. We consider postoperative gustatory dysfunction within the first months post cochlear implantation to be a relevant side effect that can significantly impair the quality of life. Hence, sufficient information must be provided to CI-candidates. Taste-strip based gustometry is a suitable diagnostic tool for the assessment of taste function in CI-patients and is recommended to be performed routinely. The extent of the intraoperative handling of the chorda tympani nerve is critically important for postoperative taste function, even though this may have little effect on non-gustatory CI outcomes.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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