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Gereğini bilgilerinize arz ederim.

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KAHRAMANMARAŞ SÜTÇÜ İMAM ÜNİVERSİTESİ
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Comparisons of Auditory and Vestibular Functions After Septorhinoplasty Performed with the Micro-compass Saw Technique and the Classical Technique

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Abstract
Aim To evaluate hearing and labyrinth functions following different osteotomy types (micro-compass saw, osteotome, and no osteotomy) performed in septorhinoplasty operations.
Material and Method The study included 74 patients operated between January 2020 and March 2022, separated into 3 groups: Group 1: 24 patients (16 females and 8 males): osteotome was used for the osteotomy; Group 2: 24 patients (12 females and 12 males): micro-saw was used for osteotomy; and Group 3: 26 patients (17 females and 9 males): open technique septoplasty with no osteotomy. At 1 day before and 1 week after the operation, all the patients underwent audiological examination, tympanometry, vestibular evoked myogenic potentials (c-VEMP), video head impulse test (v-HIT), videonystagmography (VNG), and distortion product otoacoustic emission (DPOAE) tests.
Results In the c-VEMP tests, significant differences were determined between the groups in respect of N1, P1, and N1-P1 latencies and N1-P1 amplitudes before and after the operation. In the v-HIT test, the change in right-side posterior gain postoperatively was statistically significant in the micro-saw group ($p<0.05$). The postoperative right lateral canal values were determined to be statistically significantly increased in the micro-saw group compared to the osteotome group ($p<0.05$).
Conclusion This is the only study in the literature to have determined vestibular effects with the evaluation of such a wide range of techniques. Previous studies in the literature have found no effect of osteotomy technique on the balance and hearing systems. The results of this study demonstrated that the preoperative and postoperative difference between the osteotomy techniques had an effect on the balance system. The change in the balance tests following an operation with classic osteotomy shows a greater predisposition to benign positional vertigo. In this sense, the micro-saw can be considered safer.
Level of Evidence II This journal requires that authors assign a level of evidence to each article. For a full description of these Evidence-Based Medicine ratings, please refer to the Table of Contents or the online Instructions to Authors www.springer.com/00266.

Keywords Septorhinoplasty · Osteotomy · Balance system · Hearing function · VEMP · v-HIT

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Introduction

Septorhinoplasty is a currently widely used surgical procedure applied for both cosmetic and functional purposes [1]. According to a study of 140,000 surgeons by the American Aesthetic Plastic Surgeons Association, rhinoplasty is among the most frequently applied cosmetic procedures [2]. While rhinoplasty is performed to reshape

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the nose for cosmetic or functional reasons, septoplasty corrects the septum curve to regain previous normal respiratory function [1].

Lateral and median osteotomy is one of the important stages in rhinoplasty operations. Osteotomy is used in several nasal deformity operations to close the open roof that is formed after the correction of the nasal dorsum [3]. To correct deviations in the nasal dorsum or septum, osteotomies are performed on the nasal bone or maxillary crest or vomer. The vibration energy during the strking of the surgical instruments in osteotomies spreads through the skull [4]. Labyrinthine concussion is defined as sensorineural hearing loss which can accompany vestibular symptoms resulting from intense pressure in the ear in the absence of an open labyrinth fracture following trauma [5]. Sensorineural hearing loss in the range of 4–6 KHz is characterised by high-frequency hearing loss. In brief, labyrinthine concussion affects both hearing and vestibular functions [6].

In recent years, piezoelectric and micro-saw methods have started to be used during osteotomies to prevent soft tissue damage, create regular fracture lines, and obtain the most appropriate cosmetic shape [7, 8]. The vibration effect formed during piezoelectric application can reach the cochlea through the bone pathway and can thus affect cochlear functions. When the data in the literature were examined, it was seen that although there have been investigations of the effect on auditory function of the piezoelectric method, which is being increasingly used during septorhinoplasty [1], the effect on cochlear function of rhinoplasty performed using micro-saw has not been investigated.

In addition to the patient history and physical examination, the evaluation of vestibular diseases requires various vestibular tests. The main aim in the application of vestibular tests is to determine the condition causing the vestbular disease [9]. The basic principle of many vestibular tests is to compare the functions of both vestibular organs, because the complaints of most patients are due to asymmetrical vestibular function. Therefore, in vestibular tests it is generally attempted to stimulate both labyrinths equally and compare the responses obtained. Many tests have been established on the evaluation of the vestibulo-ocular reflex (VOR) [10]. The o-VEMP and v-HIT tests are the primary tests that evaluate VOR.

Video nystagmography (VNG) is a test which records eye movements with small video cameras in a spectacle system and analyses these with computer software. VNG is the most widely used vestibular test, which includes evaluations of the central and peripheral vestibular systems together. Ocular motility is recorded with an infrared video (VNG) or electrode (electronystagmography–ENG), and this is combined with static/dynamic positional testing together with caloric stimulation. The ocular motor examination is accepted as an extension of the neurological examination with the inclusion of the evaluation of saccades, smooth pursuit, and directional gaze, and the testing of optokinetic reflexes [11]. Vestibular evoked myogenic potentials (VEMP), which evaluate the vestibulocollic reflex, are inhibitory potentials recorded from the neck muscles responding to high sound or from the extra-ocular muscles. The saccule and inferior vestibular nerve functions are assessed with the cervical VEMP (c-VEMP) test [11]. The video head impulse test (v-HIT), which has recently come into clinical use, is an easily applicable test that evaluates the VOR. Compared to the v-HIT caloric test, VOR is tested at higher frequencies, and the opportunity is provided for separate evaluation of each semicircular canal (9). Otoacoustic emissions (OAEs) are sound waves of small severity produced by the cochlea, formed as a result of the movement of outer hair cells located in the cochlea, and which can be recorded in the outer ear canal. OAEs are important for the determination of peripheral hearing function and dysfunction. The aim of measuring OAEs is to complete an objective evaluation test battery to identify hearing loss in the patient, and observe the function of outer hair cells, thereby providing differential diagnosis of cochlear or retrocochlear pathologies [12].

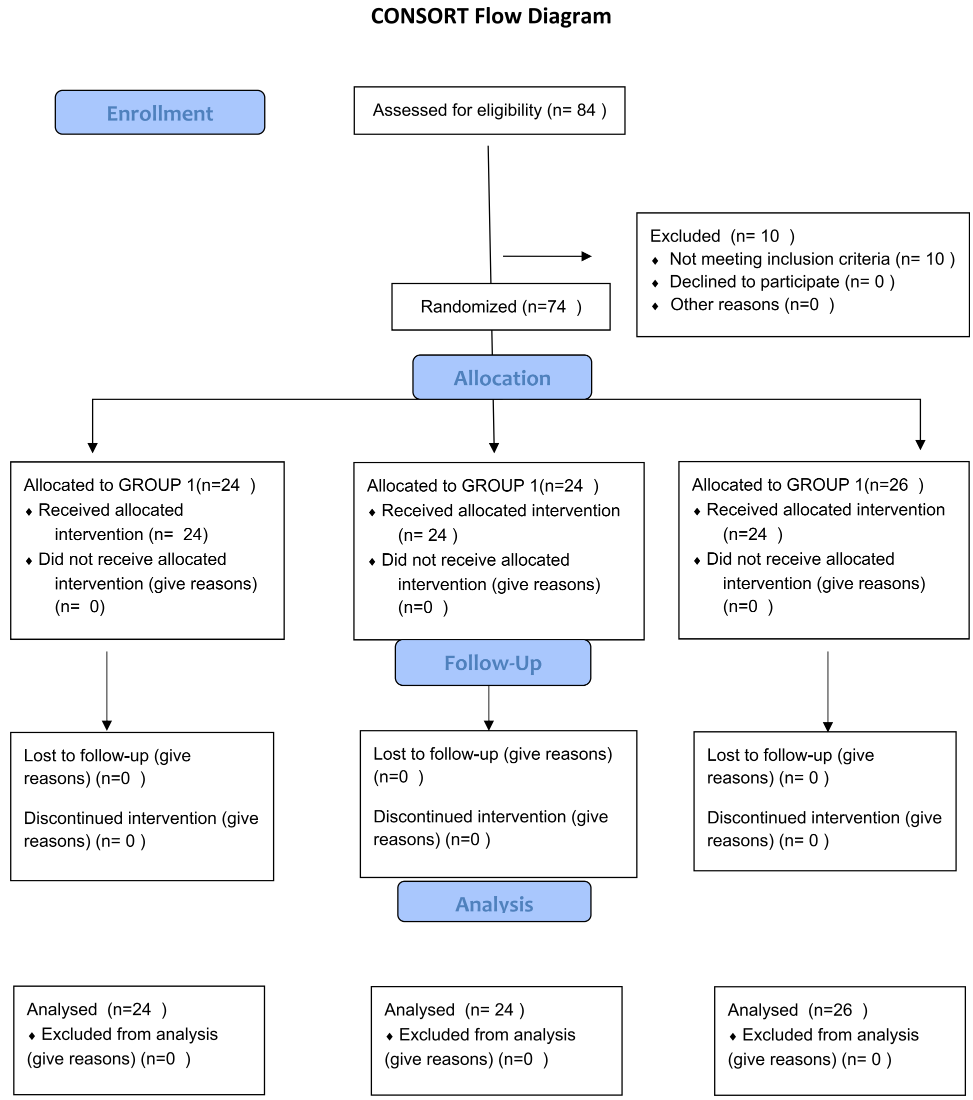
The aim of this study was to evaluate the effects on hearing function and labyrinth function of septorhinoplasty performed using a micro-compass saw compared with the classic method and surgery performed without osteotomy.

Material and Method

Approval for this prospective study was granted by the Clinical Research Ethics Committee of Kahramanmaraş Sütçü İmam University (decision no: 14, dated: 16/10/2019). All the study participants provided signed informed consent. The study was supported by the Scientific Research Projects Unit of Kahramanmaraş Sütçü İmam University (project no: 2019/6-28A). The method to be used in the operation was decided using a computer-generated randomization table (http://www.Random.org).

The study initially enrolled 84 patients between January 2020 and March 2022. After the exclusion of 10 patients who did not meet the study criteria, the evaluations were completed with 74 patients in 3 groups: Group 1 included 24 patients (16 females and 8 males) with osteotomy performed using an osteotome; Group 2 included 24 patients (12 females and 12 males) with osteotomy performed using a micro-saw; and Group 3 included 26 patients (17 females and 9 males) in whom the open technique septoplasty was

Fig. 1 Consort diagram of flow through study



performed with no osteotomy (Figure 1 Consort flow chart).

The patients included in the study were selected from those who presented at hospital with nasal deformity and breathing difficulties, were diagnosed with nasal deformity and nasal septum deviation as a result of the initial evaluation, and had indications for open technique septorhinoplasty.

Patients were excluded from the study if they had used drugs which could affect the vestibulocochlear system within the last month, had ototoxicity, dizziness, head trauma, chronic system disease, or a history of ear surgery, were determined with pathology in the ear examination or were not Type A in the tympanogram evaluation, or had any other problem such as cervical disc problem or anatomic morphological variation that could affect audiovestibular functions.

On the day before the operation, all the patients underwent audiological examination, tympanometry, vestibular evoked myogenic potentials (c-VEMP), video head impulse test (v-HIT), videonystagmography (VNG), and distortion product otoacoustic emission (DPOAE) tests. The same tests were repeated for all the groups at 1 week after the operation. The tests were performed after removal of the nasal silicon splints and cleaning of the nasal passage. The devices used were the Madsen® Astera^2 model (Natus medical, Denmark) for pure tone audiometry (PTA), the interacoustic AZ 26 model for tympanometry, and the Neurosoft model for DPOAE. PTA was applied with 250, 500, 1000, 2000, 4000, 6000, and 8000 Hz air conduction thresholds, and 500, 1000, 2000, and 4000 Hz bone conduction thresholds. The signal/noise (S/N) ratio in otoacoustic emission was measured at 500, 1000, 2000, 4000, 6000, and 8000 Hz.

The VNG tests in the study were carried out with the otometrics ICS Chartr EP 200 device (GN otometrics A/S, Denmark). The subjects were instructed to open their eyes wide during the test and not to blink unless absolutely necessary. The oculomotor tests were performed with otometrics goggles. The stages of the VNG test included calibration, gaze, saccade, pursuit, optokinetic, spontaneous nystagmus, Dix–Halpike test, positional test, and caloric test.

To record the v-HIT, the Eye-See-Cam system (otometrics, ICS Impulse, Denmark) was used.

The patients were seated 1.5m in front of a target and were instructed to continue looking at the target while the examiner turned their head. The head was subjected to passive high-acceleration, low-amplitude rotations in the planes of the horizontal semicircular canals. The eye movements of the patients were evaluated with video oculography, and head movements were recorded using inertial sensors. For each semicircular canal, at least 15 valid head movements were recorded. During the v-HIT (eye speed/head speed), vestibulo-ocular reflex (VOR) gains were measured automatically using software that calculates the regression curve between head and eye speed. Gain asymmetry of $> 5\%$ and mean saccades captured of < 0.8 determined in the lateral canal when < 0.7 was determined in the other canals was accepted as abnormal function of the canal.

c-VEMP was performed with the patient in a supine position and 30° elevation in the horizontal plane and midline. Sternocleidomastoid muscle contractions were observed throughout the recording. Electromyographic activity was recorded with a stimulated acoustic potentials system (Neuroaudio, Neurosoft, Germany). The recording electrodes were placed in the centre of the ipsilateral clavicular region, the reference electrodes were placed in the mid-third section of the sternocleidomastoid muscle, and the earth electrode was placed in the centre of the sternal manubrium.

Short tone bursts with reduced polarity (500 Hz, 95 dB normal hearing level [nHL] and 5.1/s. repeat duration) were presented using ICS Medical Insert Earphones (ER 3A/5A Insert Earphone 300 ohm; ICS Medical, IL, USA). During the test, impedance was < 5 ohms. The VEMP responses were analysed in respect of first early positive (p13) and subsequent negative (n23) peaks (waves), and the amplitudes between the waves (p13–n23 interpeak amplitude, ms). VEMP asymmetry was calculated using the following formula:

$$\text{VEMP asymmetry}(\%) = 100(\text{Ar} - \text{Al})/(\text{Ar} + \text{Al})$$

Ar: right amplitude
Al: left amplitude

Surgical Technique

The selection of the operating technique to be used was made through the application of a computer-generated randomization table (http://www.Random.org). If only a single random number is required, the number in the range wanted is specified from the section in the top right corner (True Random Number Generator) of the random.org home page and is then generated. Min indicates the smallest value, and Max indicates the largest number value. The operation method was determined as a number between 1 and 3, corresponding to the 3 groups of the study.

All the patients underwent an open technique rhinoplasty operation. Following lidocaine infiltration anaesthesia under general anaesthesia, a mid-colummellar reverse V incision was made first and the skin was elevated supraperichondrally. Subperichondral elevation was made in the bone section of the nasal dorsum. Deformities were corrected by making an anterior dorsal approach to the septum. Appropriate cartilage grafts and flaps were used. In the Group 1 and 2 patients, the dorsum was shaped by performing bilateral lateral, median, and transverse osteotomies using an osteotome in Group 1, and a micro-compass saw (Nouvag AG HighSurg11) in Group 2. All the lateral osteotomies were performed as low to low. In Group 1, an internal low to low lateral osteotomy was performed using a 4-mm straight osteotome. An incision superolateral to the inferior concha was made; then, after the opening of a subperiosteal tunnel, a lateral osteotomy was performed. In cases with a transverse osteotomy, a 2-mm straight osteotome was used. (Figure 2) (supplementary digital content). In Group 2, direct observation during use of the micro-saw was provided by extending the subperiosteal elevation to the nasomaxillary line and inner canthus. In cases where bilateral transverse and lateral osteotomies were performed, the lateral and transverse blades of the powered micro-saw were used (Nouvag AG, St. Gallen, Switzerland) (Figure 3) (Supplementary Digital Content). No osteotomy was performed on Group 3 patients. Postoperatively, a silicon plug, an aluminium splint, and a bandage were applied.

The results of the power analysis showed that a sample size of 28 patients in each group would provide an effect size of 0.40, at alpha: 0.05 and beta: 0.1 and power of test: 0.90. Therefore, the study initially included a total of 84 patients as 28 in each of the 3 groups.

Statistical Analysis

Data obtained in the study were analysed statistically using IBM SPSS version 22 (IBM SPSS for Windows version 22, IBM Corporation, Armonk, NY, USA) and R.3.3.2 software. Statistical parameters were stated as mean ± standard deviation (SD), and median (25–75% quartiles) values, or number (n) and percentage. Conformity of the data to normal distrribution was assessed with the Shapiro–Wilk test. The differences between the groups of frequency distributions of categorical variables were examined with

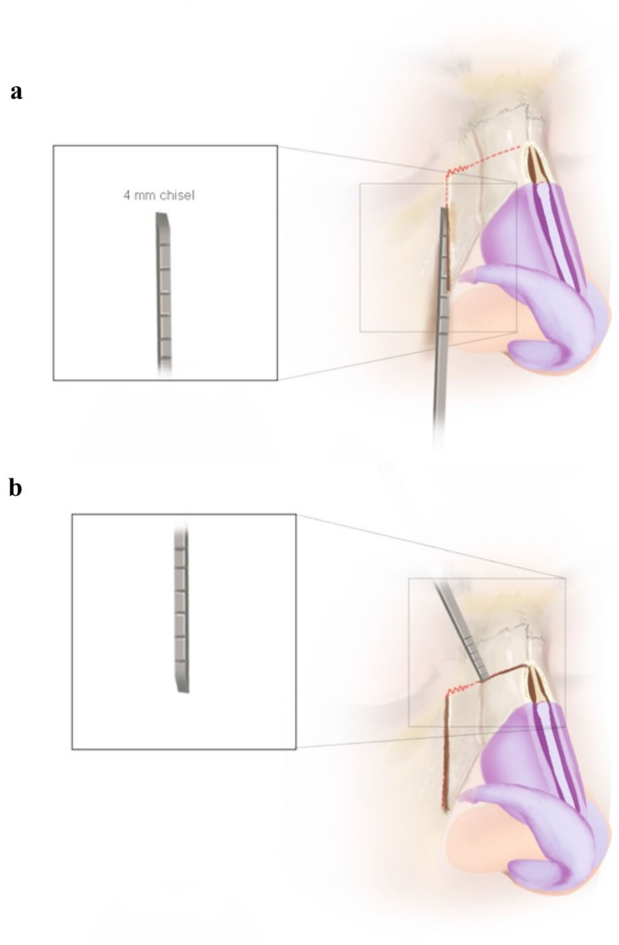


Fig. 2 Lateral (a) and transverse (b) osteotomy using chiesel

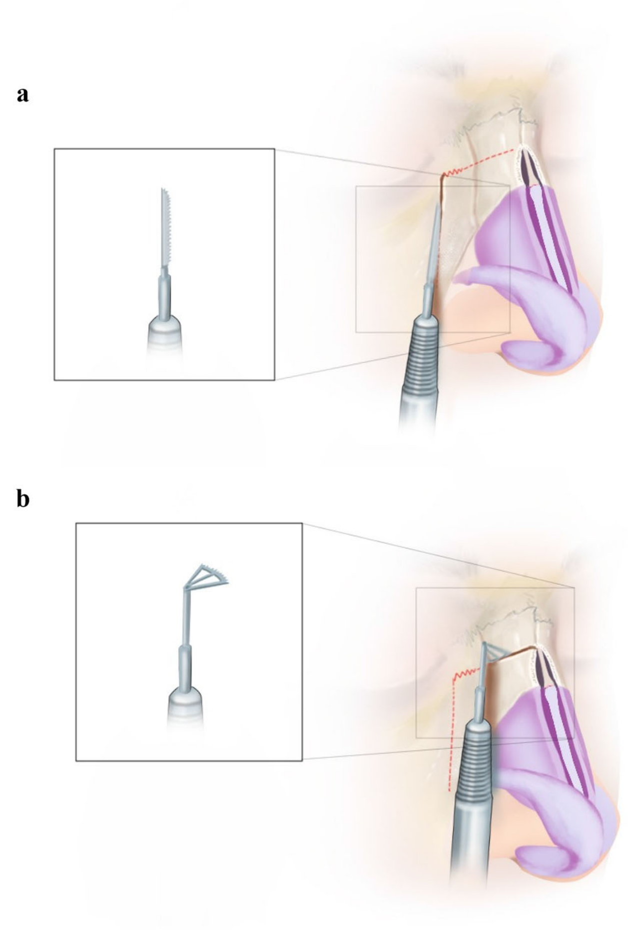


Fig. 3 Lateral (a) and transverse (b) osteotomy using micro-saw blades

the Chi-square test and the exact test. Comparisons between groups of quantitative data with normal distribution were made using the ANOVA test, and for paired comparisons, the post hoc Tukey HSD test and Tamhane T2 test were applied. In the comparisons of groups of data not showing normal distribution, the Kruskal–Wallis H test was used, and in the paired comparisons, the post hoc Dunn test and Bonferroni correction were applied. Differences between the preoperative and postoperative measurements were examined with the Wilcoxon test. A value of $p<0.05$ was accepted as statistically significant.

Results

Evaluation was made of a total of 74 patients. In Group 1, 24 patients comprised 16 females and 8 males with a mean age of 32.2 ± 6.7 years. Group 2 included 24 patients, comprising 12 females and 12 males with a mean age of 32.1 ± 11.5 years. Group 3, as the control group, included 26 patients comprising 17 females and 9 males with a mean age of 32.2 ± 9.8 years. No statistically significant difference was determined between the groups in respect of patient numbers and demographic characteristics ($p>0.05$) (Table 1).

In the PTA of all 3 groups, no statistically significant difference was determined between the preoperative and postoperative pure tone tested frequencies ($p > 0.05$). No statistically significant difference was determined between the groups in respect of the pure tone thresholds ($p > 0.05$) (Figure 4).

In the DPOAE test, no statistically significant difference was determined between the preoperative and postoperative tested frequencies in Groups 1 and 2 ($p > 0.05$). No statistically significant difference was determined between Groups 1 and 2 and the control group (Group 3) in respect of the DPOAE results ($p > 0.05$) (Figure 5).

In the c-VEMP tests, significant differences were determined between Groups 1 and 2 in respect of the preoperative and postoperative n1, p1, and n1–p1 latencies and n1-p1 amplitudes. The postoperative right n1 latency value showed a statistically significant difference between

Table 1 Demographic data of the patients

		Osteotome		Micro-saw		No osteotomy		*p*
Age (years), Mean ± SD		32.20 ± 6.70		32.10 ± 11.50		32.20 ± 9.80		0.49
Gender	Male .n (%)	8	33.3	12	50.0	9	34.6	0.414
	Female .n (%)	16	66.7	12	50.0	17	65.4	
Columella	n.n (%)	15	62.5	12	50.0	16	61.5	
	İn the centre .n (%)	4	16.7	1	4.2	6	23.1	
	Subluxation to the right.n (%)	3	12.5	5	20.8	0	0.0	0.097
	Subluxation to the left.n (%)	2	8.3	6	25.0	4	15.4	
Septum deviation	n.n (%)	2	8.3	3	12.5	5	19.2	
	to the right.n (%)	6	25.0	8	33.3	10	38.5	
	to the left.n (%)	16	66.7	13	54.2	11	42.3	0.547
Caudal septum deviation	n.n (%)	13	54.2	10	41.7	17	65.4	
	to the right.n (%)	3	12.5	5	20.8	1	3.8	
	to the left.n (%)	8	33.3	9	37.5	8	30.8	0.354
Superior septum deviation	bilateral.n (%)	1	4.2	0	0.0	0	0.0	
	n.n (%)	12	50.0	5	20.8	14	53.8	
	to the right.n (%)	3	12.5	5	20.8	2	7.7	0.118
	to the left.n (%)	8	33.3	14	58.3	10	38.5	
Nasal valve	bilateral.n (%)	5	20.8	1	4.2	8	30.8	
	n.n (%)	9	37.5	6	25.0	5	19.2	0.061
	right.n (%)	2	8.3	4	16.7	0	0.0	
	left.n (%)	8	33.3	13	54.2	13	50.0	
Hanging columella	n.n (%)	0	0.0	0	0.0	2	7.7	
	present.n (%)	10	41.7	10	41.7	8	30.8	0.444
	absent.n (%)	14	58.3	14	58.3	16	61.5	
Type support	normal.n (%)	3	12.5	3	12.5	3	11.5	
	insufficient.n (%)	21	87.5	21	87.5	23	88.5	1.00
Alar cartilage	bi-lobe.n (%)	0	0.0	0	0.0	2	7.7	
	collapsed.n (%)	6	25.0	2	8.3	3	11.5	
	malpositioned.n (%)	8	33.3	8	33.3	11	42.3	
	n.n (%)	10	41.7	12	50.0	10	38.5	0.176
	insufficient.n (%)	0	0.0	2	8.3	0	0.0	
Cartilage hump	n.n (%)	0	0.0	1	4.2	1	3.8	
	present.n (%)	23	95.8	18	75.0	23	88.5	0.323
	absent.n (%)	1	4.2	5	20.8	2	7.7	
Bonehump	n.n (%)	1	4.2	1	4.2	0	0.0	
	present.n (%)	22	91.7	17	70.8	24	92.3	0.115
	absent.n (%)	1	4.2	6	25.0	2	7.7	
Rotation1	n.n (%)	3	12.5	1	4.2	7	26.9	
	insufficient.n (%)	21	87.5	23	95.8	19	73.1	0.084
Projection1	low.n (%)	22	91.7	23	95.8	19	73.1	
	n.n (%)	2	8.3	1	4.2	7	26.9	0.060
Skin type	thin.n (%)	0	0.0	2	8.3	1	3.8	
	thick.n (%)	6	25.0	8	33.3	8	30.8	
	n.n (%)	18	75.0	14	58.3	17	65.4	0.615

Table 1 (cont.)

		Osteotome		Micro-saw		No osteotomy		*p*
Nasal dorsum	Slightly to the right.n (%)	0	0.0	2	8.7	0	0.0	
	n.n (%)	6	26.1	8	34.8	0	0.0	
	İn the middle.n (%)	2	8.7	1	4.3	11	42.3	
	to the right c-shape.n (%)	3	13.0	3	13.0	1	3.8	0.440*
	to the right ı-shape.n (%)	7	30.4	5	21.7	4	15.4	
	to the right s-shape.n (%)	1	4.3	0	0.0	0	0.0	
	to the left c-shape.n (%)	2	8.7	1	4.3	4	15.4	
	to the left ı-shape .n (%)	2	8.7	3	13.0	6	23.1	

Chi-square test; exact test; ANOVA; post hoc: Tukey HSD; Tamhane T2 Test; a: 0.05; *Statistically significant difference

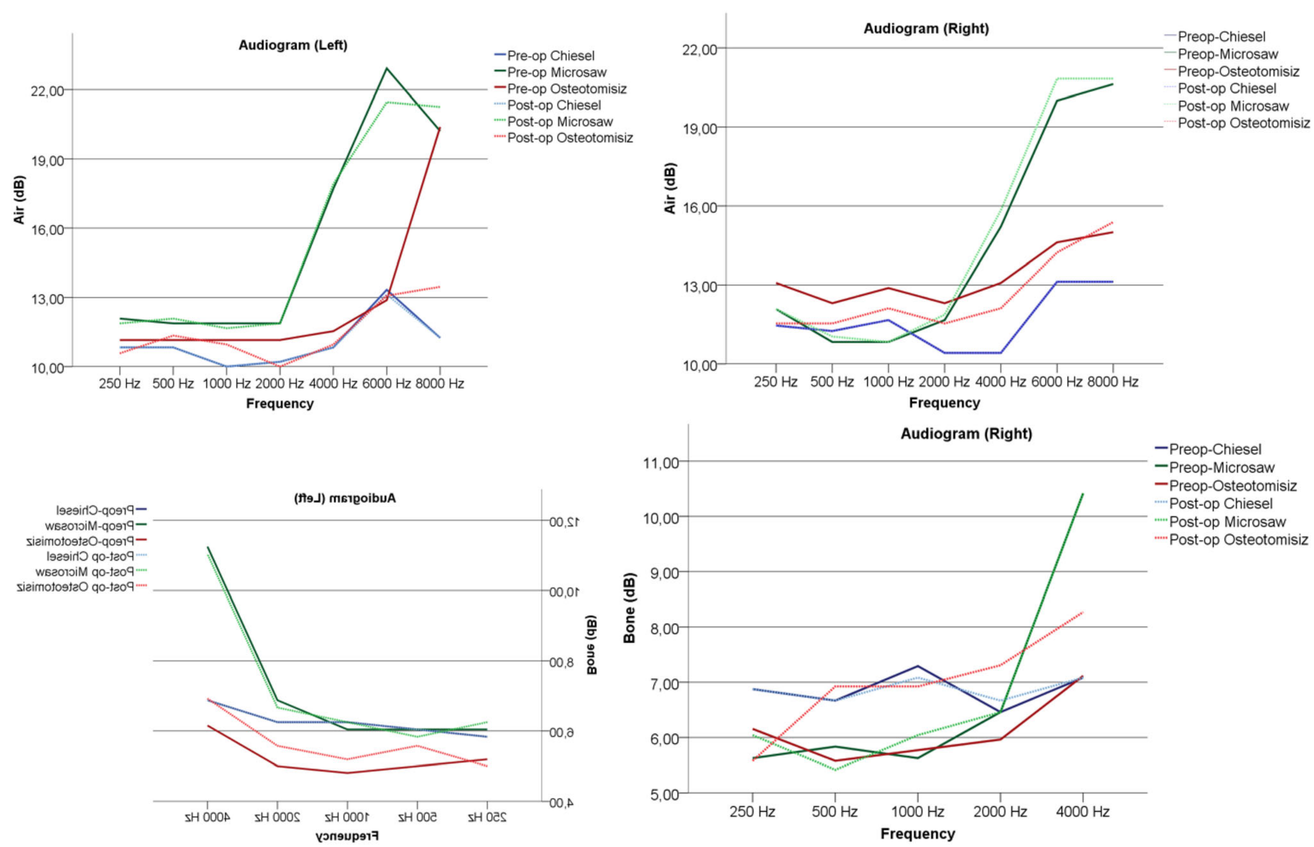


Fig. 4 Variations in air/bone gap of the right and left ears in pure tone audiometry

the osteotome group and the control group with no osteotomy ($p < 0.05$) (Table 2). The postoperative value was observed to be higher in the osteotome group, but was lower than the preoperative value. The postoperative left n1 latency value showed a statistically significant difference between the osteotome group and the micro-saw group ($p < 0.05$). The difference between all the groups in respect of the postoperative right p1 latency value was statistically significant ($p < 0.05$), but was not evaluated as significant compared to the preoperative values. The difference between all the groups in respect of the postoperative left p1 latency value was statistically significant ($p < 0.05$). The difference between the micro-saw and osteotome groups postoperatively was determined to be statistically significant ($p < 0.05$). In the osteotome group, the value was observed to be high, but the difference was not statistically significant compared to the preoperative value ($p > 0.05$). The difference between the preoperative and postoperative left n1–p1 interpeak amplitudes was determined to be statistically significant in the osteotome

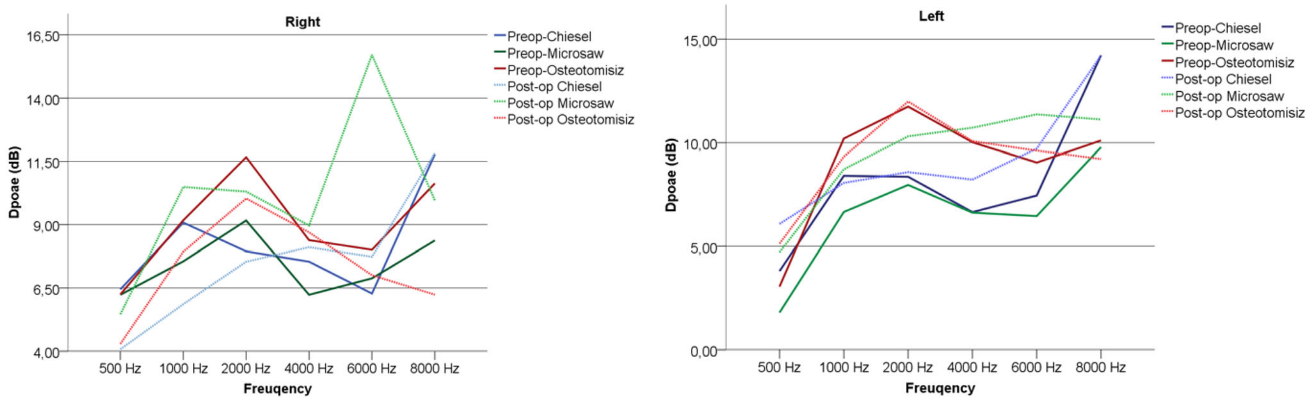


Fig. 5 Otoacoustic emission values of right and left ears

Table 2 c-VEMP values

	Osteotome Median (Q1–Q3)	Micro-saw Median (Q1–Q3)	No osteotomy Median (Q1–Q3)	*P*
c-vemp preop right n1 latency	31.4 (27.6–33.6)	24.6 (22.6–29.5)	29.4 (23.4–32.0)	0.118
c-vemp postop right n1 latency	30.4 (28.7–33.5)[c]	25.8 (22.5–31.6)	24.9 (20.2–29.2)[a]	0.013*
p[t]	0.858	0.715	0.142	
c-vemp preop left n1 latency	32.1 (29.1–37.2)	25.1 (23.1–27.3)	30.0 (26.9–32.1)	0.145
c-vemp postop left n1 latency	30.4 (28.7–33.5)[b]	25.8 (22.5–31.6)[a]	24.9 (20.2–29.2)	0.025*
p[t]	0.127	0.761	0.234	
c-vemp preop right p1 latency	22.9 (20.6–24.2)	16.0 (13.4–21.7)	22.1 (16.9–24.5)	0.215
c-vemp postop right p1 latency	22.8 (21.4–24.1)	19.4 (13.5–22.8)	19.7 (13.5–22.6)	0.015*
p[t]	0.592	0.761	0.234	
c-vemp preop left p1 latency	21.9 (20.6–23.4)	16.2 (13.5–20.7)	23.3 (19.8–24.6)	0.678
c-vemp postop left p1 latency	22.0 (20.7–23.9)[b]	18.0 (13.4–23.9)[a]	21.1 (14.6–22.5)	0.042*
p[t]	0.435	0.594	0.148	
c-vemp preop right n1–p1 interpeak amplitude	99.4 (46.5–131.6)	82.4 (50.7–114.2)	68.4 (52.7–119.7)	0.947
c-vemp postop right n1-p1 interpeak amplitude	58.1 (39.1–127.9)	71.4 (45.9–123.4)	79.6 (53.1–137.9)	0.608
p[t]	0.291	0.784	0.638	
c-vemp preop left n1–p1 interpeak amplitude	108.2 (52.2–152.8)	103.6 (39.8–149.9)	97.9 (64.2–159.9)	0.663
c-vemp postop left n1–p1 interpeak amplitude	56.0 (45.0–99.2)	71.7 (50.8–101.4)	80.7 (54.9–117.9)	0.086
p[t]	0.006*	0.078	0.091	
c-vemp preop P1N1 asymmetry ratio	7.55 (− 11.30 to 31.40)	− 4.90 (− 20.25 to 19.95)	3.10 (− 0.40 to 20.10)	0.227
c-vemp postop P1N1 asymmetry ratio	− 5.70 (− 28.55 to 14.55)	− 0.40 (− 17.55 to 23.75)	4.35 (− 12.10 to 11.80)	0.641
p[t]	0.012*	0.879	0.269	

Kruskal–Wallis h test; post hoc; Dunn test; adjusted a: 0,167; Bonferroni correction;*statistically significant difference

[a]Statistically significant difference compared to the osteotome group; [b] statistically significant difference compared to the micro-saw group; [c] statistically significant difference compared to the no osteotomy group; [t]Wilcoxon test; a: 0.05

group ($p < 0.05$). No statistically significant difference was determined between the groups in respect of the p1–n1 asymmetry ratio ($p > 0.05$). In the osteotome group, the difference between the preoperative and postoperative values was statistically significant ($p < 0.05$).

In the v-HIT test, the change in the right posterior gain postoperatively in the micro-saw group was evaluated as statistically significant ($p < 0.05$). A statistically significant difference was determined between the micro-saw group and the osteotome group in the postoperative right lateral

Table 3 Right and left ear v-HIT tests

	Osteotomy type			p
	Osteotome Median (Q1–Q3)	Micro-saw Median (Q1–Q3)	No osteotomy Median (Q1–Q3)	
v-HIT preop left lateral gain	0.92 (0.89–1.00)[c]	0.97 (0.91–1.06)	1.02 (0.96–1.17)[a]	0.134
v-HIT postop left lateral gain	0.94 (0.88–1.02)	0.94 (0.89–1.11)	0.94 (0.90–1.00)	0.855
p	0.353	0.697	0.342	
v-HIT preop right lateral gain	1.00 (0.95–1.06)	1.01 (0.96–1.08)	1.04 (0.99–1.25)	0.062
v-HIT postop right lateral gain	1.04 (0.96–1.07)	1.04 (0.98–1.12)[c]	0.97 (0.93–0.99)[b]	0.023*
p	0.297	0.420	0.167	
v-HIT preop left posterior gain	0.74 (0.70–0.78)	0.80 (0.73–0.87)	0.79 (0.72–0.85)	0.134
v-HIT postop left posterior gain	0.76 (0.71–0.80)	0.84 (0.74–0.89)	0.83 (0.74–0.88)	0.066
p	0.273	0.823	0.484	
v-HIT preop right posterior gain	0.74 (0.72–0.78)	0.76 (0.71–0.79)	0.76 (0.73–0.79)	0.606
v-HIT postop right posterior gain	0.74 (0.70–0.77)	0.73 (0.70–0.77)	0.76 (0.72–0.78)	0.107
p	0.917	0.029*	0.897	
v-HIT preop left posterior gain	0.74 (0.72–0.78)	0.76 (0.71–0.79)	0.76 (0.73–0.79)	0.365
v-HIT postop left anterior gain	0.73 (0.72–0.82)	0.76 (0.70–0.85)	0.76 (0.70–0.79)	0.997
p	0.486	0.717	0.352	
v-HIT preop right anterior gain	0.78 (0.71–0.96)	0.89 (0.76–1.03)	1.00 (0.78–1.08)	0154
v-HIT postop right anterior gain	0.82 (0.73–1.02)	0.85 (0.74–0.99)	0.97 (0.74–1.15)	0.485
p	0.058	0.765	0.534	

Kruskal–Wallis h test; post hoc; Dunn test; adjusted a: 0,167; Bonferroni correction;* statistically significant difference

[a]Statistically significant difference compared to the osteotome group; [b] statistically significant difference compared to the micro-saw group; [c] statistically significant difference compared to the no osteotomy group; [t]Wilcoxon test; a: 0.05

canal ($p < 0.05$). A greater decrease was observed in the values of the micro-saw group (Table 3).

Discussion

In this study, evaluations were made of the results on the audiovestibular system of osteotomies performed with a micro-saw, which is a technique that has become more widely used in recent years in septorhinoplasty operations reported in previous studies in the literature.

The preoperative to postoperative changes in the c-VEMP and v-HIT test of the current study were found to be significant. Previous studies have not determined any difference between groups in hearing and balance functions in the preoperative and postoperative periods [1].

In the literature, there are reports of cases who have experienced a benign positional paroxysmal vertigo (BPPV) attack, thought to be associated with osteotomy following septorhinoplasty operation [13, 14]. Surgical procedures requiring the use of a hammer and osteotome in the maxillofacial region can cause head trauma in this region, and BPPV may be seen associated with this. BPPV is seen after operations such as elevation of the sinus floor using osteotomy in the maxillofacial region, Le-Fort 1 osteotomy, orthognatic surgery, maxilloalveolar ridge expansion, and dental surgery [15–17]. At this point, VEMP and v-HIT are useful for the evaluation of balance functions. [18] .

Post-traumatic postional vertigo starts suddenly after head trauma. Adler A. first described post-traumatic vertigo in 1897 [19]. The development of BPPV due to head trauma is the most common of the defined etiologies in the literature, with frequency varying from 7 to 17%. In cases of BPPV developing after head trauma, it is most often observed in the first week [20]. It is usually seen bilaterally and involving more than one canal [21]. In patients developing BPPV postoperatively, there may be bilateral posterior canal involvement, and there is greater posterior canal involvement associated with age. Due to the close proximity to the maxilla and other bone structures, the posterior canal is exposed to indirect trauma [22]. In a study by Chiarella et al., the time to onset of BPPV after orthodontic surgery was reported to be 4.1 days. The earliest time of onset was 8 hours postoperatively and the latest, 7 days after surgery. Indirect trauma of the posterior canal due to the close proximity to the maxilla and other bone structures is a widely held view. Vibration of endolymphatic fluids and associated macula trauma has been reported to lead to otoconial separation [22].

VEMP is an important diagnostic tool for the testing of otolithic organs. In the cervical VEMP test, an inhibitor reflex (vestibulocollic reflex) is activated and is recorded to obtain information about the vestibulospinal pathway from the tonically contracting ipsilateral sternocleidomastoid muscle. This reflex arc includes saccular macular neuroreceptors, the inferior vestibular nerve, the lateral vestibular nucleus, medial vestibulospinal pathway, and spinal cord motor neurons feeding the neck muscles [18, 23]. Measurement of the VOR gains with v-HIT is helpful in evaluating the semicircular canals of the inner ear [24, 25]. The v-HIT examines eye movements at high stimulation frequencies and allows an objective evaluation of the function of the high-frequency area of the vestibular system [24, 25].

In a study by Ertuğrul et al. [26], the effect of osteotomy used in septorhinoplasty on BPPV was examined, but no difference was found between the study groups. Ilhan et al. evaluated the auditory system in septorhinoplasty with piezoelectric and groups with no osteotomy performed, and no difference was determined between the groups. The hearing functions were evaluated in these two separate groups with comparisons of audiological examination and DPOAE [1].

In the current study, a group with standard osteotomy was added and hearing was evaluated. Although there was no difference in parallel with the study by Ilhan et al., statistically significant differences were determined between the preoperative and postoperative PTA, DPOAE and v-HIT values. In v-HIT, following osteotomy with micro-saw, the gains in the right posterior canal were close to borderline and were observed to be lower than in the preoperative period (preop gain:0.76; postop gain:0.73). These values were evaluated as the lower limits of normal gain. It has been reported in the literature that the mean VOR gain for lateral canals in healthy individuals should be > 0.7, and values below this should be accepted as abnormal [27, 28]. In a study of 12 healthy individuals, mean VOR gain of 0.81 was obtained in the lateral canals with the scleral search coil test method, and it was reported that lateral canal VOR gain in healthy individuals should be ≥ 0.68 in measurements taken with v-HIT [28, 29]. Gains in VOR are examined with the v-HIT, and in healthy individuals, this gain is expected to be equal to 1 [30, 31]. As the lower and upper limits for the gain value in v-HIT are accepted as 0.68 and 0.8, respectively, gains below 0.68 are evaluated as vestibular loss [27]. When the VOR gains in the v-HIT were compared in the current study preoperative and postoperative groups, that there was a significantly greater decrease in the right posterior canal of the micro-saw group compared to the control group supported that there could be a predisposition to BPPV. This posterior canal VOR gain supports BPPV occurring after trauma and was consistent with findings in the literature. However, the decrease was within normal limits and no pathological decrease was determined.

A different opinion has been reported that nasal septum deviation causes neuron degeneration in the brain stem associated with periodic hypoxia, peripheral nerve damage, and often, vestibular dysfunction [32, 33]. Central vestibular neurons located in the brain stem are responsible for the early integration and processing of vestibular and proprioceptive inputs [34]. When factors are taken into consideration such as the anatomic proximity of vestibular nuclei to respiratory nuclei and the sensitivity of the posterior labyrinth to a hypoxic condition, the functional change of vestibular nuclei strongly suggests that it could be a marker of abnormal activity of respiratory nuclei [32]. In the current study, the changes in VOR gain could have been associated with the decrease in hypoxia.

Tekin et al. evaluated the audiovestibular system after operations performed with and without osteotomies. No statistically significant difference was determined between the groups in respect of otoacoustic emissions in the audiological evaluation [4]. In the current study, changes were determined in the c-VEMP values of the osteotome group, with a noticeable decrease postoperatively in the right and left n1 values compared to the preoperative period. A decrease was also observed in the right and left n1-p1 interpeak amplitude values. It is important to use c-VEMP in the early period of vestibular system lesions. The vibrations occurring during osteotomy affect the brain stem, and the vestibulocollic and vestibulo-ocular arcs, and this effect slows transmission on the arc, thereby explaining the changes in the c-VEMP-o-VEMP parameters.

In a study by Korres, it was shown that although there were prolonged p13 and n23 latencies in both the affected and healthy ears of patients with BPPV, there were no such prolongations in the control group. This was attributed to degeneration in the saccular macula [35]. In a similar study, Yang compared the VEMP results of 41 patients with BPPV and 96 healthy subjects. VEMP latency was seen to be prolonged in the BPPV patients, indicating a longer treatment period in patients with no VEMP response, suggesting widespread neural damage [36]. When examined in the current study, the latencies were more prolonged in the osteotomy group, whereas the latencies in the group where micro-saw was used were close to those of the control group. That the VEMP responses of the classic osteotomy were prolonged suggests that this created a greater predisposition to BPPV.

The limitations of this study include the lack of testing of vestibular and hearing functions at later time points in the postoperative period.

The vestibular system has an extremely complex structure and there is no single test method to evaluate the whole vestibular system. Therefore, the correct diagnosis should be reached by clinicians applying several vestibular tests, interpreting these correctly, and combining them with the findings of the patient. Objective audiovestibular tools were useful in this study in the evaluation of the effect of rhinoplasty on inner ear functions.

Conclusion

This is the only study in the literature to have determined vestibular effects with the evaluation of such a wide range of techniques. Previous studies in the literature have found no effect of osteotomy technique on the balance and hearing systems. The results of this study demonstrated that the preoperative and postoperative difference between the osteotomy techniques had an effect on the balance system. The change in the balance tests following an operation with classic osteotomy shows a greater predisposition to benign positional vertigo. In this sense, the micro-saw can be considered safer.

Author contributions The authors confirm contribution to the paper as follows: NB, İO, and VO conceived and designed the study; NB and KT collected the data; AD and NB analysed and interpreted the results; and NB prepared the draft of the manuscript. All authors reviewed the results and approved the final version of the manuscript.

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Declarations

Conflict of interest The authors declared no conflict of interest.

Ethical Approval Approval for the study was granted by the Local Ethics Committee (session no: 14, dated:16/10/2019).

Human and Animal Rights Statement, or Ethical Approval Approval for this prospective study was granted by the Clinical Research Ethics Committee of Kahramanmaraş Sütçü İmam University (decision no: 14, dated:16/10/2019).

Informed Consent All the study participants provided signed informed consent.

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