



## Anatomical and frequencies-specific hearing results of retrograde mastoidectomy

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### ABSTRACT

**Purpose:** The aim of this study was to evaluate the long-term anatomical and frequency-specific hearing results of canal wall down (CWD) and canal wall up (CWU) mastoidectomy by retrograde mastoidectomy (RM) surgical method.

**Materials and methods:** Patients underwent CWU and CWD procedures with method of RM, 53 and 59 patients between January 2010 and June 2015 were evaluated retrospectively. The pre- and post-operative pure tone average air-bone gap (ABG) values of these patients were recorded in detail at 0.5, 1, 2 and 4 kHz. Pre and post-operative ABG were evaluated in detail in each group in each frequency. In addition, at least two years follow-up recurrence rates were evaluated.

**Results:** In the CWU method, post-operative ABG decreased significantly at low-frequencies compared to pre-operative ABG ( $p < 0.05$ ), especially at 2 kHz ( $p < 0.001$ ). But, auditory improvement was not achieved at 4 kHz. In the CWD procedure, auditory improvement was not achieved both 1 kHz and 4 kHz. CWU and CWD recurrence rates were respectively 9.4% and 10.1%.

**Conclusion:** Postoperative hearing results of both surgical methods provide good auditory outcome at low-frequencies. This improvement is evident in CWU especially at 2 kHz. This may be related to the protection of the external ear canal. In both surgical methods of RM, a satisfactory anatomical success was achieved with recurrence rates of around 10%. RM is a good surgical technique alternative to classical canal wall down procedure with both auditory results and low recurrence rates.

### 1. Introduction

Canal wall up (CWU) and canal wall down (CWD) approaches are the two basic methods that are conventionally applied in the cholesteatoma surgery. Both methods have various advantages and disadvantages. Regardless of which method is used, the main goal is to achieve low recurrence rates with the eradication of the cholesteatoma and to obtain both anatomically and functional acceptable results [1,2].

As the posterior ear canal wall is removed in the CWD approach, control on the cholesteatoma and middle ear structures is quite good. Therefore, the recurrence rates are low. However, because of the cavities, this causes both cosmetic and anatomical problems in patients. Patients also have to consult a doctor for constant cavity cleaning. In addition, patients frequently have to seek medical care for the cavity cleaning [3–5]. In the CWU method, however, the posterior canal wall

is preserved and therefore no cavitation problem occurs. In addition, the auditory results are better because the anatomies of both the middle ear and the mastoid structures are preserved. However, adequate exposure cannot be obtained during the surgery. Because there is no comprehensive knowledge of pathology, the recurrence rates are high [3,5].

Retrograde mastoidectomy (RM), also called the ‘inside-out mastoidectomy’, is a surgical method developed to benefit from the advantages and to avoid the disadvantages of these two methods. In this technique, mastoidectomy is started as an atticotomy and progress towards the posterior to follow cholesteatoma. Posterior bony canal wall remove partially or totally to clear all of cholesteatoma. Depending on the size of defect, if partially removed, CWU is created by posterior canal wall reconstruction, but if total removed, open cavity is created by classical CWD procedure [6,7].

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Retrograde mastoidectomy has a relatively recent history. The data available in the literature is rather limited. In general, there are limited studies that contain information about the surgical method and give auditory and recurrence results [3,7]. There is no comparative evaluation with or without posterior canal wall reconstruction surgical methods. For this reason, we aim to compare the CWD and CWU generated by the RM surgical method in our study. Also to our knowledge, there is not any study offering frequency-specific effects on the hearing results of RM which CWD and/or CWU. This reason, the study also aims to evaluate whether posterior canal reconstruction has frequency-specific effects on the hearing results.

## 2. Patients and methods

The approval was received from the local ethics committee for this study (2015/4).

### 2.1. Subject

Patients who were operated for cholesteatoma between January 2010 and June 2015 were evaluated retrospectively. Patients who came the follow-up examination within last year, with primary surgery (revisions were not included), minimum follow-up duration of two years (24 months), pre- and postoperative hearing tests, the postoperative hearing test performed on the postoperative 6th month at the earliest, and incus interposition made for ossiculoplasty, and those without dead ear and without extensive cholesteatoma were included in the study. Preoperative temporal bone computed tomography (CT) evaluation is performed to all patients to whom cholesteatoma surgery is planned, in our clinic. If the CT or per-operative findings were consistent with extensive cholesteatoma, these patients were not included in the study because the outside-in approach was preferred. All patients included in the study had incus interposition for hearing reconstruction. The stapes were preserved in a way to make the ossicular reconstruction, and incuses could be used for ossiculoplasty.

Patients' demographic data (age, gender), application complaints (duration and feature), surgical procedure (CWU, CWD), follow-up periods (time from surgery to final control), pre- and postoperative hearing test results, and whether or not they had recurrent cholesteatoma recorded.

### 2.2. Surgical procedure

A similar surgical procedure is applied in our clinic to patients included in the study. All cases were applied surgeries under general anaesthesia. The procedure begins with postauricular sulcus incision. After the formation of the tympanomeatal flap, it is entered the middle ear from a place distant to the cholesteatoma, namely from the hypotympanum. Thus, the integrity of the cholesteatoma is tried to be preserved. After the flap is anteriorly taken down, the cholesteatoma pouch is removed from the epitympanum area. The incudomalleolar and incudostapedial joints are disarticulated and the malleus head and the incuses are extracted. The cholesteatoma is excised from the posterior to the anterior. Posterior canal wall is removed partially if the cholesteatoma does not exceed the posterior aspect of the lateral semicircular canal (LSSC). In this case, if the defect is small enough to allow for repair with cartilage (zygomatic buttress in the superior, posterior canal wall in the inferior and the mastoid cortex in the lateral) reconstruction is applied. The posterior canal wall cartilage and the skin are closed to form a new cylindrical posterior canal wall on the reconstructed cartilage. Usually, this cartilage is grooved middle of the cartilage and prepared as two-leaf cartilage to close the defect in the posterior canal wall appropriately to the external ear canal structure (Fig. 1 a, b). Ossiculoplasty is performed in the same session. It is placed on the stapes head by opening the acetabulum to incus. The perichondrium on one side of the tragal cartilage is elevated and spread over the reconstructed

ossicle. It is also used to close the perforation if present. The surgery is completed as a single stage (Fig. 2 a–c). If the cholesteatoma passes behind the LSSC or defect is too big to be closed, CWD is applied and the posterior canal wall is lowered over the facial spur. After the cholesteatoma has been completely cleansed, the conchal cartilage perichondrium is spread to support perforation, if any, or incus. The operation is ended in the form of the cavity with partially or totally meatoplasty.

### 2.3. Evaluation of hearing

Pure tone audiometry (PTA) results were evaluated according to guidelines of American Academy of Committee on Hearing and Equilibrium [8]. Mean values of pure tone air and bone conduction thresholds at 0.5, 1, 2 and 4 kHz were calculated from pre and postoperative PTA. The difference between air and bone averages was used to calculate air-bone gap (ABG). The postoperative ABG values of both groups were evaluated frequency-specifically. The pre- and postoperative frequency-specific ABG results of both groups were compared statistically. In addition, hearing gains of both groups were calculated from pre- and postoperative ABG values. The hearing gains obtained from the two groups were compared frequency specifically.

### 2.4. Statistical analysis

The statistical analysis of hearing results was performed using the Statistical Package for Social Sciences (SPSS) version 20.0 (SPSS Inc., Chicago, IL, USA). The pre- and postoperative PTA-ABG results and hearing gains of both groups of patients were frequency-specifically compared using the *t*-test. The statistical significance level was taken as  $p < 0.05$ .

## 3. Results

There were 53 patients aged 11–62 years with a mean age of 36.2 years. 29 (54.7%) of these patients were male, 24 (45.3%) were female and 30 (56.6%) were left and 23 (43.4%) were right in CWU. Follow-up periods were 25–61 months and average follow-up was 39 months. The number of patients with recurrence was 5 (9.4%). There were 59 patients aged 14–69 years with CWD who had a mean age of 39.2 years. Of these patients, 34 (57.6%) were male, 25 (42.4%) were female and 28 (47.5%) were affected left ear and 31 (52.5%) were affected right ear. Otorrhoea (100%) was present in all patients undergoing CWU, 40 (75.4%) were accompanied by hearing loss. Similarly, otorrhoea (100%) was present in all CWD patients and 47 (79.6%) of the patients were accompanied by hearing loss. The mean duration of complaints in CWU and CWD groups at admission was 2.9 (1.5–8) and 3.1 (1–10) years, respectively. The follow-up periods were between 24 and 63 months and the average follow-up period was 39 months. The follow-up period was detected as the last time patients applied to our clinic postoperatively. Since the patients who came to the control within the last year were included in our study, none of the patients in our study had been lost of follow-up. The number of patients with recurrence was CWU 6 (10.1%) and CWD 5 (9.4%) (Table 1). Profound retraction of the posterior canal wall that need revision surgery was not observed in any patient undergoing reconstruction of the external ear canal.

The post-operative frequency-specific ABG results were evaluated according to the American Academy guidelines and were detailed in Table 2 for both groups of patients. According to this, CWU patients are able to achieve good hearing (11–20 dB) with 24 (45.2%), 20 (37.7%) and 21 (45.2%) at 0.5, 1 and 2 kHz respectively. This gives the number of patients with the highest ratios in their frequency range. At 4 kHz, good hearing (11–20 dB) and fair hearing (> 20 dB) were obtained with equal ratios of 21 patients (39.6%). CWD patients are those with good hearing (11–20 dB) with 23 (39%), 24 (40.7%) and 29 (49.1%) at



Fig. 1. Prepared cartilage for defect in posterior canal wall. a; grooved cartilage, b; flex cartilage has two wings.

0.5, 1 and 2 kHz respectively. This gives the number of patients with the highest ratios in their frequency range. At 4 kHz, good hearing (11–20 dB) and fair hearing (> 20 dB) were obtained with equal ratios of 23 patients (39%).

Comparison of pre- and post-operative ABG values showed a significant decrease in frequencies (at low frequencies) except 4 kHz in both groups. There was also a decline of 2 kHz in CWU patients. However, there was no significant difference between pre- and post-operative values at 4 kHz in both groups (Table 3). In addition, there was no significant difference in the frequency-specific comparison of the hearing gains of both groups at 0.5 and 4 kHz, there was a significant difference at 1 kHz and there was a very significant difference at 2 kHz (Table 4). When all of the findings were evaluated together, the same level of hearing gain was achieved in both groups at 0.5 kHz, but at 4 kHz, both groups received less hearing gain compared to the preoperative period, but at the same level of hearing gain compared to each other. In patients undergone CWU surgery, at 1 kHz the hearing gain was statistically significant increase, at 2 kHz the hearing gain was statistically very significant increase.

#### 4. Discussion

Retrograde mastoidectomy was first described by Dornhoffer [9] in 2000. It is a single stage surgery where CWU and CWD procedures are combined. In this approach, cholesteatoma pouch is followed and the posterior canal wall is retrogradely removed until only the pouch is completely removed. The ossiculoplasty is performed in the same session. The defect in the posterior canal wall is with or without reconstructed [7]. After this study, Dornhoffer [6] presented another study in 2004 that included long-term follow-up results for the cholesteatoma recurrence. He reported that 50 ears had a recurrence rate of 16% with an average follow-up of 7.8 years. The rates of recurrence were acceptable and the surgery could be applied. Minovi et al. [7] reported 16.5% cholesteatoma recurrence and 90% of this recurrences occurred within 5 years. In our study, recurrence cholesteatoma rates lower than these studies. Also recurrence cholesteatoma was never seen in study of Chamoli et al. [3]. This may be related to RM applications in limited cholesteatoma just like to our study. In addition, the rate of recurrence cholesteatoma in our study of both CWD and CWU in patients who underwent RM with the right patient selection was around 10% and satisfactory. These results suggest that RM may be a good option in cases of unless expansive cholesteatoma.

Patients who have limited external ear canal defect after retrograde mastoidectomy can be reconstructed with bone, cartilage and alloplastic graft materials [6]. Retraction or collapse of reconstruction is the main problems of this technique. However, use of cartilage in the

reconstruction reduces the risk due to its durability [7]. In our study, none of the patients had a profound retraction pouch that required revision surgery. This may be related to both use of cartilage for reconstruction and our reconstruction application to patients with bone structure to be able to support cartilage.

Ossicular reconstruction methods significantly affect the functional results in the chronic otitis surgery [10]. Only patients with incus interposition were included in this study in order to standardize the auditory results. In fact, there are various concerns, such as the resorption tendency associated with the autologous incus interposition, the fact that its shape and volume can cause adhesions, and it cannot be adequately fixed on the stapes head [10]. However, as is the case with the 112 patients included in this study, the incus interposition has been applied in our clinic for many years. It does not have a distinct disadvantage. Their auditory results are quite good also in this study. This may be related to the patient selection, because this method has been preferred for patients with available incus and preserved stapes suprastructure in this study. We know that the stapes suprastructure has a strong mechanical effect on hearing [11,12]. In addition, cholesteatoma stapes has not been affected in the majority of these patients, namely the patients with more limited cholesteatoma and preserved middle ear mucosa. There are no other factors such as weak middle ear ventilation and small middle ear volume that may affect the auditory results.

The reason why the hearing test was evaluated in the postoperative 6th month at the earliest is to remove the influences on hearing associated with the acute period. Supportive materials placed in the middle ear in the early period may not have melted. In addition, pathologies that affect hearing results such as effusion may develop too.

There are several studies in the literature which give hearing results of RM according to postoperative ABG. According to these studies, the results vary between 6 and 17 dB [4,7,13]. In addition, Vaidya and Gupta [14] did not specify a value but comparing RM and classic CWD procedure and they showed that postoperative hearing of patients undergoing RM improved more than CWD. When the literature is searched in terms of frequency-specific hearing results, it is seen that there is a study where Choi et al. [10] have provided the frequency-specific hearing results in chronic ear disease. However, both cholesteatoma and non-cholesteatoma cases were evaluated together in this study. In addition, there is no patient group where external auditory canal reconstruction is performed with the RM method. In this study, the pre- and postoperative ABG changes were evaluated as is the case with our study. Patients treated with the CWU procedure showed a significant recovery at low frequencies (i.e., except for 4 kHz, which is a high frequency), while there was no significant recovery in the frequencies of 1 kHz and 4 kHz in patients undergoing the CWD procedure. They stated that this finding was especially in patients who used TORP as an

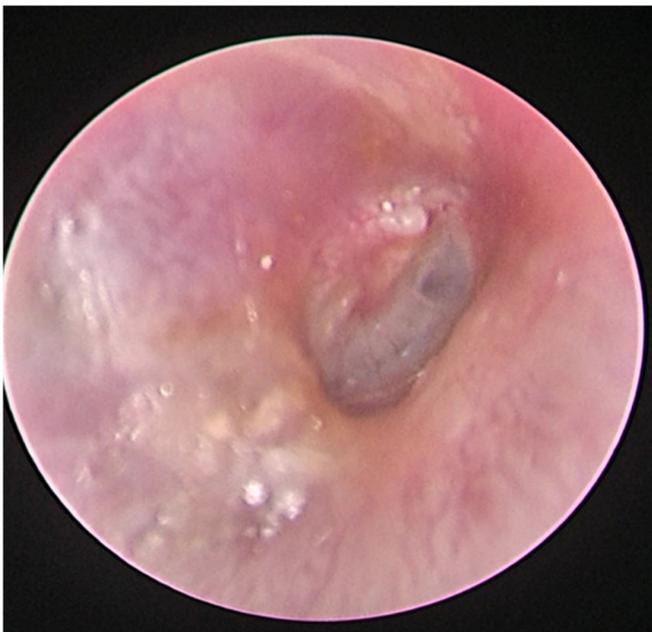
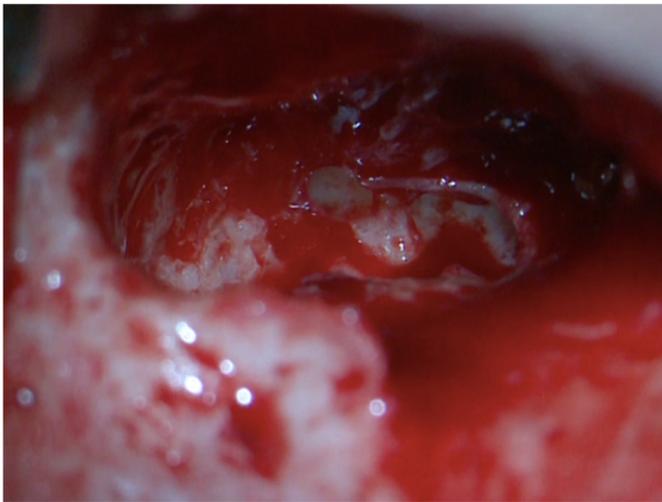


Fig. 2. a; Posterior canal wall was removed for cholesteatoma cleaning, b; Defect in posterior canal wall was repaired with flex cartilage, c; Postoperative 1st year follow-up.

**Table 1**

Demographic and clinical characteristics of patients (CWD: canal wall down, CWU: canal wall up, SD: standard deviation).

	CWD	CWU
Age: average ± SD (Min-max)	39,2 ± 15,3 (14–69)	36,2 ± 15,2 (11–62)
Sex: numerous (%)		
Female	29 (54,7)	34 (57,6)
Male	24 (45,3)	25 (42,4)
Affected ear: numerous (%)		
Left	30 (56,6)	28 (47,5)
Right	23 (43,4)	31 (52,5)
Application complaints: numerous (%)		
Otorrhoea	53 (100)	59 (100)
Hearing loss	40 (75,4)	47 (79,6)
Complaints duration: average ± SD (Min-max) (year)	3.1 ± 2,2 (1–10)	2.9 ± 1,8 (1,5–8)
Following time: average ± SD (Min-max) (month)	39 ± 10,8 (25–61)	39,3 ± 11,5 (24–63)
Recurrences: numerous (%)	5 (9,4)	6 (10,1)

**Table 2**

Frequencies-specific post-operative hearing results of CWD and CWU procedures classified according to the American Academy of Committee on Hearing and Equilibrium guidelines (CWD: canal wall down, CWU: canal wall up).

	0–10 (excellent)	11–20 (good)	> 20 (fair)	> 30 (poor)
CWU				
0.5 kHz	6 (11,4%)	24 (45,2%)	12 (22,6%)	11 (20,8%)
1 kHz	9 (17%)	20 (37,7%)	15 (28,3%)	9 (17%)
2 kHz	18 (34%)	24 (45,2%)	2 (3,8%)	9 (17%)
4 kHz	7 (13,2%)	21 (39,6%)	21 (39,6%)	4 (7,6%)
CWD				
0.5 kHz	15 (25,4%)	23 (39%)	14 (23,7%)	7 (11,9%)
1 kHz	13 (22%)	24 (40,7%)	19 (32,2%)	3 (5,1%)
2 kHz	6 (10,2%)	29 (49,1%)	19 (32,2%)	23 (39%)
4 kHz	4 (6,8%)	23 (39%)	23 (39%)	6 (10,2%)

ossicular prosthesis. Therefore, this suggests that the result was arising from the fact that the majority of the patients who used TORP were those who were applied open cavity [10]. In the present study, the similar results were obtained in patients who underwent CWD procedure. In patients who underwent RM, however, significant recoveries were observed at low frequencies, particularly at 2 kHz. It is known that the resonance effect of the posterior canal wall is more effective at frequencies where the hearing threshold is 2 kHz [15]. The posterior canal wall structure should be recreated in patients who underwent RM. More significant recovery at 2 kHz may be related to this.

The tympanic membrane has a structurally different vibration mechanism. This impairment of the vibration mechanism can affect the hearing at high frequencies [10,16]. In both groups of patients who underwent cholesteatoma surgery, the tension of the tympanic membrane may be affected. Therefore, this may lead to a lack of improvement in the ABG values of patients at high frequencies.

Air-bone gap may increase particularly at low frequencies compared to the preoperative period due to the middle ear volume decrease typically in the CWD procedures [4,17]. However, in the present study, an improvement is observed in the ABG values at low frequencies in patients who underwent CWD in the postoperative period. This suggests that enough space can be gained in the middle ear with an incus placed on a stable stapes.

We performed surgery using a microscope conventionally in both groups. However, for patients with limited cholesteatoma, a retrograde mastoidectomy may be performed using an endoscope [3]. Choose of surgical instruments can be changed depending on experience of surgeon and conditions. The anatomic and functional results of both endoscopic and microscopic approaches are satisfactory for retrograde mastoidectomy as long as the correct patient selection is made.

**Table 3**

*p* values obtained from pre and post-operative frequency-specific ABG averages and their comparison (ABG: air-bone gap, CWD: canal wall down, CWU: canal wall up, SD: standard deviation).

	0.5 kHz	1 kHz	2 kHz	4 kHz
CWU				
Pre-op: average ± SD	23,8 ± 9,6	22,7 ± 9	22 ± 8,6	23,8 ± 8,8
Post-op: average ± SD	18,7 ± 8,1	18 ± 9	13,9 ± 10,3	20,8 ± 7,6
<i>p</i> values	<b>0,004</b>	<b>0,008</b>	<b>&lt; 0,001</b>	0,062
CWD				
Pre-op: average ± SD	23,1 ± 8,7	21,7 ± 6,9	20,1 ± 6,6	22,4 ± 7,1
Post-op: average ± SD	19,2 ± 9,2	19,3 ± 7,2	17,2 ± 6,4	20,6 ± 7,9
<i>p</i> values	<b>0,02</b>	0,64	<b>0,016</b>	0,202

Bold expresses statistical significant.

**Table 4**

Frequency-specific evaluation of postoperative hearing gain in two groups (CWD: canal wall down, CWU: canal wall up, SD: standard deviation).

	0.5 kHz	1 kHz	2 kHz	4 kHz
Hearing gain				
CWU: average ± SD	5,1 ± 5,6	4,7 ± 5,0	8,1 ± 7,3	3,1 ± 5,4
CWD: average ± SD	3,8 ± 4,6	2,4 ± 4,9	2,9 ± 4,9	1,9 ± 3,8
<i>p</i> values	0.180	<b>0.017</b>	<b>&lt; 0,001</b>	0.159

Bold expresses statistical significant.

One of the limitations of our study may be that the speech discrimination is not evaluated. Because the frequencies where the resonance effect of the external ear canal is high (2 kHz) are the frequencies of speech. Therefore, whether the frequency effect of 2 kHz reflects at discrimination or not can be evaluated in this study. In addition, the hearing results can be compared after short and long follow-up periods in terms of the hearing test durations.

## 5. Conclusion

The present study suggests that RM with CWU can produce very satisfactory results in terms of hearing results. In both RM with CWU and CWD procedures, a good hearing result is achieved postoperatively at low frequencies. However, in the CWD procedure, no significant improvement was observed at 1 kHz in the postoperative period compared to the preoperative period. Besides, CWU provides more significant improvement, particularly at 2 kHz, compared to the CWD procedure. This may be related to the protection of the external ear canal. RM, both CWD and CWU are applied, is very satisfactory surgical method with its postoperative hearing improvement and low recurrence rates.

## Financial disclosure

None.

## Conflict of interest

None.

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