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Original Article

Comparison of Videonystagmography and Audiological Findings after Stapedotomy; CO_2 Laser vs Perforator

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OBJECTIVE: Various types of laser, microdrill, and perforator are effectively used in the surgical treatment of otosclerosis. However, they have certain disadvantages along with advantages. The aim of this study was to evaluate the effects of carbon dioxide (CO_2) laser and perforator stapedotomy techniques on audiological outcomes and postoperative vestibular functions via videonystagmography (VNG).

MATERIALS and METHODS: This prospective and randomized clinical study was conducted in an academic tertiary medical center. Sixty-nine patients diagnosed with otosclerosis who underwent stapedotomy were enrolled in this study. Patients were divided into two groups based on the technique used in stapedotomy: CO_2 laser and perforator. Postoperative hearing gain and VNG findings were the main outcome measures. Subsequently, the two study groups were compared for analysis.

RESULTS: The preoperative air–bone gap was 32.7±8.9 decibel (dB) in the study population and it was improved to 12.9±8.4 dB after operation. There were no differences in VNG findings and vertigo symptoms between the laser and perforator groups at postoperative day 2. There was no significant gain difference regarding the air conduction, bone conduction, and air–bone gap between the two groups (p=0.294, p=0.57, and p=0.37, respectively).

CONCLUSION: Both CO_2 laser and perforator stapedotomy have successful audiological outcomes with no difference in postoperative vestibular disturbance.

KEYWORDS: Otosclerosis, laser stapedotomy, vertigo, videonystagmography

INTRODUCTION

Since the first successful stapedectomy performed by Shea using teflon piston in May 1956, this surgery has been popular worldwide. In early 1960s, Plester suggested the partial stapedectomy technique in which only portions of the footplate are removed [1]. Subsequently, partial stapedectomy technique has been improved and refined by Marquet [2], giving rise to a novel technique called as "stapedotomy," which uses a small fenestra at the footplate.

Mechanical instruments were the only tools available to make a small fenestra at the footplate until Perkins first used an argon laser in stapedotomy [3]. Thereafter, other types of laser such as, carbon dioxide (CO_2) laser, erbiyum yttrium aluminum garnet (Er:YAG) laser, and potassium titanyl phosphate (KTP) laser, became available for middle ear surgery. Currently, surgical perforators, microdrills, and various types of laser are efficiently used in stapedotomy, although each technique has various advantages and disadvantages. Footplate fractures and sensorineural hearing (SNHL) loss were more frequent in conventional stapedotomy than in laser stapedotomy [4]. Recent data suggest that laser stapedotomy provides better hearing results compared to non-laser stapedotomy; however, subgroup analysis among the lasers was not available because of the lack of sufficient number of subjects [5]. In other studies, CO_2 laser had more favorable hearing outcomes than various other laser types [6, 7].

Stapedotomy may adversely influence vestibular functions. Postoperative symptoms of vertigo were reported between 27% and 52% among different studies [8–11]. These symptoms usually subside within the early postoperative days, but very rarely, they may extend up to 6 months. Pressure and mobility changes in labyrinthine fluids, suppurative labyrinthitis, decrease of blood flow to the labyrinth, inner ear injury due to enzymatic process, and footplate complications are the proposed reasons for postoperative vertigo [12]. Perilymphatic fistula and malposition or inappropriate length of prosthesis leads to the persistence of vertigo [13]. Sneezing and coughing increase the symptoms as they increase the perilymphatic pressure. We suggested that the technique used in stapedotomy may also influence postoperative vestibular symptoms. However, there are only very few studies that objectively evaluated the association between different techniques and vertigo via videonystagmography (VNG) [8–10].

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We argued that stapedotomy with a perforator may cause severe vertigo compared to stapedotomy with laser because the former imparts direct trauma to the vestibule. Thus, the aim of this study was to assess the effects of CO_2 laser and perforator stapedotomy techniques on audiological outcomes and postoperative vestibular functions via VNG and to compare the difference between these two techniques.

MATERIALS and METHODS

This prospective study was conducted between June 2012 and January 2014 at the Uludağ University School of Medicine, Department of Otolaryngology. Sixty-nine patients diagnosed with otosclerosis who underwent surgery were enrolled in this study. Patients with congenital nystagmus and a history of middle ear surgery were excluded. The patients were randomized into two groups according to the order of listing in the operation schedule as first one into laser stapedotomy and following into perforator stapedotomy. Surgeons performed both techniques in equal numbers for randomization. Data including the intraoperative findings, surgical technique, hearing outcomes, complications, vertigo symptoms, nystagmus, and VNG findings were retrieved. The study was approved by the ethical committee of Uludağ University School of Medicine and written informed consent was obtained from each patient.

All surgical interventions were performed under general anesthesia by senior surgeons using both techniques. Transcanal or endaural incisions were used to reach the middle ear. After the suprastructure of stapes was removed, fenestration of the footplate was done either via CO_2 laser at a 27-Watt single pulse mode on a scanner (Acupulse 40ST; Lumenis, Israel) or via a needle perforator manually. We used a 0.6-mm diameter teflon loop piston to reconstruct conduction between the footplate and incus. No oval window graft was used.

The patients were enquired for vertigo symptoms and examined for nystagmus during the early postoperative period. The hearing outcomes were assessed via postoperative changes in air conduction (AC), bone conduction (BC), and air–bone gap (ABG) at frequencies of 0.5, 1, 2, and 4 kHz (Intercoustics AC 40; Assens, Denmark). Postoperative ABG ≤10 decibel (dB) was accepted as an outcome of successful hearing.

We could perform VNG recording in only 38 patients, both on day 2 and at the first month after surgery (ICS CHARTR ENG/VNG 7.0.1 VNG; Otometrics, Taastrup, Denmark). VNG recordings of the second postoperative day consisted spontaneous nystagmus, gaze nystagmus and positional nystagmus. At the end of the first month, we evaluated all the parameters of VNG including directional preponderance via caloric testing. Other 31 patients did not attend the testing appointment at the first month. The slow phase velocity (SPV) limit was determined as 5 degrees per second. Maximal SPV value and direction of nystagmus were considered as criteria for the assessment of caloric responses in the diagnosis of canal paresis and directional preponderance.

Statistical analysis was carried out using Statistical Package for Social Sciences (SPSS) v.22 (IBM Corp.; NY, USA). The comparisons of continuous variables between discrete groups were done via the Student's t-test, if data was normally distributed and via the Mann-Whitney U test if not. The comparisons of categorical variables between discrete groups were done via the Pearson Chi-square test. Level of significance was set at $\alpha=0.05$.

Table 1. The demographic findings of patients

	Total	Laser	Perforator	p
Patient number	69	38	31	
Age	41.4±11.3	41.9±10.4	40.7±12.4	0.68
Gender				
Female	44	25	19	0.70
Male	25	13	12	
Side				
Right	39	18	21	
Left	30	20	10	
Follow-up (months)	4±4.5 (1–28)	4.4±5.5 (1–28)	3.5±3 (1–12)	0.98
Patients who underwent VNG	38	19	19	

VNG: videonystagmography

Table 2. The audiological findings in the laser and perforator groups

	Perforator (n: 31)	Laser (n: 38)	p	Total (n: 69)
Preop AC	55.4±11.4	59.6±15.9		57.7±14.1
Postop AC	28.0±11.8	32.0±14.0	0.29	30.2±13.1
Preop BC	22.2±10.2	27.3±11.4		25.0±11.1
Postop BC	16.5±10.6	17.9±10.7	0.57	17.3±10.6
Preop ABG	33.2±8.2	32.3±9.6		32.7±8.9
Postop ABG	11.5±6.9	14.0±9.3	0.37	12.9±8.4

Values are in dB±std dev.

AC: air conduction; BC: bone conduction; ABG: air-bone gap

RESULTS

Of the 69 patients in the study group, 44 (63.8%) were females and 25 (36.2%) were males. Mean age of the study group was 41.4±11.3. The study group was divided into two different groups based on the surgical technique used: the perforator group (n: 31) and laser group (n: 38). Mean follow-up duration was 4±4.5 months. There was no difference between the perforator and laser groups with regard to age, gender, side, and follow-up duration (Table 1). Otosclerosis was present in 38 patients, tinnitus in 29 patients, and preoperative vertigo in two patients. In all, 38 patients of the study population underwent VNG recordings. Transcanal approach was used in 52 patients and endaural approach in 17 patients.

Audiological Findings

In the study population, preoperative BC, AC, and ABG were found to be 25±11.1 dB, 57.7±14.1 dB, and 32.7±8.9 dB, respectively, and postoperative BC, AC, and ABG were found to be 17.3±10.6 dB, 30.2±13.1 dB, and 12.9±8.4 dB, respectively. The comparative analysis between the perforator and laser groups with regard to BC, AC, and ABG findings is presented in Table 2. There was no significant difference between the two groups in postoperative audiological findings ($p=0.37$ for ABG, $p=0.294$ for AC, $p=0.57$ for BC). The distribution of postoperative ABGs in the two patient groups is given in Table 3.

Vestibular Findings

Vertigo symptoms were observed in 11 patients who underwent laser stapedotomy and in 13 patients in the perforator group on postoper-

Table 3. The distribution of air–bone gap (ABG) gains in the laser and perforator groups

Postop ABG	Laser (n: 38)	Perforator (n: 31)
0-10 dB	18 (47%)	17 (54.8%)
11-20 dB	12 (31.5%)	14 (45.1%)
21-30 dB	6 (18.4%)	0
>30 dB	2 (5.1%)	0

Db: decibel; ABG: air-bone gap

Table 4. Videonystagmography and vestibular findings between the groups at postoperative day 2

	Perforator	Laser	p
Vertigo symptoms	13 (n: 31)	11 (n: 38)	0.26
Spontaneous nystagmus at VNG	3 (n: 19)	0 (n: 19)	0.07
Gaze nystagmus at VNG	9 (n: 19)	9 (n: 19)	0.07
Positional nystagmus at VNG	4 (n: 19)	3 (n: 19)	0.68

VNG: videonystagmography

Table 5. The audiological findings in patients with or without postoperative vertigo

	Vertigo (+) (n: 24)	Vertigo (-) (n: 45)	p
Preop AC	55.3±13.2	60.0±14.6	0.20
Postop AC	27.4±13.5	31.7±12.8	0.14
Preop BC	23.4±12.2	25.8±10.5	0.18
Postop BC	16.0±12.7	18.0±9.4	0.25
Preop ABG	32.0±8.6	33.2±9.2	0.58
Postop ABG	11.4±6.5	13.7±9.2	0.50

Values are in dB±std dev.

AC: air conduction; BC: bone conduction; ABG: air-bone gap

Table 6. Postoperative complications in the laser and perforator groups

	Perforator	Laser
Floating footplate	4	1
BPPV	1	2
Sensorineural hearing loss	1	-
Chorda tympani injury	-	2
Tympanic membrane perforation	-	1
Persistent postoperative vertigo	1	1

BPPV: benign paroxysmal positional vertigo

ative day 2 (p=0.26). We observed nystagmus in three patients in the laser group (n: 38) and in six patients in the perforator group (n: 31) at the early postoperative period (6 h after surgery) (p=0.16). VNG findings on postoperative day 2 are shown in Table 4. There was no significant difference between the laser and perforator groups with regard to the presence of spontaneous nystagmus, gaze nystagmus, and positional nystagmus (p=0.07, p=0.07, and p=0.68, respectively). The comparisons of audiological outcomes between patients with or without vertigo symptoms revealed no difference (Table 5). VNG findings showed no abnormality in patients at the first month. The number of complications and their distribution between the groups are shown in Table 6.

DISCUSSION

The application of laser in stapedotomy has recently gained popularity. Laser stapedotomy results in fewer footplate complications with better control during perforation [4]. Previous studies have shown successful hearing outcomes using laser stapedotomy. Moscillo et al. [14] compared the ABG closure between CO_2 laser stapedotomy and conventional stapedotomy and indicated higher success rates in using CO_2 laser (90.6% vs 86%). In another study, Malafronte et al. [15] found ABG≤10 dB in 92% of patients who underwent CO_2 laser stapedotomy and 90% of patients who underwent drill stapedotomy. In a study by Motta and Moscillo, there was a significantly higher rate of successful ABG closure with CO_2 laser compared with microdrill [16]. A recent review comparing hearing outcomes between laser versus non-laser stapedotomy pointed out that laser surgery had significantly better results [5]. We did not find a difference with respect to ABG gain between the manual perforator and CO_2 laser techniques. This finding may be due to lower success rates of hearing thresholds via both techniques and low number of patients in our study.

Improvement in BC is another parameter of comparison between the laser and perforator stapedotomy groups. Kisilevsky et al. [17] indicated that bone conduction did not change following stapedotomy in a large series of primary cases. Moscillo et al. [14] did not show any difference in BC thresholds between the groups although both groups showed improvement. In a study by Brase et al. [18], better postoperative BC threshold via laser stapedotomy was observed compared to manual perforator, but the difference was not significant. Similarly, another study reported significant improvement in BC via laser compared to conventional stapedotomy [19]. In our study, we found better results in BC gain via laser compared to a perforator (9.4 dB vs. 5.7 dB, respectively), but there was no statistical significance.

The association between the technique of stapedotomy and postoperative vertigo remains controversial. Silverstein et al. [20] reported a higher incidence of postoperative vertigo in the laser stapedotomy group compared to the conventional group (39% vs. 12%, respectively). However, in another study, there was no difference between these groups in video-oculographic findings at postoperative week 1 [9]. Similarly, we did not find statistical difference between two techniques with regard to vertigo symptoms and objective findings in VNG. The relation between the existence of postoperative vertigo and hearing improvement is another topic of debate. In their study, Aantaa and Virolainen [8] showed that there was no association between hearing outcomes and both the surgical technique and postoperative vertigo. Similarly, Birch and Elbrond [21] found that the presence of postoperative vertigo had no influence on postoperative hearing levels. In another study, Ozmen et al. [22] reported no correlation between vestibular changes and audiological results via posturography. In our study, there was no association between the existence of vertigo and hearing results, which is consistent with previous studies.

Benign paroxysmal positional vertigo (BPPV) is another cause of postoperative vertigo. Cupulolithiasis resulted due to manipulations on the footplate was suggested as the causative factor [23]. Atacan et al. [24] found significant difference in the incidence of BPPV in patients after stapedotomy compared to the control group. On the contrary, Grayeli et al. [25] showed no difference between controls and patients who underwent stapedotomy with regard to the existence of BPPV. There were three patients who had postoperative BPPV in our study with no significant difference between the two study groups.

Although stapedotomy is technically safe, there may be complications even when performed by experienced surgeons. SNHL is a very rare complication after stapedotomy. Inner ear injury due to direct trauma to the footplate via perforator usage or piston application, bacterial labyrinthitis, reparative granuloma, intralabyrinthine hemorrhage, and perilymphatic fistula are the possible causes [4, 26]. The incidence of postoperative SNHL was reported to be between 0.2% and 3% in different studies and 1.4% in our study [16, 27, 28]. Footplate fractures or floating footplate may lead to further mobilization of the footplate into the vestibule. These complications generally occur when the footplate is manually perforated. Thick or biscuit footplates are also potential risk factors. Nguyen et al. [29] found lower number of footplate injuries in laser stapedotomy compared to conventional technique (3.6% vs. 21.3%, respectively). Malafronte et al. [15] pointed out that of seven patients with intraoperative footplate complications, five were in the perforator group. Similarly, in our study, floating footplate complication was more common in the perforator group compared to the laser group; 5.7% vs. 1.4%. We suggested that higher incidence of footplate complications because of using a perforator is due to larger mechanical trauma to the underlying tissues.

In conclusion, we found no differences between CO_2 laser stapedotomy and conventional stapedotomy with regard to postoperative hearing gain and vertigo. However, laser provides a secure surgery with lesser footplate complications and also has the advantage of easy application.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Uludağ University School of Medicine.

Informed Consent: Written informed consent was obtained from patients who participated in this study.

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REFERENCES

1. Häusler R. General history of stapedectomy. Adv Otorhinolaryngol 2007; 65: 1-5.
2. Marquet J. "Stapedotomy" technique and results. Am J Otol 1985; 6: 63-7.
3. Perkins RC. Laser stepedotomy for otosclerosis. Laryngoscope 1980; 90: 228-40. [CrossRef]
4. Wegner I, Kamalski DM, Tange RA, Vincent R, Stegeman I, van der Heijden GJ, et al. Laser versus conventional fenestration in stapedotomy for otosclerosis: a systematic review. Laryngoscope 2014; 124: 1687-93. [CrossRef]
5. Fang L, Lin H, Zhang TY, Tan J. Laser versus non-laser stapedotomy in otosclerosis: a systematic review and meta-analysis. Auris Nasus Larynx 2014; 41: 337-42. [CrossRef]
6. Kamalski DM, Wegner I, Tange RA, Vincent R, Stegeman I, van der Heijden GJ, et al. Outcomes of different laser types in laser-assisted stapedotomy: a systematic review. Otol Neurotol 2014; 35: 1046-51. [CrossRef]
7. Vincent R, Bittermann AJ, Oates J, Sperling N, Grolman W. KTP versus CO2 laser fiber stapedotomy for primary otosclerosis: results of a new comparative series with the otology-neurotology database. Otol Neurotol 2012; 33: 928-33. [CrossRef]
8. Aantaa E, Virolainen E. The pre- and postoperative ENG findings in clinical otosclerosis and the late hearing results. Acta Otolaryngol 1978; 85: 313-7. [CrossRef]
9. Kujala J, Aalto H, Hirvonen TP. Video-oculography findings in patients with otosclerosis. Otol Neurotol 2005; 26: 1134-7. [CrossRef]
10. Kujala J, Aalto H, Hirvonen TP. Video-oculography findings and vestibular symptoms on the day of stapes surgery. Eur Arch Otorhinolaryngol 2010; 267: 187-90. [CrossRef]
11. Hirvonen TP, Aalto H. Immediate postoperative nystagmus and vestibular symptoms after stapes surgery. Acta Otolaryngol 2013; 133: 842-5. [CrossRef]
12. Causse JB, Causse JR, Cezard R, Briand C, Bretlau P, Wiet R, et al. Vertigo in postoperative follow-up of otosclerosis. Am J Otol 1988; 9: 246-55.
13. Woldag K, Meister EF, Kosling S. Diagnosis in persistent vertigo after stapes surgery. Laryngorhinootologie 1995; 74: 403-7. [CrossRef]
14. Moscillo L, Imperiali M, Carra P, Catapano F, Motta G. Bone conduction variation poststapedotomy. Am J Otolaryngol 2006; 27: 330-3. [CrossRef]
15. Malafronte G, Filosa B, Barillari MR. Stapedotomy: is the color of the footplate important in the choice of the type of perforator? Otol Neurotol 2011; 32: 1047-9. [CrossRef]
16. Motta G, Moscillo L. Functional results in stapedotomy with and without CO2 laser. ORL J Otorhinolaryngol Relat Spec 2002; 64: 307-10. [CrossRef]
17. Kisilevsky VE, Dutt SN, Bailie NA, Halik JJ. Hearing results of 1145 stapedotomies evaluated with Amsterdam hearing evaluation plots. J Laryngol Otol 2009; 123: 730-6. [CrossRef]
18. Brase C, Keil I, Schwitulla J, Mantsopoulos K, Schmid M, Iro H, et al. Bone conduction after stapes surgery: comparison of CO2 laser and manual perforation. Otol Neurotol 2013; 34: 821-6. [CrossRef]
19. Shabana YK, Allam H, Pedersen CB. Laser stapedotomy. J Laryngol Otol 1999; 113: 413-6. [CrossRef]
20. Silverstein H, Rosenberg S, Jones R. Small fenestra stapedotomies with and without KTP laser: a comparison. Laryngoscope 1989; 99: 485-8. [CrossRef]
21. Birch L, Elbrond O. Stapedectomy and vertigo. Clin Otolaryngol 1985; 10: 217-23. [CrossRef]
22. Ozmen AO, Aksoy S, Ozmen S, Saraç S, Sennaroğlu L, Gürsel B. Balance after stapedotomy: analysis of balance with computerized dynamic posturography. Clin Otolaryngol 2009; 34: 212-7. [CrossRef]
23. Causse JB, Causse JR, Parahy C. Stapedotomy technique and results. Am J Otol 1985; 6: 68-71.
24. Atacan E, Sennaroglu L, Genc A, Kaya S. Benign paroxysmal positional vertigo after stapedectomy. Laryngoscope 2001; 111: 1257-9. [CrossRef]
25. Grayeli AB, Sterkers O, Toupet M. Audiovestibular function in patients with otosclerosis and balance disorders. Otol Neurotol 2009; 30: 1085-91. [CrossRef]
26. Rangheard AS, Marsot-Dupuch K, Mark AS, Meyer B, Tubiana JM. Postoperative complications in otospongiosis: usefulness of MR imaging. Am J Neuroradiol 2001; 22: 1171-8.
27. Szymacski M, Goebel W, Morshed K, Siwiec H. The Influence of the sequence of surgical steps on complications rate in stapedotomy. Otol Neurotol 2007; 28: 152-6. [CrossRef]
28. Parrilla C, Galli J, Fetoni AR, Rigante M, Paludetti G. Erbiumyttrium–aluminum–garnet laser stapedotomy, a safe technique. Otolaryngol Head Neck Surg 2008; 138: 507-12. [CrossRef]
29. Nguyen Y, Grayeli AB, Belazzougui R, Rodriguez M, Bouccara D, Smail M, et al. Diode laser in otosclerosis surgery: first clinical results. Otol Neurotol 2008; 29: 441-6. [CrossRef]