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REVIEW ARTICLE

Laser vs drill for footplate fenestration during stapedotomy: a systematic review and meta-analysis of hearing results

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Abstract

Objective Stapes surgery is the gold standard surgical treatment nowadays for otosclerosis. Several controversies on the procedure have been reported; surgical techniques for most favorable outcomes are still on discussion. The objective of this study is to present an update of evidence-based medicine concerning the utilization of lasers and drilling for footplate fenestration during stapedotomy surgery. A systematic review and meta-analysis were conducted.

Materials and methods Publications in English in the last 5 years were searched in the PubMed/MEDLINE database and were systematically reviewed. A total of three articles were included according to the inclusion criteria, obtaining a total of 1531 patients managed surgically for otosclerosis, using laser or drill for footplate fenestration. Data were systematically extracted and hearing results were compared in a meta-analysis.

Results For the drill group, a total of 978 patients were retrieved and data were obtained as follows: mean age was 50 years old; the female proportion was 62%; mean preoperative air–bone gap (ABG) of 28 dB; mean postoperative ABG of 8 dB; mean ABG improvement of 20 dB; an ABG closure rate to < 10 dB of 74%. For the laser group, a total of 553 patients were retrieved, data were obtained as follows: mean age was 47 years old; the female proportion was 63%; preoperative ABG of 26 dB; postoperative ABG of 8 dB; mean ABG improvement of 18 dB; an ABG closure rate to < 10 dB of 72%.

Conclusion The results from this study reveal that in regard to postoperative hearing results, surgical outcomes are comparable, and there is no statistically significant difference between the utilization of drills and lasers as a surgical instrument for the fenestration of the stapes footplate during stapedotomy surgery.

Keywords Laser stapedotomy · Drill stapedotomy · Stapedotomy · Stapedotomy meta-analysis · Stapedotomy review

Introduction

Otosclerosis is characterized by abnormal bone growth in the middle ear, allowing progressive hearing loss to develop [1]. Surgery for otosclerosis is one of the great achievements in the history of otology [2]. Rosen introduced the first stapes surgery for the management of otosclerosis in 1953. Since then, numerous surgical techniques have been reported, including the lateral semicircular canal fenestration, stapedectomy, and stapedotomy [3]. Since the first laser stapedotomy was completed by Perkins in 1978, several laser procedures have been clinically approved for otosclerosis, with the intention to reduce expected inner ear damage, associated with that induced on standard surgery [4]. The laser-assisted stapedotomy procedure has been supported for primary stapes surgery and also has been recommended as a standard method in revision stapes surgery [5, 6].

Over time, stapedotomy fenestration techniques have developed from the use of micro-instruments to microdrills and, in more recent years, to lasers. The key advantages of the laser are that it merges the high precision of its utilization and the low risk of footplate mobilization, as a result of the no-touch principle of this procedure. Being inner ear injury as a result of mechanical trauma is less probable, the potentially harmful effects of laser use should not be depreciated. Thermic damage

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on the perilymph associated with CO_2 laser use; acoustic trauma in Er:YAG laser use; and penetration of the neuro-endothelium by the argon and potassium-titanyl phosphate (KTP) laser, could all hypothetically provoke inner ear dysfunction [7].

The use of lasers, particularly the CO_2 laser, is correlated with increased costs of surgery, compared to microdrill or KTP laser. While some costs are unavoidable and associated with hospital fees or surgical complexity. Some variables, including surgical equipment, allow a possibility for cost reduction and improved value for patients [2].

It is widely debated whether, during the stapedotomy procedure, the fenestration of the stapes footplate should be done by applying a laser or a mechanical method, and which one contributes to better postoperative hearing results.

The objective of this study is to present an update of evidence-based medicine regarding this subject, by conducting a systematic review and meta-analysis.

Materials and methods

Study selection

A literature search was performed in the PubMed/MEDLINE database from the last 5 years, from January 2015 to March 2020. Having as primary objective studies with patients who have undergone stapedotomy surgery for otosclerosis with the utilization of lasers and drills for stapes footplate fenestration. Using this framework, three reviewers retrieved studies and were critically evaluated. Language restrictions were applied and only studies written in English were included. From a total of 185 articles evaluated, 3 studies continued to meet the established criteria and were further analyzed. During the search procedure, the keywords selected for the study were "laser stapedotomy", "stapedotomy", "drill stapedotomy", "stapes surgery", and "otosclerosis laser". Keywords were either combined with each of the other keywords individually or in groups. Also, references of the retrieved articles were searched (Fig. 1); only studies

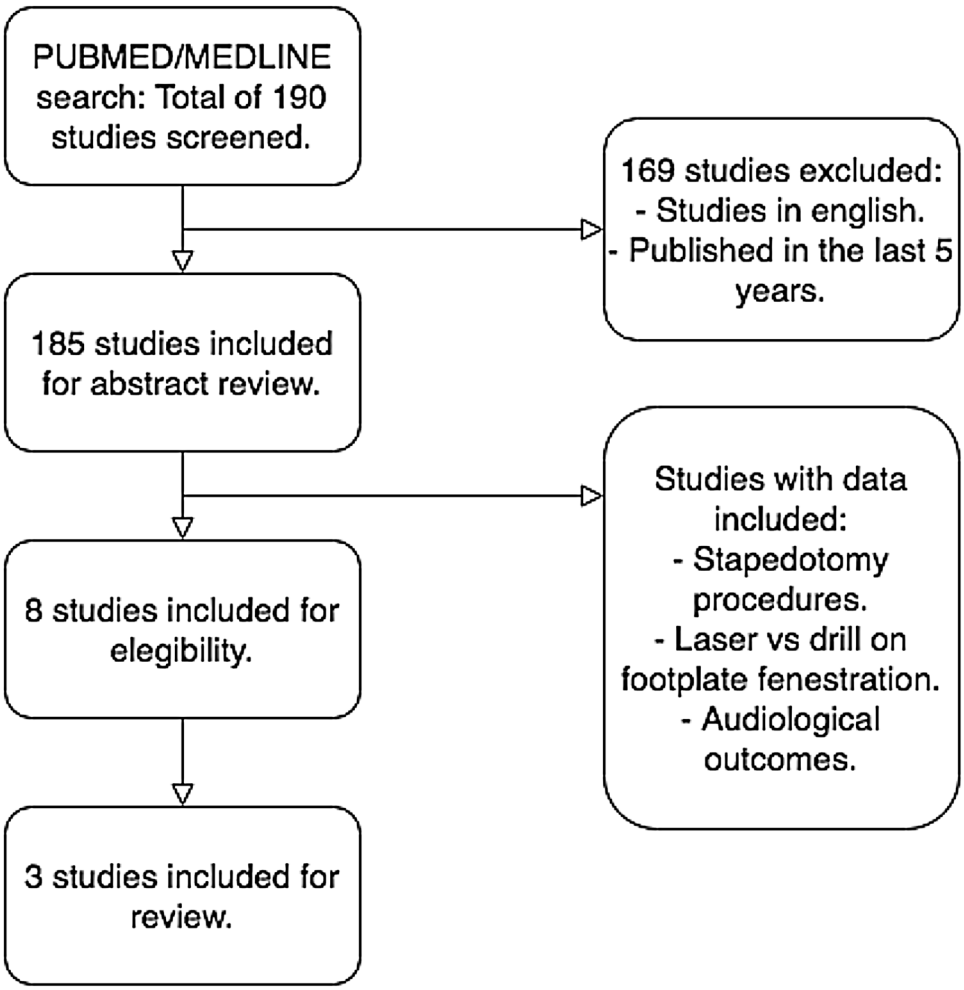

Fig. 1 Study selection flowchart

in which a direct comparison between the use of lasers or drills for stapes footplate fenestration were included. Hearing results must have been measured according to the AAO-HNS pure-tone audiometry (PTA) criteria for hipoacusia assessment. Mean audiometric results at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz at air and bone-conduction thresholds were obtained.

Data extraction and outcome measurement

Tables with analytic data were made to compare age; sex; preoperative air-conduction (AC) thresholds; preoperative bone-conduction (BC) thresholds; preoperative air–bone gap (ABG); postoperative ABG and postoperative ABG improvement. The proportion of postoperative results of ABG reduced to less than 10 dB was also obtained. Surgery was considered successful if the postoperative audiogram showed an ABG of 10 or fewer decibels (ABG < 10 dB). Results were measured differently depending on the total number of patients gathered for each variable, discarding all patients in the studies where non-available data were found. For the laser group, a CO_2 laser was utilized for fenestration in all 553 patients. KTP laser was utilized in 221 cases, handheld fiber was used only for dividing the stapes tendon and partition of the crus of the stapes, and these patients were included in the drilling group, as the stapes fenestration was made with a 0.6 mm electric burr. For the drill group, 0.6 mm electric or mechanical micro-drills were included for analysis.

Meta-analysis and statistics

For the meta-analysis of the measure of association, the logarithm of the odds ratio (log OR) and its 95% confidence interval (CI) were calculated using Jamovi statistical software [The jamovi project (2020). jamovi (Version 1.2) (Computer Software). Retrieved from https://www.jamovi.org]. For analysis, a result of the 95% CI not including 0 was assumed statistically significant. We evaluated evidence of heterogeneity with I2 and p values. A random-effects model (DerSimonian and Laird's method) was employed. A meta-regression was used to examine whether the use of drilling or laser for footplate fenestration, during stapedotomy procedures. No statistically significant difference was obtained.

Results

Data collection

Three studies were appraised, a total of 1531 patients were retrieved, 978 on the drill group, and 553 on the laser group.

1. Drill group (Table 1): From a total of 978 patients retrieved, data were obtained as follows: mean age was 50 years old (SD 12.8); a female proportion of 62%; mean preoperative AC of 54 dB (SD 18.7); mean preoperative BC of 26 dB (SD 12.9); mean preoperative ABG of 28 dB (SD 10); mean postoperative ABG of 8 dB (SD 7.9); a mean ABG improvement of 20 dB; and in 724 cases, the postoperative ABG closed to less than 10 dB (74%).
2. Laser group (Table 2): From a total of 553 patients retrieved, data were obtained as follows: mean age 47 years old (SD 12.2); a female proportion of 62.6%; preoperative AC of 51 dB (SD 14.4); preoperative BC of 26 dB (SD 11.1); preoperative ABG of 26 dB (SD 9.7); postoperative ABG of 8 dB (SD 7); a mean ABG improvement of 18 dB; and in 400 cases the postoperative ABG closed to less than 10 dB (72.3%).

Meta-analysis (Fig. 2)

Using a random-effects model (DerSimonian and Laird's method) for dichotomous variables, a forest plot was conducted that compared the proportion of successful surgeries (postoperative ABG < 10 dB) between groups. A comparison of the effectiveness of laser against drill for footplate fenestration was made. There was considerable heterogeneity in the odds ratios (OR) of the studies (I2 = 80.6%, $p = 0.006$). On the forest plot, there was no statistical difference between using laser or drill for footplate fenestration for closing the ABG to less than 10 dB (log OR −0.17 CI −0.8 to 0.47).

Discussion

Stapedotomy is the present standard surgical intervention for the treatment of otosclerosis. The purpose of the stapes surgery is to improve hearing and reduce the risk of hearing damage associated with this procedure.

The main objective of this study was to conduct a systematic review and meta-analysis to acquire an update that would help to answer still controversial questions. Up to this date, there is still no evidence that either laser fenestration or conventional fenestration methods are superior to each other in relation to hearing outcomes. Consequently, becoming comfortable with one's technique and use what works best for each otologist appears to be the most suitable approach for this type of surgery.

We can observe that there is a predomination for female sex to this pathology, as approximately 62% of the subjects appeared to be women, which is compatible with the literature [1, 10]. Also, there was a postsurgical ABG improvement of 20 dB and 18 dB for the drill and laser group, respectively. For both groups, the proportion of subjects who

Table 1 Drill group

Drill	*N*	Age (SD)	Female (%)	AC preop (SD)	BC preop (SD)	ABG preop (SD)	ABG postop (SD)	ABG imp	ABG < 10	%
Altamani [8]	424	51 (12.4)	64	47 (16.1)	25 (11.3)	23 (9.9)	5 (8.7)	18	342	80.7
Pauli [9]	523	50 (13.2)	61	59 (21.2)	28 (14.4)	31 (10.2)	9 (7.3)	22	365	69.8
Karaca [10]	31	41 (12.4)	61	55 (11.4)	22 (10.2)	33 (8.2)	12 (6.9)	22	17	54.8
Total	978	50 (12.8)	62	54 (18.7)	26 (12.9)	28 (10)	8 (7.9)	20	724	74

SD standard deviation, *AC* air conduction, *BC* bone conduction, *ABG* air–bone gap, *Imp* improvement

Table 2 Laser group

Laser	*N*	Age (SD)	Female (%)	AC preop (SD)	BC preop (SD)	ABG preop (SD)	ABG postop (SD)	ABG imp	ABG < 10	%
Altamani [8]	318	46 (12.1)	63	47 (13.1)	24 (10.2)	22 (9.5)	5 (6.7)	17	269	84.6
Pauli [9]	197	50 (12.8)	61	57 (16.1)	27 (12.5)	30 (10)	11 (7.1)	19	113	57.4
Karaca [10]	38	42 (10.4)	66	60 (15.9)	27 (11.4)	32 (9.6)	14 (9.3)	18	18	47.4
Total	553	47 (12.2)	62.6	51 (14.4)	26 (11.1)	26 (9.7)	8 (7)	18	400	72.3

SD standard deviation, *AC* air conduction, *BC* bone conduction, *ABG* air–bone gap, *Imp* improvement

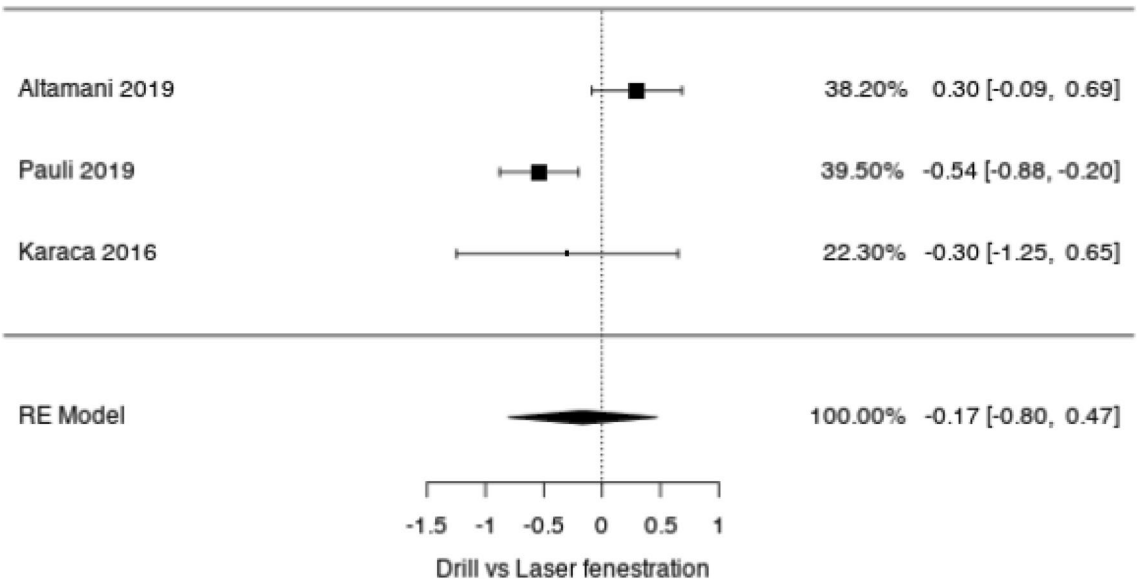

Fig. 2 Forest plot. Forest plot of the meta-analysis. On the left side drill group and on the right side laser group

achieved a postoperative ABG < 10 dB was higher than 70%. Even though the difference between groups was not statistically significant, stapes surgery appears to be an effective procedure for treating otosclerosis.

Over the years, many studies have been conducted to compare results between laser and non-laser procedures. One prominent study is a meta-analysis conducted in 2014 by Fang et al. [11]. Their outcomes determined that laser procedures achieved more satisfying hearing results while maintaining similar complication rates. After extracting data from posterior studies to this meta-analysis, it was observed that two studies showed improved results for drilling procedures [9, 10], while one presented better outcomes with the use of lasers for fenestration [8]. Various new types of laser, particularly diode laser, are being investigated in these last few years. Still, evidence (including one randomized-controlled trial) is not revealing improved results in relation to the conventional types of laser or standard mechanical fenestration [12, 13].

A study about costs in stapes surgery was conducted by Cazzasa et al. published in 2019, in which the main objective was to identify significant expenses for stapedotomy and clarify details of cost-efficiency among surgeons. While some costs are inevitable and related to hospital charges or case complexity, some variables, including medical supplies, allow an opportunity for lowering costs of surgery. It was concluded that increased surgical supply cost was most correlated with laser utilization, with an average cost of $563.37 per application. The utilization of the CO_2 laser was significantly more expensive than the KTP-laser or no-laser application. Although, there was no variation in the mean cost among those cases in which the KTP laser was used and those where no-laser was applied. This suggests that CO_2 laser is an important contributor that increases costs in stapes surgeries [2].

Study limitations: Most of the conducted studies about hearing results are measured according to the AAO-HNS pure-tone audiometry (PTA) criteria for hipoacusia assessment. This means that audiometric outcomes are measured at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz at air and bone-conduction thresholds. This study lacks the data regarding higher frequencies, as higher frequencies are known to be more commonly affected by trauma that occurs during footplate fenestration, regardless of the technique. Also, a more subtle indicator of potential cochlear injury related to footplate fenestration can be a decline in word recognition scores after surgery. Unfortunately, no data related to word recognition scores were able to be retrieved from the analyzed studies. As this study is limited to postoperative hearing results, no assessment of postoperative complications was conducted.

It can be deduced from this study that with respect to postoperative hearing outcomes, the use of lasers or drills for fenestration of the stapes footplate, presumably, will not produce significant clinical differences. Although surgeons can have their own preferences during surgery, in which, probably, best results are achieved with the devices that suit best for each surgeon and situation.

Conclusion

The results from this study reveal that in regard to postoperative hearing outcomes, there is no clinical nor statistically significant difference between the use of drills or lasers as

a surgical instrument for the fenestration of the stapes footplate during stapedotomy surgery. Consequently, becoming comfortable with one's own technique and use what works best for each otologist appears to be the most suitable approach for this type of surgery.

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