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"One Shot" Stapedioplasty with Scanner-Assisted CO_2 Laser and 980 nm Diode Laser

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Introduction

Stapedioplasty is a surgical operation performed to solve stapedio-ovalar fixation due to otosclerosis. Firstly proposed by Shea in 1958, for many years total stapedectomies were performed, entailing complete removal of the stapes and opening of the labyrinth that was subsequently closed with a fragment of vein, pericardium, simple fat or cellulose gelatine. The stem of the prosthesis, of variable shape, was then positioned on the interposed tissue and attached to the long process of the incus.

At the end of the '70s, Gordon Smith and others proposed a partial posterior platinectomy with or without tissue used to seal the perforation in the footplate. Stapedotomy gradually became widely practiced, simply in the form of a small aperture in the footplate into which the "customised" stem of the prothesis was fitted.

Over the years, stapedotomy has been performed using various instruments, from manual perforators to different types of drills, the most recent and codified of which is the Skeeter® Oto-Tool. The use of the laser beam has also been conceived and proposed in various configurations: from the CO_2 laser (Lesinski, 1989, Motta et al., 1996), to the argon-laser (Causse and Gherini, 1993), taking in the erbium laser (Hausler et al. 1999), through to the diode laser (Nguyen 3 et al., 2008) and the return to fashion of the CO_2 laser enhanced by the new "robotic" systems with micromanipulators and scanners.

While all these technologies offer great benefits, they also have disadvantages that should be kept in mind to enable a targeted choice and optimise the results for patients. Upon closer analysis, for example, we can note that the **Erbium laser** (2940 nm) was not widely accepted in this type of surgery, since the impossibility of working in continuous mode (CW) meant that it had to be used in pulsed mode, thus generating high-intensity pressure sound waves on the footplate and the underlying structures of the inner ear. This sound pressure is also magnified by the high absorption of this wavelength by water and therefore by the labyrinthine fluids, reducing the safety and reproducibility of the procedure. The **diode laser** (940 nm-980 nm) is currently quite widely used to perform this type of surgery.

It should be clarified, however, that low-power diode lasers (10/15 W) require the use of optical fibres with small diameters, usually 200 µm or 300 µm, which make it impossible to perforate the footplate using the "one shot" technique, instead requiring a series of micro perforations using the "rosette" technique. In our opinion, it is preferable to use higher-power diode lasers (30/50 W) and optical fibres with larger diameters (400, 500, 600 µm, according with the diameter of the prosthesis used) so that the aperture in the footplate can be made with the "single shot" technique, guaranteeing repeatability of the results in terms of perforation dimensions.

The disadvantages of the diode laser derive from the fact that, as with other methods (e.g. piezosurgery), it is still "contact" type surgery and therefore causes trauma, albeit slight. Added to which there is reduced visibility in the operating "canal" due to the insertion of the fibre and if necessary the handpiece. The **microdrill** technique is extremely effective and well documented in literature, even though it features

Figure 1. Robotic beam scanning system (HISCAN Surgical) coupled with a CO_2 micromanipulator.

several intrinsic problems, such as transmission of the vibrations generated by the drill motor to the structures of the inner ear and the possibility of causing fractures or mobilization of the footplate. The CO_2 laser (10600 nm), conveyed by means of the micromanipulator, has been used at length in this type of surgery to make the perforation in the footplate using the "rosette" technique, exactly like the low-power diode laser. This operating method offers the typical disadvantages of the "rosette", in addition it requires considerable manual skill and is less repeatable, unless the perforation is finished off with the Skeeter®, thereby losing the benefits of the "no touch" technique.

Today, with the advent of robotic beam scanning systems coupled with micromanipulator, it is the laser system that moves the beam on the target, with powers and dwell times controlled and monitored from the database in a fully automatic mode. The specialist is still responsible for selecting the scanning dimensions to be set on the machine display before performing the footplate perforation, depending on the dimensions of the prosthesis used. The laser works in continuous mode (CW) to avoid the photo-acoustic effect, while the scanner produces circular ablation, providing the right amount of energy for making the perforation with the "one shot" technique.

The benefits of the CO_2 laser derive from the lack of contact which practically eliminates the risk of fractures, mobilization of the footplate or microtraumas to the hearing apparatus. The disadvantages are mainly due to crowding of the operating area by the micromanipulator and related accessories positioned in front of the microscope.

The CO_2 laser is considered the gold standard for revision operations and in all cases of suspected risk of mobilization of the footplate. In the light of the above, it seems obvious that the availability of a range of instruments, CO_2 lasers, diode lasers and microdrills offers surgeons the best possible operating conditions.

Materials and methods

The case studies presented here refer to 12 cases operated between June 2009 and November 2010, representing approximately 40% of all the patients operated by the senior author (S.D.) during the same period. The criteria for use of the CO_2 laser instead of the microdrill technique were mainly linked to the clinical validation programme of the **SmartXide²** laser with the **Easy Spot** micromanipulator and **Hi-Scan Surgical** robotic system. The only preferential element of choice was the presence of an on-off stapedial reflex with the impedancemetry.

The author's surgical technique entails the transcanal pathway, atticotomy with a curette and the succession of classic steps with a 0.8 mm posterior stapedotomy for placement of the Schuknecht platinum-Teflon type prosthesis with a diameter of 0.6 mm.

The operating distance of the microscope used is 300mm in order to guarantee smoother and more practical access for the surgical instruments, otherwise partially obstructed by the presence of the micromanipulator and related accessories in front of the microscope.

The CO_2 laser is used to cut the stapedial tendon and for the posterior crurotomy, as well as for the calibrated platinotomy. Powers of 8 W in CW with a dwell time of 2 ms and a 0.8 mm scanning size are used to cut the tendon and perform the crurotomy. This operation may require more than one shot. The use of microfragments of Gelfoam® dipped in saline solution is recommended to protect the sides of the posterior crus and prevent the risk of lesions of the fenestral-promontorial osseous wall caused by accidental exposure to the CO_2 laser. The crurotomy is completed with a pick, then a large hook is located at the root of the anterior crus and used to fracture it with a downwards (cranial-caudal) movement.

The superstructure of the stapes, still joined to the incus, is then gently detached and removed. The footplate, previously cleaned of any fibrous remnants and carefully inspected, is illuminated by the laser spotlight, focussed on the posterior hemiplate. The robotic scanner delivers a spiral figure where the energy is dispersed uniformly over the entire scanning area. The parameters used are 20 W in continuous emission (CW) with a dwell time of 3 ms. A one-shot laser technique must permit the creation of a calibrated perforation, with a diameter of between 0.5 and 0.8 mm, to house the most frequently used prostheses with diameters of 0.4, 0.5 and 0.6 mm.

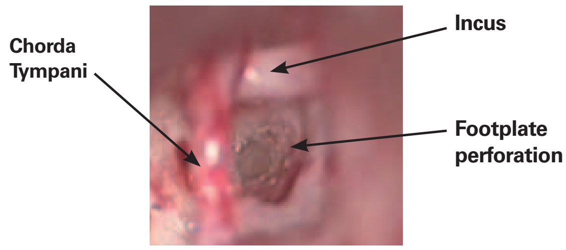

Figure 2. 0.8 mm diameter platinotomy performed with $C0_2$ "single shot" laser

If the shape or diameter of the perforation is inadequate, it can be safety finished off either with additional laser shots in the same point, since the perilymph layer protects the underlying labyrintine (saccular) structures, or using microdrill.

The operation is completed with the positioning and attachment of the prosthesis, verification of optimal mobility of the new ossicular chain, final checks, and the folding back/repositioning of the tympanometal flap. The auditory canal is plugged with a Merocel® micro-cigar dipped in antibiotic, which is removed after 48-72 hours.

The patient is discharged 24-48 hours later, always after a post-op examination of the bone conduction.

Analysys of the results

The main descriptive parameters of the case studies are summarised in Table 1.

Gender	Sex	Age Date of birth	Stage	Preop on-off	Chorda Tymp saved	Otosclerotic Focus	One Shot	Type of prosthesis	Post-op bone conduc.	Post operative Dizziness	Hearing recovery % (*)	Max. recovery time	Pre op. tinnitus	Post op. tinnitus
1. C E	F	65 (2-4-44)	II monol	yes	yes	standard	yes	Schukhn 0.6 mm	ok	no	> 90	at pack removal	yes	no
2. S E	F	43 (24-7-65)	III bilat	no	no	overhang edge	yes ("tight "hole)	Sanna 0.5 mm	ok	no	> 90	at 1 month control	yes	yes
3. S T	M	48 (17-4-61)	III bilat	yes	yes	< window size	yes	Schukhn 0.6 mm	ok	no	> 80 **	at 1 month control	yes	yes
4. S L	F	49 27-10-70	II monol	no	yes	standard	yes	Schukhn 0.6 mm	ok	no	> 90	at pack removal	no	no
5. M M	F	42 (9-1-67)	II monol	no	yes	standard	yes	Soft clip 0.6 mm ***	ok	no	> 90	at pack removal	yes	no
6. T MR	F	70 (5-7-39)	III bilat	no	yes	standard	yes	K piston 0.4 mm ***	↓ low freq	no	> 90	at pack removal	no	no
7. G DN	M	50 (18-9-59)	II-III monol	yes	yes	standard	yes	Schukh 0.6 mm	ok	no	> 90	at pack removal	yes	<
8. P MP	F	58 (20-10-51)	II-III contralat early	no	no	standard	yes	Schukh 0.6 mm	ok	1 epis vomiting; no nystagmus	> 90	at 1 month control	yes	no
9. P O	F	45 (13-6-65)	IV monol	no	yes	standard	yes	Schukh 0.6 mm	ok	no	> 90	at 1 month control	no	no
10. P R	F	50 (9-9-59)	III monol	yes	no	standard	yes ****	Schukhn 0.6 mm	↓ 0.5 hz	positional sympt no nystagmus	> 80 *****	at 1 month control	yes	no
11. F E	F	35 (18-12-74)	I monol	no	yes	standard	yes (+ 1, +1) ****	Schukhn 0.6 mm	ok	nausea at movem no nystagmus	> 90	at 1 month control	yes	<<
12. I CM	F	47 (9-4-1963)	I monol	no	yes	standard	yes	Schukhn 0.6 mm	ok	no	> 90	at 1 month control	no	no

Table 1. Parameters of the case studies

* % of air-bone gap closure; ** hearing aid removed in the operated ear; *** slightly difficult prosthesis positioning but no significant trauma to the ossicular chain and the inner ear; **** hole slightly tight and refined with a microhook. Atraumatic procedure; ***** >50 % hearing gain on 9 post-op day. Worsening of the bone conduction and speech discrimination on 15 p-o day. >80 % hearing gain on 30 p-o day.

Conclusions

The cases assessed here demonstrate how the use of the **SmartXide²** CO_2 Laser with the **Easy Spot** micromanipulator and **Hi-Scan Surgical** robotic system make it possible to achieve excellent results that are fully comparable with the best results obtained using the microdrill technique.

It can therefore be argued that where CO_2 laser is available for other uses, first and foremost oncological laryngeal microsurgery, it should also be considered and used whenever there is reason to suspect incomplete fixation of the stapes (persistence of the on-off effect) and is often decisive in the presence of significant complications such as a floating footplate. Devices on the market that combine the CO_2 laser source and high-power diode laser source, with the possibility of a rapid selection between both types, represent the gold standard choice in ENT, and undoubtedly extend the sphere of application of laser to otologic microsurgery.

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