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Effect of KTP laser on implants used in middle-ear surgery

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Abstract

The present study is intended to explore the effects of the KTP laser on various types of implant, used in middle-ear surgery. A laboratory study was undertaken to evaluate the interaction between the KTP laser (KTP-532 Orion Laser, Laserscope, UK) and individual middle-ear implants. A variety of middle-ear implants were used: a silicone sheet, Teflon®, hydroxylapatite, ionomeric cement, gold and titanium prostheses as well as gelfoam. Following exposure to the laser, these implants were studied by direct inspection using an operating microscope.

The KTP laser induced no detectable alteration in any of the implants when they were clean and dry. However, in the presence of fresh blood, under the influence of the energy of the absorbed laser, the silicone burnt and melted and the Teflon® piston was vaporized. Likewise, a few tiny holes appeared on the surface of the ionomeric implant and then the prosthesis deformed. The hydroxylapatite implant broke into two pieces. However, no detectable alteration could be observed on gold or titanium pistons, even in the presence of blood.

The authors conclude, that in the presence of blood, interaction between the KTP laser and both silicone and hydroxylapatite implants needs to be avoided. Teflon® prostheses can be cautiously vaporized. Gold and titanium prostheses were unaffected by laser even in the presence of blood.

Key words: Lasers; Ear, Middle; Prostheses and Implants

Introduction

The application of various lasers in middle-ear surgery has shown steady growth over the past two decades. In addition to laser-assisted tympanoplasty[1–4] and stapedotomy,[5–7] laser is applied by several authors in acoustic tumour surgery.[8,9] CO_2 lasers adapted to microscopes are mainly used in stapes surgery, while visible-spectrum lasers operated by means of micromanipulators and fibre-optics (argon and KTP) are applied in stapedotomy, tympanoplasty and also in the surgery of acoustic tumours. New types of ossicular implants are now made of different materials and lasers are becoming available in clinical practice. This raises questions about the possible nature of the interaction between these lasers and implants used in ear surgery.

Implants made of synthetic materials have long been used in ear surgery. Criticism of their use usually concerns the possibility of rejection and dislocation in the middle ear. Because of these limitations, autograft and homograft cartilage and bone continue to remain in popular use.[10,11] The possibility of transmitting certain diseases (AIDS, Creutzfeldt-Jakob disease) by using homografts is now widely accepted.[12,13] Thus, there is renewed interest in prostheses made from biologically compatible materials (Polycel, Proplast and Plastipore), bioceramics (aluminium hydroxide, ceravital, hydroxylapatite) and, very recently, ionomeric cement, gold and titanium.[14–16]

During the past few years several authors have suggested that KTP and argon lasers are ideal tools for removing and changing previously used prostheses in revision stapes and tympanoplasty operations, as the vaporization of the granulation tissue around the prostheses and the cutting of the scars can be carried out without any manipulation of the ossicles, minimizing the risk of iatrogenic injury to the cochlea.[17–19] The aim of the present study was to investigate the interaction between the KTP 532 Orion laser and the individual implants.

Materials and methods

The interaction between KTP laser (KTP-532 Orion Laser, Laseroscope, UK) and the individual implants was studied in the laboratory by direct inspection using the operating microscope. Photos and video-records of each implant were taken and the effect of laser irradiation studied. Based on references found in the published literature on laser-assisted middle - ear surgery and on our own clinical experience with the KTP laser, we used an output of 1–4 W on the

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FIG. 1
Teflon piston vaporized after repeated laser impulses.

FIG. 2
Hydroxylapatite implant broke into two pieces when exposed to laser.

various implants. The duration of the pulse varied between 0.1 and 1.0 second. The implants used in the study were as follows: silicone sheet (Xomed®), Teflon® fluoroplastic piston (Richard Inc., Memphis), TAM hydroxylapatite 'total replacement' prosthesis, (HC Implants B.V., Leiden, the Netherlands), ionomeric prosthesis (IONOs® Ossicle Total, Xomed), gold stapes piston (K-piston-gold, Kurz) and titanium middle-ear prosthesis (Titanium-total-middle-ear implant, Spiggle and Theis). Gelfoam frequently used in middle-ear surgery was also studied to find out whether or not the penetration of the laser can be determined in addition to the interaction with the KTP laser.

The interaction with the laser in the case of each prosthesis was studied in the laboratory on commercially available clean, dry implants, identical to those used in clinical practice. Due to the well-known fact that the KTP laser is highly absorbed in pigmented tissues, the interaction was also examined in the presence of freshly drawn human blood dripped on the implants. The output of the laser and the duration of each individual impulse were gradually increased and the changes observed as each set of values were recorded in the protocol.

Results

The investigation of the interaction between KTP lasers and various middle-ear implants revealed no detectable alteration when the implants were dry and clean. The investigations were repeated in the presence of fresh human blood dripped on the implants. The results are summarized in Table I.

Silicone sheet

The KTP laser penetrated through clean, dry silicone sheets without causing any alteration to them. When blood was dripped either under, or over, the silicone sheet, the sheet gradually burnt. This phenomenon could be observed with outputs as low as 1 W and 0.1 second of pulse length.

Teflon® (fluoroplastic)

The KTP laser caused no observable alteration on clean, dry Teflon® pistons. When, however, blood was dripped on the piston, the surface of the prosthesis burnt at an output as low as 1 W and a pulse length of 0.1 second and, following repeated laser impulses, the Teflon® prosthesis melted (Figure 1). When the output was increased to 2 W,

TABLE I
EFFECT OF KTP LASER ON MIDDLE EAR IMPLANTS

	Interaction between KTP laser and implants	
Implants	Dry, clean implant	Blood-stained prosthesis
Silicone	No effect (4 W, 1 sec)	Laser penetrated through silicone sheet Blood drop under sheet: secondary burn (1 W, 0,1 sec) Blood drop on sheet: direct burn (1 W, 0,1 sec)
Teflon piston	No effect (4 W, 1 sec)	Superficial burn (1 W, 0,1 sec single pulse) Vaporization (2 W, 0,1 sec repeated pulse)
Hydroxylapatite	No effect (4 W, 1 sec)	Minimal superficial alteration (1 W, 0,1 sec single pulse) Breaking (2 W, 0,1 sec repeated pulse)
Ionomeric cement	No effect (4 W, 1 sec)	Tiny holes (1 W, 0,1 sec single pulse) Deformation (2 W, 0,1 sec repeated pulse)
Gold stapes piston	No effect (4 W, 1 sec)	No effect
Titanium prosthesis	No effect (4 W, 1 sec)	No effect
Gelfoam	No effect (4 W, 1 sec)	Superficial coagulation (1 W, 0,5 sec single pulse) Penetration/vaporization (2 W, 1 sec repeated pulse)

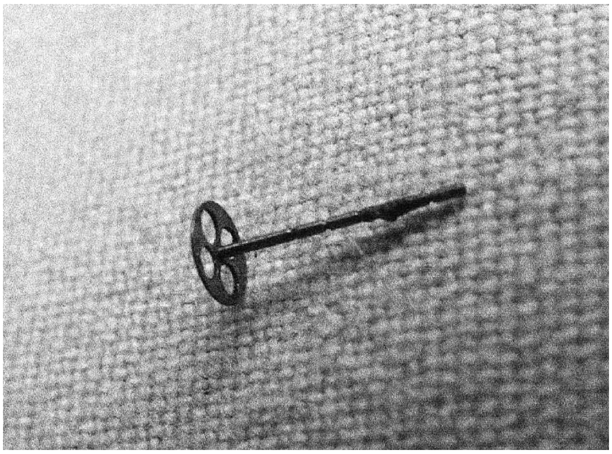

FIG. 3

Laser exposure caused no visible alteration on titanium implant (A drop of coagulated blood can be seen on the tip of the prosthesis).

repeated pulse emissions resulted in the vaporization of the prosthesis.

Hydroxylapatite

The KTP laser cause no detectable alteration on clean, dry hydroxylapatite implants even when the output was as high as 4 W and a pulse length of 1 second. However, in the presence of blood, at an output of 1–2 W a single 0.1 second pulse caused minimal changes, while repeated 2 W and 0.1 second-long pulses caused the prosthesis to break into two (Figure 2).

Ionomeric cement prosthesis

As with other dry prostheses, no visible interaction with the KTP laser was observed. In the presence of blood, tiny holes could be observed on the surface of the prosthesis following 1 W and 0.1 second pulses. 2 W repeated pulses resulted in the deformation of prostheses made of ionomeric cement.

Gold stapes piston and titanium ossicular replacement prostheses

No alteration of dry gold and titanium implants could be observed, even at outputs of 4 W and 1 second pulse length. Repeated investigations in the presence of blood dripped on the surface of the prosthesis showed that neither gold nor titanium implants (Figure 3) underwent any detectable alteration as a result of exposure to the laser.

Gelfoam

Gelfoam soaked with physiological salt solution did not absorb KTP laser. In the presence of pigmented materials at an output of 1 W and 0.5 seconds pulse length, superficial alterations could be observed. Impulses repeated at the same site resulted in the laser going through the gelfoam. The higher the output of the laser (up to 4 W), the faster it penetrated and vaporization of the gelfoam took place. The thickness of the gelfoam layer also had an influence on the depth of penetration, i.e. the laser was slower to penetrate thicker gelfoam layers.

Discussion

Those involved in middle-ear surgery have long articulated the need for biocompatible implants that provide excellent sound conduction following middle-ear surgery. Experience with implants made from synthetic materials was not always favourable, as such prostheses were often rejected by the organism or were dislocated within the middle ear. This may be the reason why autograft and homograft implants remained comparatively popular among ear surgeons.[10,11] Nowadays, however, a change of view concerning implants is taking place, that may be explained by several factors. On the one hand, the biocompatibility of the implants has dramatically improved. In the case of some implants, biointegration can be achieved.[14] On the other hand, several authors seem to prefer prefabricated implants produced in different sizes thus helping to avoid the time-consuming final shaping of the prostheses during surgery.[15,16] A third, equally important factor is that certain diseases have turned out to be transmissible through homografts and thus the application of homografts in some areas – including middle-ear surgery – has become a source of concern.[12,13]

As well as advances in biotechnological research that has made many types of middle-ear prosthesis readily available, the use of lasers in middle-ear surgery has also gained increasing acceptance.[5–7,20] This has happened, because the problem of adapting various lasers to surgical microscopes has been solved, and, as a result, visible-spectrum lasers (KTP, argon) can find their way to the most hidden parts of the middle ear by means of fibre-optics and hand-held laser probes. CO_2, KTP and argon lasers are frequently applied in both stapes and acoustic tumour surgery. Laser stapedectomy is proved to be a safe, bloodless operation without causing significant cochlear trauma.[3,5,7] Acoustic tumours can be effectively vaporized especially with KTP and argon lasers.[8,9] In addition, KTP and argon lasers have been found to be extremely useful tools in cholesteatoma surgery, ossicular reconstruction and re-operation of tympanoplasty.[1,2,4] These lasers enable the surgeon to obtain a more effective disease removal in a bloodless field.[1–3] Hypertrophic mucous membrane and granulation tissue inside the middle ear or on the lateral surface of the drum can be vaporized without touching the ossicular chain, such that cochlear trauma can be avoided. These lasers delivered via a flexible optic fibre enable the surgeon to obtain a more effective disease removal in a bloodless field.[1–3] Several studies have also investigated the effect they have on the inner ear.[21,22] Animal experiments and several clinical studies, including our own clinical experience, indicate that in the hands of experienced otologists, aware of the physical characteristics of individual lasers, that CO_2, KTP and argon lasers can be safely used.[7,23,24] The advantages of KTP and argon lasers in revision stapes and tympanoplasty surgery have already been observed by several authors, especially in relation to the removal of dislocated or fixed implants.[1,17,19] There is still surprisingly little data available on the interaction between visible-spectrum lasers and the new types of ossicular prostheses.

In the presence of blood, the KTP laser penetrating through a silicone sheet can be absorbed in a few drops of blood on the medial wall of the middle ear and in the richly pigmented mucous membrane. This can lead to injury of structures located in the peripheral parts of the field of vision (facial nerve, round window membrane, etc).

However, surgeons need to be reminded that there is a difference between our laboratory model and an *in vivo* situation, as all the implants inserted into the middle ear would have been enveloped by a fibrous sheath. Most of the surgeons utilize laser during revision surgery to remove the fibrous sheath to facilitate retrieval of the unwanted implants. Hence, a lot of the collateral effect on the implant is due to laser removal of the fibrous sheath. Moreover, surgeons have to bear in mind, that the main risk of KTP or argon laser is the thermal damage to the surrounding vital structures.[7,21]

The damage to bloodstained hydroxylapatite implants following laser exposure in laboratory circumstances highlights the brittleness of the implant. Likewise, vaporization of a bloodstained Teflon® piston in laboratory circumstances raises the question of whether the use of lasers in revision stapes surgery, when there is granulation tissue as well as scars around the prosthesis, should be attempted as there may be unwanted heat damage to the vestible. However, Wanamaker reported his experience using argon laser, to 'melt' Polycel® prostheses on the incus and the head of the stapes, thus stabilizing the ossicular chain without experiencing significant inner ear damage.[25]

Although, the laser appears not to damage metal (titanium, gold), it is possible that the heat could be transmitted through metal to vital structures.

During laser – ionomer interaction no clear sign of vaporization was observed in laboratory circumstances. However, the prosthesis became deformed which suggests, that laser-ionomer interaction should be avoided in the middle ear.

Bartels[7] points out that clean gelfoam soaked with physiological salt solution forms a layer in the middle ear to protect more deeply located structures. It is obvious that on the surface of the physiological salt solution KTP laser does not absorb, i.e. the penetration into the deeper areas depends on the duration of laser exposure and laser power applied. Special care is needed in case the gelfoam layer is thin and is soaked with blood. In such cases gelfoam needs to be exchanged more frequently and the surgical field needs to be irrigated.

Conclusions

Advances in laser technology during the past 10 years and the development of new types of middle-ear implants have opened up new perspectives in middle-ear surgery. The knowledge of the interaction between the KTP laser and the various types of implants may be instructive for clinicians. The present study provides support for the view that the KTP laser can be used safely in the presence of most middle-ear implants. However, direct contact between the KTP laser and bloodstained hydroxylapatite needs to be avoided. In the case of primary operations the placement of the implants is recommended following laser exposure. In the case of revision surgery previously placed silicone sheets need to be removed before the laser is applied. Gold and titanium prostheses are unaffected by the KTP laser even in the presence of blood. However, surgeons have to bear in mind the unpredictable transmission of heat through metal and Teflon® to vital structures. Wet gelfoam may form a protective layer in the middle ear. However, on applying gelfoam soaked in blood, special care needs to be taken, as again thermal damage may occur.

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