

# Investigation of scleral thermal injuries caused by ultrasonic pars plana phacoemulsification and aspiration using pig eyes

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Received: 24 June 2018 / Accepted: 11 October 2018 / Published online: 23 October 2018  
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## Abstract

**Purpose** The purpose of this study was to investigate the thermal injuries caused by ultrasonic pars plana phacoemulsification and aspiration (PPPEA) using pig eyes.

**Method** Using a 20-gauge (G) vitrectomy system (Accurus<sup>®</sup>, Fragmatome; Alcon Laboratories) in both the ‘open-tip’ and ‘closed-tip’ techniques, PPPEA was performed in pig eyes and the subsequent thermal injuries generated around the scleral wound were measured by infrared thermal imaging (thermography). Post surgery, the state of the scleral wound was observed under a microscope, and a tissue slice containing the scleral wound was then prepared and observed under an optical microscope.

**Results** Thermography measurements revealed a slight temperature rise around the scleral wound in the open-tip case, yet a marked temperature rise in the closed-tip case. The scleral wound incision produced by the open tip was linear, while that produced by the closed tip was expanded. Histological examination

revealed mild degeneration of the sclera around the wound in the open-tip case, yet marked tissue degeneration by thermal injuries in the closed-tip case. **Conclusion** Our findings showed that in PPPEA, the temperature of the tip of a 20G vitrectomy system rapidly increases due to the closed-tip technique, thus producing obvious thermal damage to the scleral wound. In order to prevent thermal injuries to the scleral wound during PPPEA, it is important to shorten the time of ultrasonic oscillation during surgery as much as possible while the tip is occluded with nuclear fragments.

**Keywords** Thermal injury · Ultrasonic pars plana phacoemulsification and aspiration (PPPEA) · Infrared thermal imaging · Scleral wound · Histological examination

## Introduction

Due to a rise in the popularity of micro-incision vitrectomy surgery (MIVS) [1], the number of patients undergoing 20-gauge (G) vitreous surgery has dramatically decreased. However, pars plana phacoemulsification and aspiration (PPPEA) is still a useful surgical technique for special cases such as lens subluxation, a dropped lens nucleus during cataract surgery, and the removal of hard residual lens tissue after congenital cataract surgery, etc. [2]. The usual

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surgical procedure of PPPEA involves the insertion of a 20G US-tip into the scleral wound without a mantle, with the assistant spreading water for cooling of the scleral wound during the procedure. There have been numerous reports about thermal injuries caused by the ordinarily used ultrasound phacoemulsification tip at the sclerocorneal wound [3–7]. However, and to the best of our knowledge, there are no previous reports of the examination of thermal damage to the scleral wound caused by tips during PPPEA using an animal-eye model. In this study, we report the thermographic observation and histological examination of the thermal injury in the scleral wound post PPPEA using pig eyes.

## Materials and methods

For use in this study, 6 enucleated adult pig eyes were generously gifted from a local abattoir (Osaka-City General Meat Market Inc, Osaka Japan), and our experiments were performed approximately 6–7 h after the enucleation. Of the 6 enucleated eyes, 3 underwent PPPEA via the ‘open-tip’ technique and 3 underwent PPPEA via the ‘closed-tip’ technique. For the experiments, the Accurus<sup>®</sup> 1500 Surgical System (Alcon Laboratories, Inc., Fort Worth, TX, USA) was used as an ultrasonic emulsification aspiration device, and an ordinary 20G Fragmatome<sup>™</sup> Accessory Pak (Alcon Laboratories) ultrasonic human-lens fragmentation tip not treated with Teflon was used as an ultrasonic tip. To measure the temperature of the ultrasonic tip and scleral wound, a high-sensitivity thermal imager (Thermo Tracer 6T62; NEC San-ei Instruments, Ltd., Tachikawa, Tokyo, Japan) was used as a thermograph [8].

### Tip temperature change

#### *Open tip*

For the open-tip case, a 20G infusion cannula was attached to the pig eye at a position 3.5 mm from the corneal limbus, and the perfusion bottle height was adjusted so that the perfusion pressure was approximately 40 mmHg. Next, a scleral wound was made at another position 3.5 mm from the corneal limbus with a 20G V-lance (Alcon Laboratories), and a Fragmatome<sup>™</sup> tip was inserted into the lens. A continuous

ultrasonic wave was then generated for 1 min under a suction pressure of 400 mmHg and an ultrasonic power output of 50%. The temperature change of the ultrasonic tip during that 1 min time period was recorded with a video thermograph.

#### *Closed tip*

For the closed-tip cases, the interior of the tip was closed by burying the chestnuts, with PPPEA then being carried out via the same settings as described above.

### Microscopy examination of the scleral wound

After ultrasonic waves oscillated via the two above-described methods, the tip was removed, and the state of the scleral wound was examined under a surgical microscope (L-0990-A, Inami & Co., Ltd., Tokyo, Japan).

### Histological examination of the scleral wound

For histological examination, the wall of the eyeball around the scleral wound of the pig eye was cut into 10 mm × 10 mm blocks, fixed in formalin, dehydrated, and then embedded in paraffin. Next, sliced sections including cross sections of the scleral wound were prepared, stained with hematoxylin–eosin, and examined under an optical microscope (EMZ-5HP; Meiji Techno Co., Ltd., Saitama, Japan).

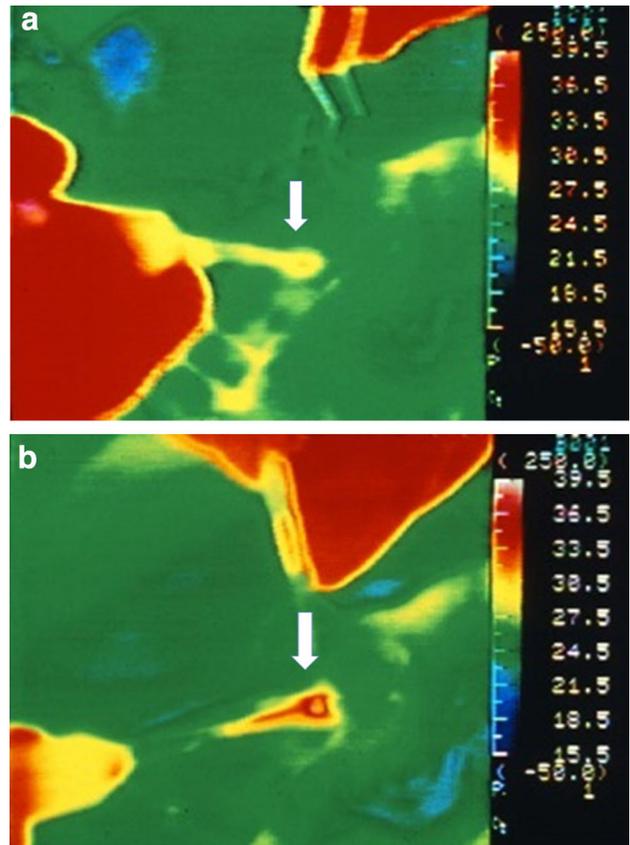
## Results

### Tip temperature change

#### *Open tip*

In all 3 eyes, the transducer part of the device became hot over time, and the thermograph showed red. However, the temperature rise at the tip part was comparatively mild and the thermogram showed a change to the color yellow (i.e., approximately 27.5–30.5 °C), where it remained (Fig. 1a). At the same time, some bubbles were observed in the lens around the ultrasonic tip, yet the lens around the tip insertion portion remained relatively transparent.

**Fig. 1** Tip temperature change. The temperature rise at the open tip was mild, and changed to the color yellow, where it remained (**a**, arrow). However, the temperature rise of the closed-tip was significant, and the thermogram showed a change to the color red (**b**, arrow)



### *Closed tip*

In all 3 eyes, the transducer part became hot over time, and the thermograph showed red. However, and unlike in the open-tip cases, the temperature rise of the tip part was remarkable and the thermogram color remained red (i.e., approximately 30.5–39.5 °C) (Fig. 1b). At the same time, the interior of the lens became cloudy with numerous bubbles around the ultrasonic tip, and lens transparency markedly decreased.

### Microscopy examination of the scleral wound

In the 3 open-tip cases, the scleral wounds retained the linear incisions cut with the 20G V-lance, and the vitreous cavity was barely exposed (Fig. 2a). However, in the 3 closed-tip cases, the sclera of the scleral wound markedly contracted due to the heat, the wound opened to a gradually larger size, and some ciliary body tissues and vitreous body were exposed (Fig. 2b).

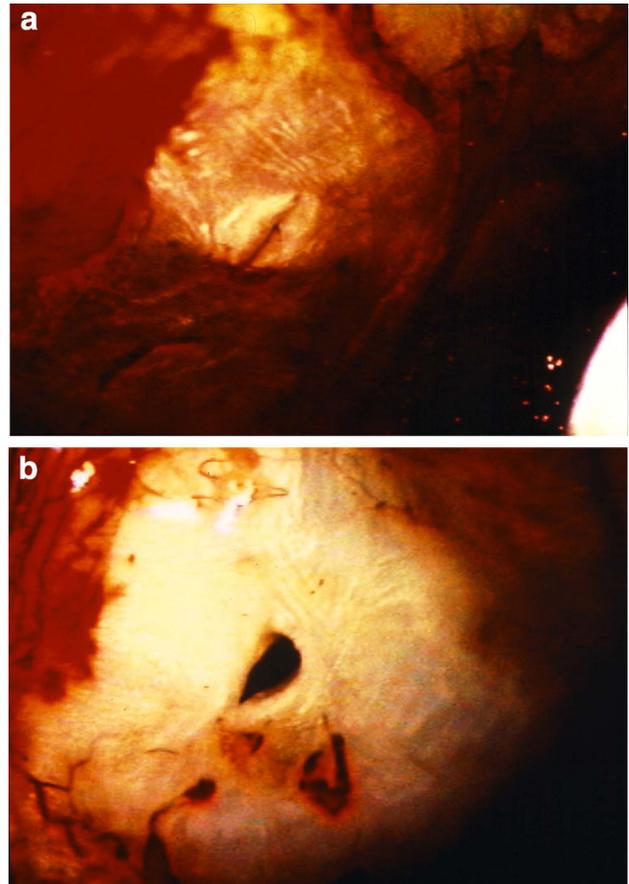
### Histological examination of the scleral wound post surgery

Similar to the postoperative surgical-microscopy findings, in the 3 open-tip cases, histological examination revealed mild degeneration of the sclera around the scleral wound (Fig. 3a, 4a), yet in the 3 closed-tip cases, there was prominent contraction of the sclera and tissue injury due to heat (Fig. 3b, 4b).

### Discussion

Although the number of patients who undergo PPPEA has decreased, it is still a useful surgical method for treating hard lens tissues in such cases as lens subluxation, a dropped lens nucleus, and rigid residual lens material after congenital cataract surgery, etc. [2]. Moreover, since it can be performed as an additional procedure of vitreous surgery, it eliminates the need to create a sclerocorneal wound on the upper side. Since the conjunctiva can be preserved, there are advantages

**Fig. 2** Microscopy examination of the scleral wound post surgery. In the open-tip case, the scleral wound retained the linear incision cut with the 20-gauge V-lance (Alcon Laboratories), and the vitreous cavity was barely exposed (a). However, in the closed-tip case, the sclera of the scleral wound became markedly contracted due to heat, the wound gradually opened larger, and some ciliary body tissues and vitreous body were exposed (b)



in cases where glaucoma filtration surgery has been performed and/or is planned in the future.

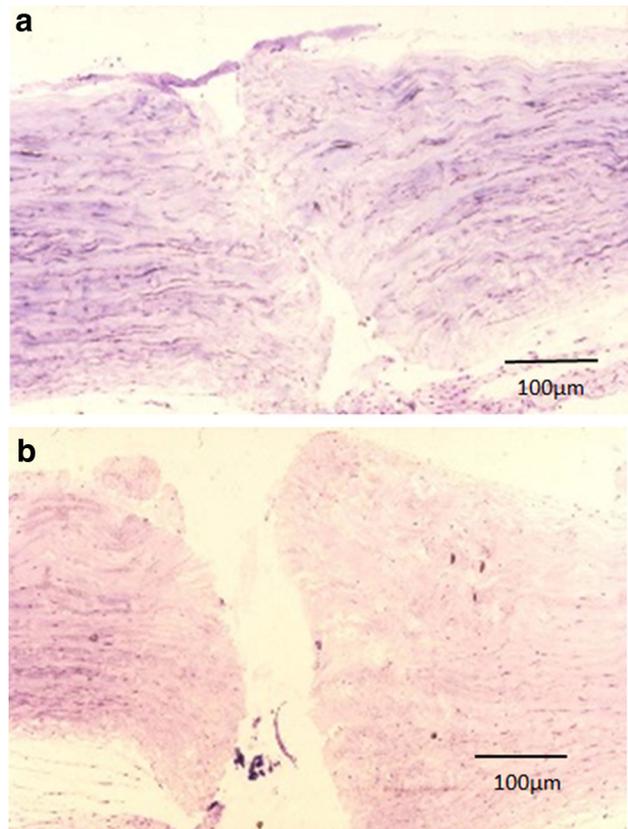
Although the use of MIVS has now become widespread, having PPPEA as an additional surgical option provides a flexible treatment strategy in various difficult cases and intraoperative problems. Due to recent advancements in MIVS, it has now become possible to remove the lens by use of a 23G or 25G vitreous cutter alone in cases of soft nuclei [9, 10], yet in the cases of rigid nuclei there is still a limit. Recently, a few studies have reported methods of using a 20G Fraxiom<sup>TM</sup> in combination with MIVS [11–15], and other studies have reported methods of inserting the Fraxiom<sup>TM</sup> into the vitreous cavity from sclerocorneal wounds when necessary [16, 17].

However, and as numerous surgeons who perform PPPEA have experienced, there is no mantle of the tip in this system, so thermal injury on the scleral wound by the tip itself becomes a problem. During normal

ultrasound phacoemulsification and aspiration (PEA), thermal injury at the corneal wounds is slight due to the cooling effect on the tip by the perfusion in the sleeve. However, in PPPEA where the tip is exposed, thermal damage can occur. Numerous previous studies have reported thermal damage caused by tips used for ordinary ultrasound PEA on the corneal wound [3–7]. However, and to the best of our knowledge, there have been no previous studies of thermal damage to the scleral wound by the tip used during PPPEA using an animal-eye model. Therefore, in this present study, we thermographically and histologically examined the degree of thermal damage in the scleral wound of PPPEA using pig eyes.

It is well known that in PPPEA, as well as in ordinary PEA, if the lens tissue is clogged in the tip, a rapid temperature rise occurs [18]. Particularly in cases in which rigid nuclei is sucked, the tip tends to get occluded (i.e., clogged) by the nuclear particles. Since pig eyes have no nucleus [19], the lens is

**Fig. 3** Histological examination of the scleral wound post surgery. Similar to the postoperative microscopy findings, in the open-tip case, there was mild degeneration of the sclera around the scleral wound (a). However, in the closed-tip case, there was prominent contraction of the sclera and tissue injury due to heat (b)



relatively soft and occlusion caused by lens tissue is rare. Therefore, in this study, thermal injuries occurring in scleral wounds were examined for two specific cases, ‘open tip’ and ‘closed tip’ with intentionally buried chestnuts.

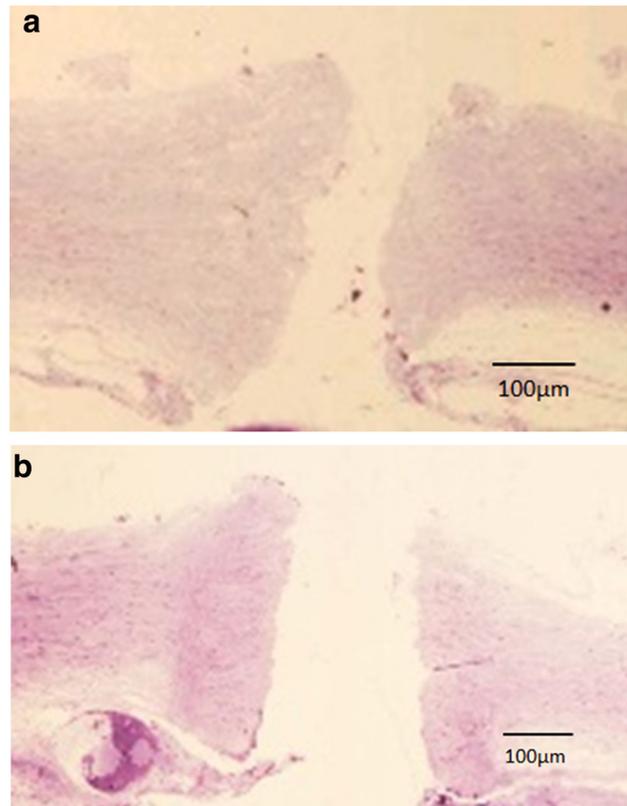
Although thermography examination revealed only slight heat generation in the open-tip case, heat generation was clearly evident in the closed-tip wound under the same conditions. In addition, microscopy examination performed at the end of surgery revealed that the sclera around the linear incision was only slightly contracted in the open-tip case, yet in the closed-tip case, the sclera was markedly contracted due to heat, ultimately resulting in a gradual opening of the wound, consistent with frequently observed clinical results. Histological examination indicated similar results.

In previous studies by Tsuneoka et al., the authors reported making the sclerocorneal wound smaller by performing ultrasound PEA while perfusing from the side port via another route with the mantle of the ultrasonic lens tip removed, as well as examining the

thermal damage of the sclerocorneal wound [20, 21]. Their findings revealed that when the perfusate leaks into the surroundings of the tip to some extent, the thermal damage is not very strong, yet if the leak is small, the thermal damage easily occurs. Similar to this present study, they used a pig eye when examining the phenomena of heat generation using a thermogram and a thermometer when first testing their procedure, and their findings revealed that the generation of heat depends on the amount of perfusate around the tip.

As the findings described above illustrate, in order to minimize the thermal damage of scleral wounds when PPPEA is performed, a somewhat larger scleral wound can be prepared in advance and lensectomy can be performed while leaking intraocular irrigating solution to some extent in the periphery of the tip. However, with this method, the vitreous body and the ciliary body tissue will be incarcerated to the wound, which increases the risk of causing complications such as iatrogenic oral dialysis. Currently, and as a conceivable method to prevent thermal damage, in addition to the surgical assistant continuously

**Fig. 4** Histological examination of the scleral wound in two other cases post surgery. Similar to the cases shown in Fig. 3, in the open-tip case, there was mild degeneration of the sclera around the scleral wound (a). However, in the closed-tip case, there was prominent contraction of the sclera and tissue injury due to heat (b)



applying the perfusion solution to the scleral wound during the operation, it is important to be aware of numerous bubbles around the tip caused by nucleus fragments, and the like, creating blockage of the tip. When such bubbles are observed, oscillation of the ultrasonic waves should immediately be discontinued and the nuclear fragments clogging the tip should be removed prior to continuing surgery. It should be noted that the setting of the ultrasonic oscillator at the time of performing PPPEA is important, as the suction pressure should be set somewhat higher (i.e., at 300–400 mmHg) and the ultrasonic power needs to be properly adjusted in accordance with the hardening of the nucleus. It is also important to occasionally keep an interval of the ultrasound oscillation while paying attention to ocular collapse during surgery.

In conclusion, the findings in this study show that with proper procedures it is possible to minimize the thermal injury to the scleral wound during PPPEA.

**Acknowledgements** The authors wish to thank John Bush for editing the manuscript.

#### Compliance with ethical standards

**Conflict of interest** The authors declare that they have conflicts of interest.

**Ethical approval** This article does not contain any studies with human participants and animals performed by any of the authors.

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