Robotic Surgery in Ophthalmology

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1. Introduction

Innovations in ophthalmology have developed rapidly in recent years with the advent of small incision surgery and the engineering of more efficient phacoemulsification and vitrectomy machines(Georgescu, Kuo et al. 2008; Hubschman, Bourges et al. 2009). We feel that these latest developments lend themselves to the mechanization of ocular surgery, and the next major advancement in ophthalmology will probably be the integration of robotics. The potential benefits of robotic surgery in ocular surgery include increased precision, elimination of tremor, reduction of human error, task automation and the capacity for remote surgery.

In increasing complexity and with distinct demands, ocular procedures can be grouped as extraocular surgery, intraocular anterior segment surgery, or intraocular posterior segment surgery. Intraocular surgery currently requires state of the art operating microscopes. Although the requirement of specialized microscopes and visualization systems presents a challenge to the adaptation of robotics in ocular surgery, robotic surgery has the capacity to include new visualization devices such as digital microscopy and/or endoscopy, which would be an advantage over conventional operating microscopes.

The purpose of this chapter is to present the unique issues of ocular surgery in the application of robotics and to summarize the progress which has already been made towards the goal of robotic ocular surgery for clinical patient care. We will also discuss the previous and current ocular robotic prototypes and the utilization of surgical motion sensors to assess the mechanical requisites of eye surgery.

2. Early ocular surgery robotic prototypes

One of the first ocular robotic systems was described by Guerrouad and Vidal in 1989. (Guerrouad & Jolly 1989; Guerrouad & Vidal 1989; Guerrouad & Vidal 1991; Hayat & Vidal 1995). It was called the Stereotaxical Microtelemanipulator (SMOS) and included a spherical micromanipulator mounted on a x, y, z stage, which allowed 6 degrees of freedom. This prototype was fabricated and performance tests were completed. Yu et al developed in 1998 a patented spherical manipulator, similar to Guerrouad and Vidal, for intravascular drug

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delivery, implantation of microdrainage devices and the intraretinal manipulation of microelectrodes. These tasks were successfully carried out with minimal tissue damage(Yu, Cringle et al. 1998) (Figure 1).

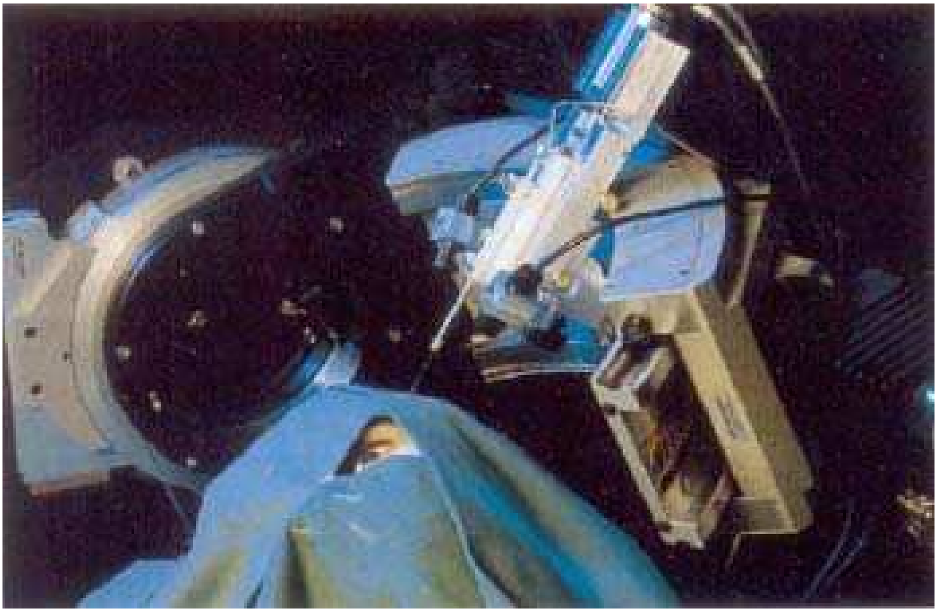

Fig. 1. Picture of one of the earliest ocular robotic prototypes in position related to the head. From Yu, D. Y., S. J. Cringle, et al. (1998). "Robotic ocular ultramicrosurgery." Aust N Z J Ophthalmol 26 Suppl 1: S6-8.

These first prototypes already had an adapted remote centre of motion for intraocular surgery as well as a relatively good range a motion but they were too premature to raise a tangible interest for further development.

In 1997, Steve Charles and collaborators described a new telerobotic platform which was called Robot Assisted MicroSurgery (RAMS)(Charles S 1997)(Figure 2). This lightweight and compact 6 DoF master-slave system demonstrated 10 microns of precision and a wide range of motion. The slave robot arm (2.5 cm in diameter and 25 cm long) and the master device were built with associated motors, encoders, gears, cables, pulleys and linkages that caused the tip of the robot to move under computer control and to measure the surgeon's hand precisely. The 3 joints of the arm were torso joint rotating about an axis aligned with the base axis. This design allowed low backlash, high stiffness, fine incremental motion and precise position measurement. The complexity of the software control as well as the lack of mechanical remote center of motion were the main limitations of this model.

In 1997, a laboratory in Northwestern University needed to measure the intraluminal pressure inside feline retinal vessels as well as extract retinal blood samples for research purposes. The retinal vessels ranged in internal diameter from 20 to 130 microns. The researchers were unable to achieve this goal with human dexterity, and therefore designed another one of the earliest ocular surgery robotic prototypes(Jensen, Grace et al. 1997). The prototype used the Stewart based platform which had already established its place in machine tool technology (Figure 3).

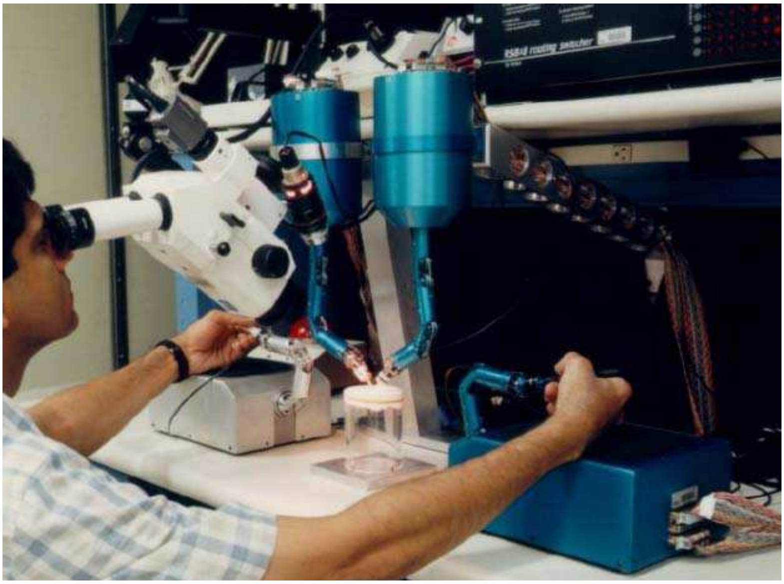

Fig. 2. RAMS master slave robotic system. From Charles S, D., H, Ohm T (1997). "Dexterity-enhanced tele-robotic microsurgery." Proc. IEEE int conf adv Robot.

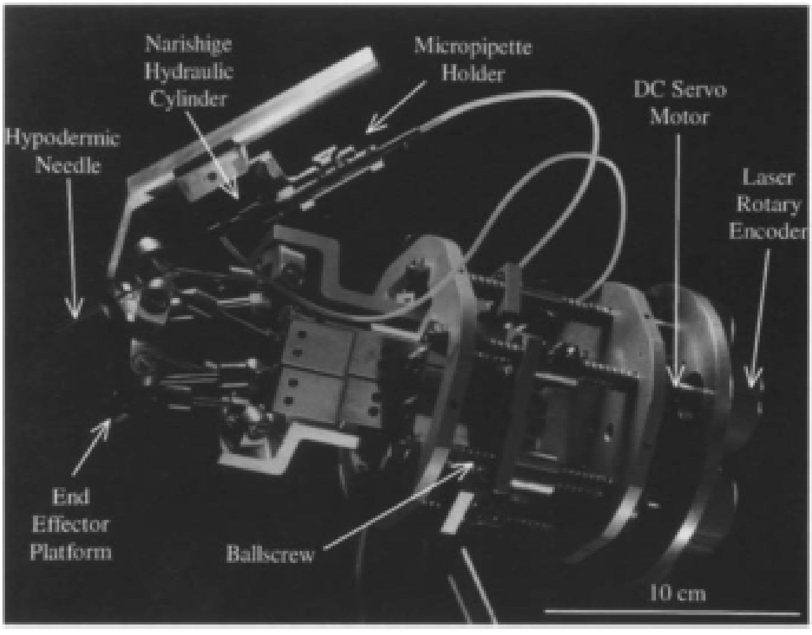

Fig. 3. Photograph of the robotic manipulator based on a stewart platform design. From Jensen, P. S., K. W. Grace, et al. (1997). "Toward robot-assisted vascular microsurgery in the retina." Graefes Arch Clin Exp Ophthalmol 235(11): 696-701.

Advantages of the effector platform design in this early prototype were its inherent stiffness, ability to pivot, and capacity to perform large displacements. Ball screws were rotated using DC servo motors and laser rotary encoders tracked their motions. The device was capable of operating in 6 degrees of freedom with both translational and rotational motion (x,y,z, pitch, roll, and yaw). The operator controlled the slave arm by using a handheld trackball and two buttons, and the intended direction of motion was entered into the computer software before performing it. This control mechanism which was practical at the time for laboratory research purposes may not be the best input system today because the motions needed for modern day eye surgery are more complicated and the robot effector in ocular surgery needs to respond more quickly. Nonetheless, the constructed device was successfully used to cannulate and take samples from retinal blood in anesthetized cats for laboratory use.

3. Current ocular robotic prototypes

3.1 *Da Vinci* surgical system

At present, the Food and Drug Administration approved *da Vinci* Surgical System (Intuitive Surgical, Sunnyvale, CA), is the most commonly employed robotic platform in human surgery (Figure 4). It is being used routinely in fields such as general surgery, urology, gynecology, and cardiac surgery(Diaz-Arrastia, Jurnalov et al. 2002; Hemal & Menon 2004; Katz, Van Praet et al. 2006; Kumar & Hemal 2006; Kypson & Chitwood 2006). This design consists of three robotic slave arms that are controlled by the surgeon via a remote console. Image capture is achieved with a dual-channeled endoscope on one of the arms, and a binocular viewfinder on the remote console allows stereoscopic viewing. In 2006, our team started to evaluate the possibility of performing ocular surgery with the *da Vinci* Surgical System(Bourla, Hubschman et al. 2008).

Fig. 4. The *da Vinci* surgical master (right) and slave (left) platform at the CASIT Center for Advanced Surgical and Interventional Technology at the University of California, Los Angeles.

3.1.1 Extraocular surgery

A typical scenario in ocular surgery is closing a partial thickness corneal laceration after surgical or accidental trauma. This relatively simple to perform maneuver is most similar to surgery on other parts of the body. Therefore, we elected to start testing the *da Vinci* Surgical System in ocular surgery with the task of closing a full thickness corneal and scleral laceration created on an enucleated porcine eye (Tsirbas, Mango et al. 2007). Portions of corneal wound closure such as passing the needle in a smooth arc through the tissue and throwing knots squarely were successfully carried out using *da Vinci* Surgical System (Figure 5). There was human assistance with steps such as loading the needle and cutting the suture.

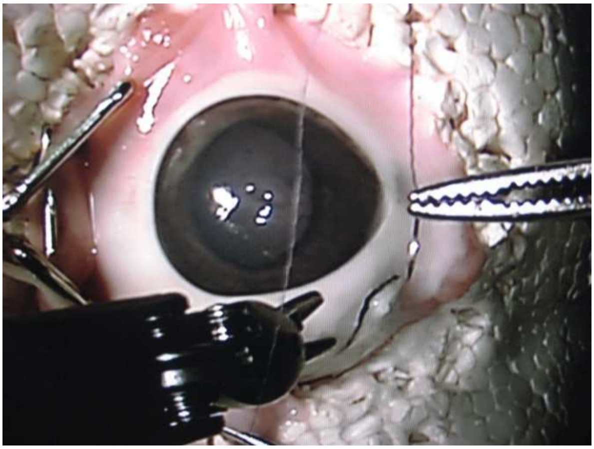

Fig. 5. A porcine eye with a full thickness scleroconjuntival wound is being sutured using the *da Vinci* surgical platform.

These early experiments used 10-0 nylon suture, which is the standard for corneal wound closure; however, the smallest suture typically used with the *da Vinci* needle holders are 7-0 Prolene suture in cardiac surgery. There was some bulkiness of the *da Vinci* needle holder when compared with traditional ocular surgery needle holders. Future work should include miniturizing the needle holders for ocular surgery as well as incorporating additional components to automate tasks which were performed by humans such as loading the needle and cutting the suture.

Visualization is important in all surgery, but paramount in ocular surgery and prior to these experiments it was unknown whether adequate visualization for ocular surgery could be achieved with the original design of the da Vinci endoscope. An important conclusion was that the mounted endoscope provided adequate image capture and depth perception for extraocular surgery.

3.1.2 Intraocular anterior segment surgery

Cataract surgery, the most common ocular surgery procedure performed in the United States, was attempted robotically with the *da Vinci* Surgical System. The feasibility of performing intraocular cataract surgery in enucleated porcine eyes was assessed with the commercially available *da Vinci* Surgical System combined with standard ocular surgery instruments.

An important principle in modern day cataract surgery is to create a biplanar self-sealing wound through the clear cornea and to manipulate this opening as little as possible

intraoperatively in order to maintain constant pressure inside the eye for the purposes of controlling hemostasis and maintaining the shape of the eye. This self-sealing wound was difficult to achieve with the *da Vinci* system because wound gape constantly let fluid egress out of the eye, allowing the eye to collapse and lose its spherical shape.
The major problem was that the remote center of motion of the *da Vinci* surgical arm was preset and located 9 cm away from the surface of the eye (Figure 6). The major emphasis of these initial trials of cataract surgey using robotics was that to make instrument movement safe during intraocular surgery, the remote center of motion (or pivot point) must be at the surface of the eye.

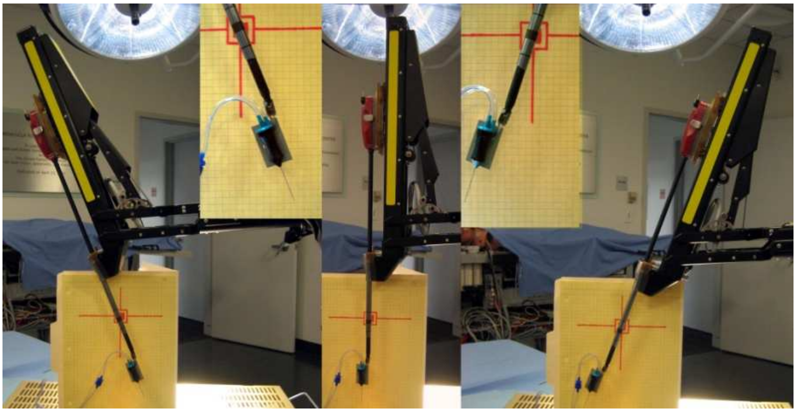

Fig. 6. Visualization of the Remote Centre of Motion (RCM) and its distance from the tip of the forceps.

To augment visualization during cataract surgery, retroillumination is a valuable technique that increases contrast between two transparent tissue planes. This is carried out by aligning the viewing microscope to be co-axial with the light source which allows light to be reflected out of the eye and illuminate ocular tissue from behind. This optical phenomenon of retroillumination was not possible using the *da Vinci* endoscope for visualization because the comparatively bulky endoscope arm and illumination source could not be lined up coaxially. Nevertheless, the dual channel endoscope offered a sufficient optical resolution of the surgical target to perform anterior segment eye surgery.
On the other hand, a bimanual teleoperated robotic penetrating keratoplasty (PK) has been succesfully performed with the *da Vinci* in porcine and human eyes with no difficulties. The precise placement of continuous sutures was facilitated by the wrested-end forceps. The anatomic contours of the orbital rim and nose did not limit the range of surgical motions(Mulgaonkar, Hubschman et al. 2009).

3.1.3 Intraocular posterior segment surgery

Intraocular posterior segment surgery, which is more complex than anterior segment intraocular surgery, was attempted robotically(Bourla, Hubschman et al. 2008). Pars plana vitrectomy is the most common intraocular posterior segment surgery performed in the United States. The *da Vinci* Surgical System was used to perform pars plana vitrectomy using standard 25-gauge vitrectomy instruments (Figure 7 and 8). The commerically available vitrectomy handpieces were adapted with magnets so that they could be stored for easy and independent pick up by the robotic slave arm forceps.

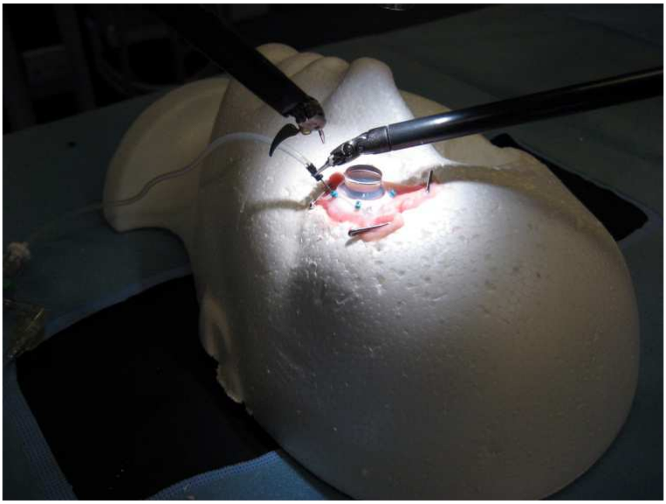

Fig. 7. The *da Vinci* surgical system was used to insert 3 trans-scleral cannulas which is necesaary for minimally invasive vitrectomy surgery. In addition to axial motion, the wrist-like tips of the robotic instruments have roll, pitch, yaw and grip to facilitate delicate manipulations.

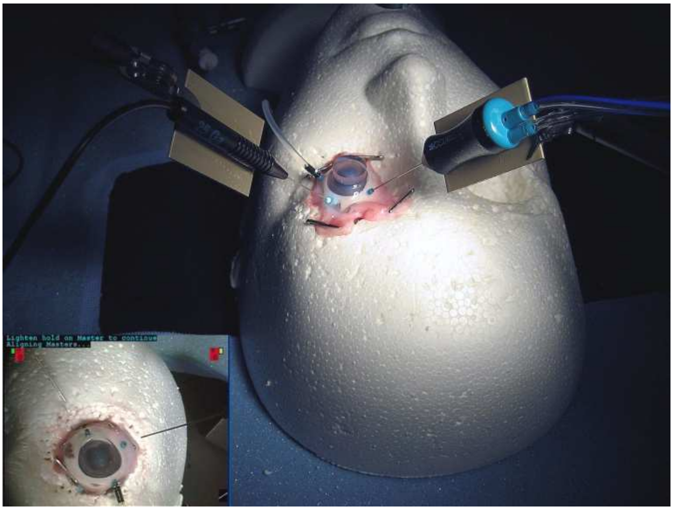

Fig. 8. Insertion of the modified 25-gauge vitreous cutter and endo illuminator with the robotic arms. Left corner - high magnification view through the robotic endoscope.

In our experiments, wound entry using a 25-gauge vitrectomy system was easier than in cataract surgery because of surgically inserted ports which facilitated and guided instruments into the eye. However, the remote center of motion (or pivot point) still needed to be located at the surface of the eye to control intraocular maneuveability and avoid distortion of the globe. As discovered during trials of anterior segment surgery, this was not possible with the *da Vinci* Surgical System because its pivot point was preset 9 cm from the tip of the instrument.

The image quality of the endoscope, although adequate for external eye surgery was not to the standards of microscopes typically used for intraocular surgery. Also, the limited field of view of the endoscope required constant repositioning when entering the eye for vitrectomy surgery, which was tedious and impractical.

Furthermore, vitrectomy surgery needs specialized microscopes, lenses, and image inverters to make intraocular visualization optically possible. Lack of this telescope system with the *da Vinci* Surgical System made posterior segment intraocular surgery impossible to achieve.

3.1.4 *da Vinci* surgical system summary

With the above earliest attempts at extraocular surgery, intraocular anterior segment surgery, and intraocular posterior segment surgery, there were general observations made regarding the use of the *da Vinci* Surgical System in ocular robotic surgery. Wrist turning movements seemed intuitive and facile to perform, and x-y planar movements using robot arms were well suited for ocular surgery when kept in a limited surgical field .

In conclusion, using the *da Vinci* Surgical System, extraocular surgery was carried out successfully, although imperfect due to the large size of the instrument tips and incomplete automation. Intraocular surgery, both anterior and posterior segment procedures, were difficult and limited due to the preset pivot point on the *da Vinci* instrument arms being external to the eye. Future work in ocular robotic surgery will need to include improving visualization systems such as with digital microscopy or endoscopy and more importantly incorporating an adapted remote center of motion during intraocular procedures.

3.2 Hexapod surgical system

To overcome the remote center of motion problem for intraocular surgery posed by the *da Vinci* Surgical System, we sought to modify this macrorobot with the addition of a microrobotic platform. We chose to combine the *da Vinci* system with the Stewart based manipulator, described above, because it had six degrees of motion and was originally designed for robot-assisted cannulation of retinal vessels with success (Jensen, Grace et al. 1997).The platform had a parallel manipulator with a fixed based and used an octahedral assembly of struts.

The Stewart platform was customized to fit onto the arms of the *da Vinci* Surgical System, and the combined device was named the Hexapod Surgical System (Figure 8). Its major advantage over the *da Vinci* Surgical System alone was the ability to place the remote center of motion at the site of ocular penetration using automated software. As described above, this was the major limitation of the *da Vinci* system alone which prevented further progress towards the application of robotics in intraocular surgery.

The remote center of motion, controlled by software on the Hexapod Surgical System, was able to constantly reposition the pivot point of the intraocular instruments to be located at the entry point. Each actuator was also equipped with a linear potentiometer type sensor to facilitate feedback control by the computer. As an additional safety measure, tasks performed with the Hexapod Surgical System were limited to joystick movements that maintained the remote center of motion at the ocular surface.

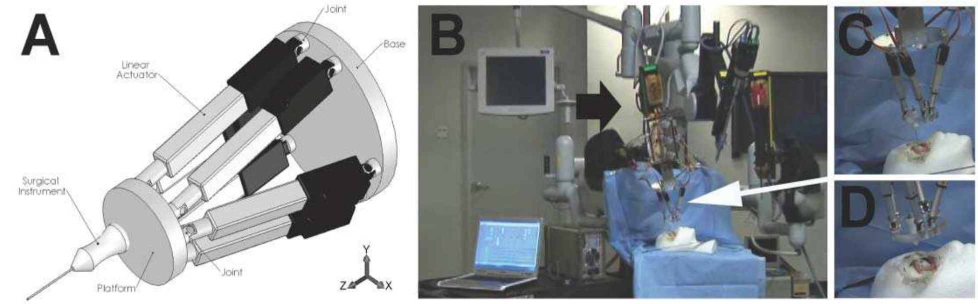

Fig. 8. The Hexapod Surgical System (HSS) consists of a Stewart Platform (A). The protype (B) was built based on six linear actuators changing length when remotely given a command voltage. The HSS is able to integrate the *da Vinci* robot (C) to adapt a second RCM to the needs of intraocular microsurgery (D). The probe held by the Hexapod Surgical System easily entered the targeted sclerotomy when remotely actuated by using a dedicated joystick that could be adapted to the *da Vinci's* command console (B,C,D).

Experiments were designed to assess the range of motion of the Hexapod Surgical System in vitro as well as while penetrating the eye during simulated vitrectomy in enucleated porcine eyes (Mulgaonkar, Hubschman et al. 2009). Briefly, platform rotations around the desired range of motion of instruments were simulated using MATLAB code to predict the required change in leg length by the inverse kinematics calculation. A vitreous cutter or any other intraocular instrument could be positioned on the Hexapod Surgical System's platform.

The results showed that maximum translations with the Hexapod Surgical System were 10 cm (x, y-planes) and 5 cm (z-plane). Mean translation and angulation stabilities at the tip of the probe were 1.2 mm and 1 mm, respectively. When a vitreous cutter attached to the Hexapod arm was inserted into porcine eyes through 20-gauge sclerotomy sites, there was minimal tension observed at the site of ocular penetration indicating that the remote center of motion could be maintained in the correct location.

The major limitation of the Hexapod Surgical System causing it to be not adequate for modern eye surgery was its limited translation and angulation ability. Essentially, the instruments were confined to a 30 degree cone inside the eye. In retinal surgery, it is important to have access to the periphery where there is often pathology such as retinal tears or vitreous traction. This range of motion might have been large enough for the original intent of the Stewart platform, namely retinal vessel cannulation, but it was not adequate for more general applications of posterior segment intraocular surgery such as pars plana vitrectomy. The problem was that the ball bearing joints which connected the legs of the Stewart platform were spherical, allowing only 30-40 degrees of maximum swivel. This range of motion was further decreased as the remote center of motion was placed futher away from the center of the Stewart platform.

In summary, combining the *da Vinci* Surigcal System with the Stewart platform to create the Hexapod Surgical System solved the problem of a dynamic remote center of motion in intraocular surgery. This novel device also demonstrated a high level of precision and dexterity, but its major limitation was a restricted range of angulation when used inside the eye (Mulgaonkar, Hubschman et al. 2009).

3.3 Surgical microhand

An advantage of ocular robotic surgery over traditional ocular surgery is the ability for increased dexterity beyond the limits of human adroitness. Towards this goal, we wanted to design dedicated microinstruments to be used in robotic intraocular eye surgery. The first instrument specially designed for ocular robotic surgery at the University of California, Los Angeles, was a pneumatically operated micromanipulator, called the microhand (Figure 9). It consisted of balloon-based joints and interconnecting silicone phalanges (Hubschman, Bourges et al. 2009).
The motion of the microhand was driven by compressed air and pneumatic actuation technology. This was ideal for intraocular posterior segment surgery because vitrectomy consoles used this same technology to power vitreous cutters. In the future, the microhand and currently available vitrectomy system could be combined into one piece of equipment, both using the same pneumatic actual technology.

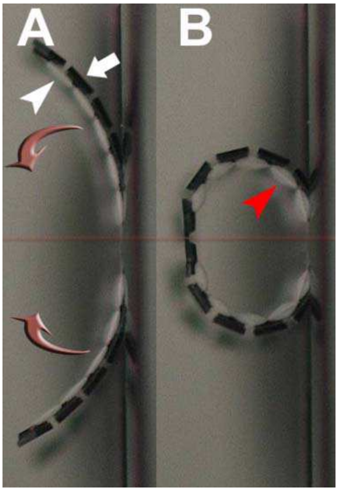

Fig. 9. The Microhand forceps is a four-fingered Microhand articulated by six silicone phalanges (A, white arrow) and joined by inflatable balloons (A, arrow heads). When balloons are inflated (B, red arrow head), fingers are incurved (A, red arrows and B) and face themselves along the central axis (red line). From Hubschman, J. P., J. L. Bourges, et al. (2009). "'The Microhand': a new concept of micro-forceps for ocular robotic surgery." Eye.

The microhand designed for ocular surgery trials had 4 mm-long x 0.8 mm-wide fingers with 6 micron thick inflateable balloons. When compressed air was introduced into the microhand, the balloon joints inflated and the attached silicone phalanges made out of plane motions. Each finger was a a six-phalange and six-balloon system which curled in response to compressed air, mimicking the action of a human finger (Figure 9). The microhand device was designed to achieve a large lifting force which was measured by using coil-shaped metallic weights of known mass.
The microhand was tested for ocular surgery use on flat-mounted porcine eyes to assess its functional capacity. Retinal tissue was manipulated by displacing it a pre-set distance without damage by carefully controlling the amount of pressure created with compressed air. A 65 psi (448 kPA) air pressure was necessary to pinch the retina, and the applied force

for this maneuver was estimated to be less than 5 mN. The promising results of these studies was not only a novel application of the previously developed surgical microhand, but it also allowed a way to quantitate pressure exerted on ocular tissues which will be important when piloting ocular robotic surgery in the future.

3.4 The steady hand manipulator

Russel Taylor and his team at the Johns Hopkins University developped a steady-hand robotic system for microsurgery(Taylor, Jensen et al. 1999; Mitchell B 2007). This robotic system, described for the first time in 1999, was designed to extend a human's ability to perform small-scale manipulation tasks requiring human judgment, sensory integretion and hand-eye micromanipulation. With this device, the intraocular surgical tool is held simultaneously both by the operator's hand and the specially designed actively controlled robot arm. The robot controller senses forces applied by the surgeon on the surgical tool and uses them to provide smooth, tremor-free, precise and scaled motion of the arm. The device includes an adapted RCM for intraocular surgery and 5 degrees of freedom (Figure 10). The first prototype has been recently optimized and tested on a biological model. The successful cannulation of an 80 micron vein was rapidly and reliably achieved with minimal dammage to the surrounding tissues.

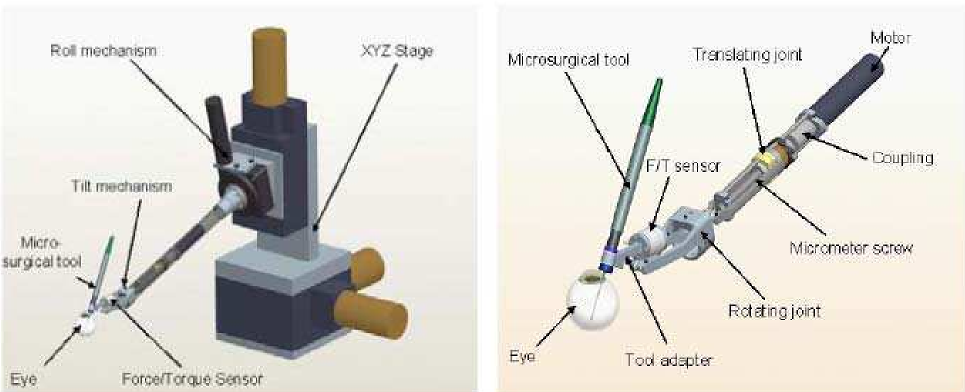

Fig. 10. Robot mechanical system: general view (left) and tilt mechanism (right). From Mitchell B, K. J., Iordachita I, et al (2007). "Development and application of a new steady-hand manipulator for retinal surgery." Proc IEEE Int conf Robot.

3.5 Japanese ocular robotic prototype

As already indicated, intraocular posterior segment surgery was the most demanding of ocular procedures and the most difficult to translate into robotic surgery. Recently, Ueta et al. demonstrated success with intraocular posterior segment surgery with a custom built micromanipulator prototype (Ueta, Yamaguchi et al. 2009). The controle console communicated with the slave arm in real time with a custom computer console. The high-definition video camera was capable of 2010 x 1096 pixel resolution with steroscopic image capture using a beam splitter. The surgeon obtained a three-dimentional view of the operating field using a prism lens viewer.

This robotic instrument was constructed with a pair of spherical guides, allowing x-axis and y-axis planar motion as well as the ability to push and pull, which allowed for z-axis movement with 5 degrees of freedom. The remote center of motion was set at the entry point of the eye to reduce stress on the eye. Ophthalmic surgical instruments such as a microscissor, microforcep, microneedle, and microcannula were attached at the tip to perform intraocular posterior segment procedures.

Experiments were carried out to test pointing accuracy using graph paper as well as to assess the feasibility of performing posterior vitreous detachment, retinal vessel sheathotomy, and retinal vessel microcannulation in porcine eyes. The group reported success with all these procedures, except for retinal vessel microcannulation. They attributed the achievement of this task to be limited by visualization difficulty given the lack of contrast of retinal vessels in enucleated porcine eyes.

4. Surgical motion sensors

As progress continued towards applying robotics to ocular surgery, it became important to better define the range of motion and other spatial parameters of ocular surgery. Motions that are natural and innate for human hands to perform needed to be precisely measured to custom design robots to mimick the same movements. Therefore, we wanted to determine the range of motion required to carry out common intraocular surgical tasks. This was done with electromagnetic sensors which were capable of quantifying microscopic translational and angulational movements. Experiments were carried out using enucleated porcine eyes (Son, Bourges et al. 2009).

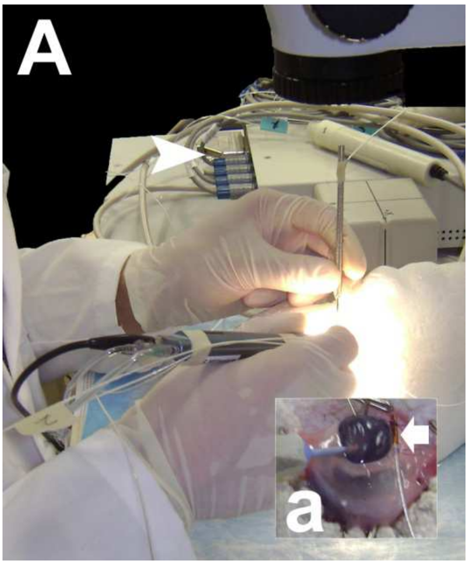

Fig. 11. (A) Porcine eyes were operated on with intraocular surgical instruments which were affixed to sensors connected to the control unit (white arrow-head). (a) To record motion at the entry site of instruments into the eye, a sensor was tightly sutured to the limbus (white arrow).

Electromagnetic sensors (MicroBird, Ascension Technology, Burlington, VT) were adapted to be surgical motion sensors by attaching them to instruments used in cataract surgery (i.e phacoemulsification handpiece, cataract chopper) and vitrectomy surgery (i.e. vitreous cutter, intraocular lightpipe) (Figure 11). These intruments were chosen to mimic typical bimanual surgical techniques in anterior segment and posterior segment surgery.
A reference sensor was sutured to the limbus of the porcine eye to detect and measure the motion relative to the eye during these procedures. Experienced ophthalmologists performed successive trials of cataract surgery and vitrectomy on porcine eyes as the x,y, and z coordinates of the intraocular instruments were continuously tracked. Maximal angulation areas of instruments were also determined for each surgical step.
The results of this study showed that robotic ocular surgery devices which hold instruments should be designed to allow a minimum translation of 3.65 cm, 3.14 cm, and 2.06 cm respectively in the x, y, and z-planes. A minimum angulation of 116 degrees and 106 degrees were needed intraocularly in the x and y-planes (Figure 12). This information is useful to assess currently available instruments as well as design upcoming instrument prototypes for intraocular robotic surgery.

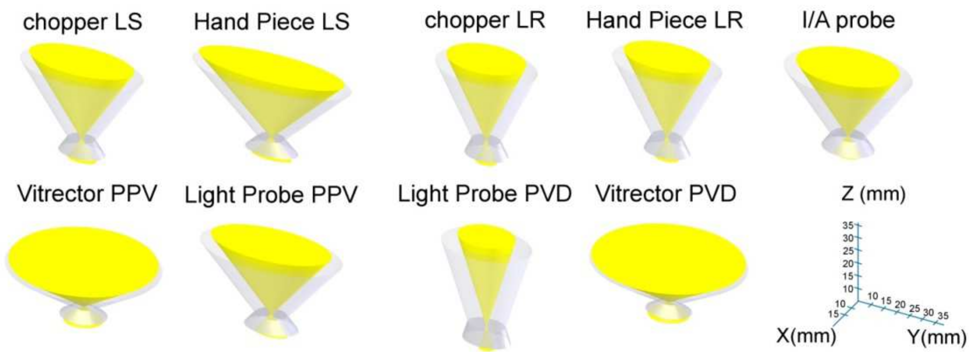

Fig. 12. The maximal angulation of each tool during various surgical steps (yellows areas) and standard deviations (gray areas) are plotted around a mean calculated position.

5. Further applications

Applications of robotic surgery include training and educating physicians in a safe, controlled, and feedback oriented way. Furthermore, with ongoing advancements, remote telesurgery and surgical automation may soon become a reality in the field of ophthalmology.

5.1 Training surgeons

Surgical training is an important part of ophthalmology residency, and there is much debate about the ideal way to safely and effectively teach ocular surgery (Goh 2009). There is no standardization of surgical experience during ophthalmology residency and in particular many training programs are not able to offer in depth experience in retinal procedures (Shah, Reddy et al. 2009).
Robotic ocular surgery would be an ideal adjunct to the methods now used to teach ocular surgery. Current means of ocular surgeon training rely on wet lab practice on porcine eyes

(Henderson, Grimes et al. 2009) and the use of computerized surgical simulators (Solverson, Mazzoli et al. 2009). Present day surgical skill assessment would include tools such as motion sensors and video grading which would lend itself to training physicians with robotic ocular surgery(Ezra, Aggarwal et al. 2009).

5.2 Telesurgery

In the *da Vinci* Surgical System, the control module was spatially separated from the robotic arm module. This made the idea of telesurgery possible. Telesurgery is the concept of the surgeon sitting in one location and operating on someone via a robot in another location.
In 2001, the first transatlantic robotically assisted remote surgery was performed on an animal model (Marescaux, Leroy et al. 2001), and this was followed by a transatlantic robot-assisted laparoscopic cholecystectomy in a human being (Marescaux, Leroy et al. 2002). Over the last several years, telesurgery has been demonstrated successfully on multiple occasions (Marescaux & Rubino 2004). Ocular robotic telesurgery may also be feasible in the future, bringing emergency eye care to remote locations.

5.3 Autonomous robots

In the distant future, we may see surgical robots with artificial intelligence and the resulting capacity to make surgical decisions and act on them without the input of a human being. More likely, in the coming years, we may see robots with the ability to perform a routine task independent from the controlling surgeon.

6. Conclusions

Ocular robotic surgery poses unique challenges such as intraocular accessibility, instrument refinement, and visualization. The diversity of ocular procedures requires a myriad of new instruments and surgical techniques, and the application of robotics to ocular surgery in humans will likely evolve in stages. Rapid progress in ocular robotic surgery has been made in recent years with the evaluation of the *da Vinci* Surgical System, the development of the Hexapod Surgical System, the creation of the surgical microhand, the utilization of surgical sensors, and the refinement of micromanipulators.
Advantages that robotic surgery offers include increased precision, improved range of motion, elimination of tremor, ability to maneuver in a confined anatomic space, reduced error, increased predictability, and increased surgeon safety. Future work will continue to integrate traditional surgical techniques with new devices to bring the advantages of robotics to the field of ophthalmology.

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Robotic surgery is still in the early stages even though robotic assisted surgery is increasing continuously. Thus, exact and careful understanding of robotic surgery is necessary because chaos and confusion exist in the early phase of anything. Especially, the confusion may be increased because the robotic equipment, which is used in surgery, is different from the robotic equipment used in the automobile factory. The robots in the automobile factory just follow a program. However, the robot in surgery has to follow the surgeon's hand motions. I am convinced that this In-Tech Robotic Surgery book will play an essential role in giving some solutions to the chaos and confusion of robotic surgery. The In-Tech Surgery book contains 11 chapters and consists of two main sections. The first section explains general concepts and technological aspects of robotic surgery. The second section explains the details of surgery using a robot for each organ system. I hope that all surgeons who are interested in robotic surgery will find the proper knowledge in this book. Moreover, I hope the book will perform as a basic role to create future prospectives. Unfortunately, this book could not cover all areas of robotic assisted surgery such as robotic assisted gastrectomy and pancreaticoduodenectomy. I expect that future editions will cover many more areas of robotic assisted surgery and it can be facilitated by dedicated readers. Finally, I appreciate all authors who sacrificed their time and effort to write this book. I must thank my wife NaYoung for her support and also acknowledge MiSun Park's efforts in helping to complete the book.

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