FEMTOSECOND LASER APPLICATIONS IN ANTERIOR SEGMENT SURGERY

Essay

Submitted for partial fulfillment of Master Degree in Ophthalmology

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Cairo 2011

تطبيقات ليزر الفيمتوثانية فى جراحات الجزء الأمامى من العين

رسالة

تمهيداً للحصول علي درجة الماجستير فى
طب وجراحة العيون

مقدمة من

الطبيبة/ كارولين عاطف جرجس توفيق
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القاهرة ٢٠١١

The FSL is a new surgical tool, almost anything in corneal surgeries can be done using this computer controlled laser knife. With the rapid development of the programs running these machines; modification of old techniques, discovering new approaches and inventing new procedures will be an applicable dream to future ophthalmology surgeons.

The FSL is an infrared laser that gives ultra fast pulses with a spot size of about 1 μm, FSL uses a wavelength of 1053 nm that can pass through the outer layers of the cornea with no effect on the tissue until it reaches the pre–programmed target. With the energy and firing pattern controlled by computer, the laser is capable of cutting tissue at various depths and patterns.

The laser essentially vaporizes small volumes of tissue by photodisruption, producing plasma, shock wave, cavitation, and gas bubbles. The laser spots may be fired in a vertical pattern for trephination (side) cuts or in a spiral or raster (zigzag) pattern to achieve lamellar cuts.

FSL applications in corneal and refractive surgeries are increasing day after day, at present, corneal flap creation in LASIK surgery is the most common application. Some studies have shown equivalency between the FSL and the mechanical keratome whereas other studies have reported improved visual results.

Advantages of FSL over mechanical microkeratomes include: reduced incidence of flap complications such as buttonholes, epithelial abrasions, short flaps, and free caps (some

Acknowledgment

First and foremost, I'd like to thank God who had given me the power to follow my passion and patience to pursue my dreams.

It would not have been possible to write this essay without the help and support of the kind people around me, to only some of whom it is possible to give particular mention here.

Above all, I would like to thank my husband Adel for his personal support and great patience at all times. My parents, and brother have given me their unequivocal support throughout, as always, for which my mere expression of thanks likewise does not suffice.

This work would not have been possible without the help, support and patience of my principal supervisor, Prof. Bahaa Eldin Abdallah. The good advice and support of my second supervisor, Dr. Ahmed Hosni, has been invaluable on both an academic and a personal level, for which I am extremely grateful.

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ABBREVIATIONS

AC : Anterior Chamber
ACI : Acufocus Corneal Inlay
AH : Aqueous Humour
ALK : Anterior Lamellar Keratoplasty
AMO : Advanced Medical Optics
ASOCT : Anterior Segment Optical Coherence Tomography
BCVA : Best Corrected Visual Acuity
BSCVA : Best Spectacle Corrected Visual Acuity
BSS : Balanced Salt Solution
CCI : Clear Corneal Incision
CCT : Central Corneal Thickness
CDVA : Corrected Distance Visual Acuity
CPD : Cycle Per Degree
CQ : Clinical Quality
CS : Contrast Sensitivity
CXL : Collagen Cross-Linking
D : Dioptre
DALK : Deep Anterior Lamellar Keratoplasty
DLEK : Deep Lamellar Endothelial Keratoplasty
DLK : Diffuse Lamellar Keratitis
DM : Descemet's Membrane
DSAEK : Descemet Stripping Automated Endothelial Keratoplasty
DSEK : DESCEMET Stripping Endothelial Keratoplasty
ELP : Effective Lens Position
FAB : Femtosecond Assisted Diagnostic Corneal Biopsy
FALK : Femtosecond-Assisted Anterior Lamellar Keratoplasty
FALT : Femtosecond-Assisted Anterior Lamellar Corneal Staining–Tattooing

FDA : Food and Drug Administration

FDALK: Femtosecond-assisted Deep Anterior Lamellar Keratoplasty

FDOCT: Frequency-Domain OCT

FLAK : Femtosecond Laser Assisted Keratoplasty

FLEK : Femtosecond-assisted Endothelial Keratoplasty

FLEx : Femtosecond Lenticule Extraction

FS-AK : Femtosecond Laser Assisted Astigmatic Keratotomy

FSL : Femtosecond Laser

GUI : Graphical User Interface

HOAs : High Order Aberrations

ICRS : Intrastromal Corneal Ring Segments

IOLs : Intraocular Lenses

IOP : Intraocular Pressure

IR : Infra-Red

J : Joule

KHz : Kilo Hertz

KP : Keratoplasty

LAR : Laser Arcuate Wedge Shaped Resection

LASIK : Laser in SITU Keratomileusis

LIOB : Laser Induced Optical Breakdown

LOCS : Lens Opacities Classification System

LRI : Limbal Relaxing Incision

MHz : Mega Hertz

mJ : Milli Joule

MK : Microkeratome

mm : Millimeter

Nd : Neodymium-Doped

YAG : Yttrium Aluminium Garnet

nJ : Nanojoule

nm : Nanometer

NPDS : Non-Penetrating Deep Sclerectomy

ns : Nanosecond

OBL : Opaque Bubble Layer

OCT : Optical Coherence Tomography

ODM : Ophthalmodynamometer

PK : Penetrating Keratoplasty

PMMA : Poly Methyl Methacrylate

PRK : Photorefractive Keratectomy

ps : Picoseconds

PTK : Phototherapeutic Keratectomy

PVDF : Polyvinylidene Fluoride

RI : Refractive Index

SD : Standard Deviation

SE : Spherical Equivalent

SHIM : Second Harmonic Imaging Microscope

SMILE : Small-Incision Lenticule Extraction

TLSS : Transient Light Sensitivity Syndrome

UDVA : Unaided Distance Visual Acuity

UNVA : Unaided Near Visual Acuity

UV : Ultraviolet

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In addition to the nanosecond (ns) and picoseconds (ps) lasers used in ophthalmology, a relatively new laser technology is becoming popular for use in refractive correction. The ultrashort laser pulses of the femtosecond (FS) laser, which focuses the laser beam to a spot size of several micrometers in diameter and does not exceed a pulse energy of 1 μJ, are in the range of 100–200 fs pulse duration. What is unique about the fs laser is its ability to produce a cut within the corneal stroma, rendering the need for a microkeratome unnecessary. **(Lubatschowski et al., 2000)**

Femtosecond lasers have ultrashort laser pulses which means that the pulse energy is decreased and that there is a reduction in the amount of thermal and mechanical damage to the surrounding corneal and stromal tissue. **(Lubatschowski et al., 2000)**

The first commercially available fs laser model, the IntraLase FS laser (Abbott Medical Optics Inc., Santa Ana, CA, USA), was introduced in 2001. Since then other fs lasers, including the Femtec (Technolas Perfect Vision, Heidelberg, Germany), Femto LDV (Ziemer Ophthalmic Systems, Port, Switzerland), and the VisuMax (Carl Zeiss Meditec AG, Jena, Germany), have entered the market. **(Soong and Malta, 2009)**

The technology was marketed as a replacement for the mechanical microkeratome. **(Sugar, 2002)**

Although each system boasts its own unique features and offers various configurations, all fs lasers have the same interaction process based on nonlinear absorption and tissue disruption. **(Lubatschowski, 2008)**

They allow three-dimensional tissue processing and absorption beneath the corneal surface. This technology offers many advantages for refractive correction, including precise cuts and minimal complications. Once designed as a simple flap cutter for refractive surgery, the FS laser is being used in new and exciting applications, including preparing cuts for intrastromal corneal ring segments, lamellar keratoplasty, and presbyopia correction. **(Noack and Vogel, 1999) (Heisterkamp et al., 2002) (Vogel et al., 2005)**

Using the FS laser to create a flap prior to LASIK has become established as a standard procedure. Between 2006 and 2007, the number of FS-created flaps during LASIK was more than doubled, with 15–17% of surgeons changing over from the mechanical microkeratome to the FS laser. **(Optics.org)**

Its use eliminates most of the complications associated with microkeratome-created flaps including variable flap thickness and reduction of mechanical and thermal side effects. **(Behrens et al., 1999) (Gimbel et al., 2000) (Vongthongsri et al., 2000)**

One of the most recent developments in the ophthalmologic application of FS lasers is its use in the correction of presbyopia. Previously, the only successful methods for presbyopic correction included lens implants or monovision surgery. Ripken et al., studied the effects of using the FS laser to create gliding planes inside the crystalline lens. The investigators postulated that the procedure, lentotomy, would not only help to regain elasticity and increase accommodation, but would do so without harming the lens capsule. **(Ripken et al., 2008)**

Another proposed method of presbyopic correction is photophaco modulation. **(Krueger et al., 2005)**

Manual Penetrating keratoplasty requires a long learning curve and a lengthy procedure time. **(Steinert et al., 2007)**

The FS laser can be used to create a “top hat”-shaped PKP that boasts creation of penetrating corneal incisions in one step. It has been found that the “top hat”-PKP configuration causes less wound leakage and provides a platform for looser sutures, which theoretically may decrease suture-induced astigmatism and allow faster visual recovery. Additionally, using the fs laser during PKP provides a better match at the wound edge between donor and recipient. **(Busin, 2003)**

These new lasers have the means of not only removing the cataract, but of creating precise capsulorhexis and treating astigmatism via arcuate relaxing incisions. The three companies which are working on these lasers are: LenSx Lasers (Aliso Viejo, CA, USA), LensAR (Winter Park, FL, USA), and Optimedica (Santa Clara, CA, USA). **(Dick et al., 2010)**

The great potential of all three laser systems is the automation these lasers can provide in creating the capsulorhexis and in pre-chopping the nucleus, reducing the overall energy needed to remove the cataract. Using the fs laser for incisions makes them more precise and repeatable, and they have been proven to self-seal more reliably. Astigmatic incisions can be programmed to be precisely repeatable, which should lead to greater accuracy. The capsulorhexis can be placed exactly where the surgeon wants it to be, which is different to the current situation. **(Dick et al., 2010)**