University of Al-Mustaqbal
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Dep. Medical physics

Medical Laser Applications

Third Stage

Lec 4

Types Of Techniques Used

In

Eye Surgery

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Introduction

The field of eye surgery, or ophthalmology, has advanced significantly over the years with the integration of physics-based techniques. The human eye, being a highly sensitive and intricate organ, requires precise and minimally invasive methods for effective treatment. Physics plays a vital role in understanding and implementing these techniques, particularly in areas such as optics, lasers, and material science.

This lecture will discuss the major types of techniques used in eye surgery, focusing on the underlying physics principles.

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1. Refractive Surgery Techniques

Refractive surgery is aimed at correcting vision problems such as myopia, hyperopia, and astigmatism by reshaping the cornea.

a) LASIK (Laser-Assisted In Situ Keratomileusis):

- **How It Works:**
  - A femtosecond laser creates a thin flap on the cornea.
  - An excimer laser reshapes the corneal stroma to correct the refractive error.
  - The flap is repositioned.
- **Physics Principle:**
  - The excimer laser uses UV light to break molecular bonds in the cornea (photoablation) with high precision, without generating heat.

b) PRK (Photorefractive Keratectomy):

- **How It Works:**
  - The epithelial layer is removed.
  - An excimer laser reshapes the cornea directly.
- **Physics Principle:**
  - Similar to LASIK, it relies on photoablation to sculpt the corneal surface.

c) SMILE (Small Incision Lenticule Extraction):

- **How It Works:**
  - A femtosecond laser creates a lenticule (thin disc) within the cornea.
  - The lenticule is removed through a small incision.
- **Physics Principle:**
  - Femtosecond laser pulses generate micro-cavitation to create precise incisions.

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2. Cataract Surgery Techniques

Cataracts involve clouding of the natural lens, and surgery replaces it with an artificial intraocular lens (**IOL**) .

*The term (**IOL**) stands for **Intraocular Lens**. It is an artificial lens implanted in the eye to replace a natural lens that has been removed, often during cataract surgery.*

a) Phacoemulsification:

- **How It Works:**
  - Ultrasound waves break the cloudy lens into small pieces.
  - The pieces are suctioned out, and an (**IOL**) is implanted.

- **Physics Principle:**
    - Ultrasonic vibrations (high-frequency sound waves) cause the lens material to emulsify, using cavitation and mechanical forces.

b) Femtosecond Laser-Assisted Cataract Surgery (FLACS):

- **How It Works:**
    - A femtosecond laser makes precise incisions in the cornea and softens the lens.
    - This enhances the precision of IOL placement.
- **Physics Principle:**
    - Laser pulses interact with tissue via plasma-mediated ablation, minimizing collateral damage.

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3. Retinal Surgery Techniques

Retinal surgeries address conditions like retinal detachment, diabetic retinopathy, and macular holes.

a) Vitrectomy:

- **How It Works:**
    - The vitreous gel is removed and replaced with a gas bubble or silicone oil.
- **Physics Principle:**
    - Fluid dynamics governs the replacement process to ensure stability of the retina.

b) Laser Photocoagulation:

- **How It Works:**
    - A laser creates small burns on the retina to seal tears or reduce abnormal blood vessels.

- **Physics Principle:**
    - The focused laser light delivers energy to coagulate tissue, using thermal effects.

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4. Glaucoma Surgery Techniques

Glaucoma involves increased intraocular pressure, which can damage the optic nerve.

a) Trabeculectomy:

- **How It Works:**
    - A small flap is created in the sclera to drain excess fluid.
- **Physics Principle:**
    - Fluid mechanics dictates the controlled drainage of aqueous humor.

b) Laser Trabeculoplasty:

- **How It Works:**
    - A laser is used to open the drainage canals in the trabecular meshwork.
- **Physics Principle:**
    - The laser delivers thermal energy to induce structural changes and improve fluid outflow.

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5. Corneal Transplantation

Corneal transplants replace a damaged cornea with donor tissue.

a) DSAEK (Descemet's Stripping Automated Endothelial Keratoplasty):

- **How It Works:**
    - A thin layer of donor tissue is transplanted.

- **Physics Principle:**
    - Requires precise surgical tools to maintain optical clarity and structural integrity.

b) Corneal Cross-Linking:

- **How It Works:**
    - UV light activates a riboflavin solution to strengthen the cornea.
- **Physics Principle:**
    - Photochemical reactions lead to cross-linking of collagen fibers, increasing biomechanical strength.

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6. Emerging Techniques

- **a) Wavefront-Guided LASIK:**
    - Customizes corneal reshaping using wavefront aberrometry.
    - **Physics:** Involves advanced optics and interference patterns.
- **b) Robotic-Assisted Surgery:**
    - Enhances precision using robotics and computer guidance.
    - **Physics:** Relies on motion tracking and mechanical systems.

Conclusion

Physics forms the backbone of modern eye surgery techniques, enabling precision and safety. From lasers and ultrasound to fluid dynamics and photochemical processes, advancements in this field continue to push the boundaries of what is possible in ophthalmology.

Discussion

1. What is the primary goal of refractive surgery?

A) Treating cataracts

B) Correcting vision problems like myopia

C) Repairing the retina

D) Reducing intraocular pressure

E) Strengthening the cornea

Correct Answer: B

2. Which laser is used in LASIK for reshaping the corneal stroma?

A) Femtosecond Laser

B) Argon Laser

C) Excimer Laser

D) CO_2 Laser

E) Nd:YAG Laser

Correct Answer: C

3. What physical process underpins LASIK surgery?

A) Plasma-Mediated Ablation

B) Thermal Coagulation

C) Photoablation

D) Cavitation

E) Ultrasonic Vibration

Correct Answer: C

4. In PRK, which layer of the cornea is removed?

A) Stroma

B) Endothelium

C) Epithelial Layer

D) Bowman's membrane

E) Descemet's membrane

Correct Answer: C

5. What is the role of the femtosecond laser in SMILE?

A) Reshaping the cornea

B) Removing the epithelial layer

C) Creating a corneal flap

D) Generating micro-cavitation to create precise incisions

E) Delivering thermal energy

Correct Answer: D

6. Which surgery involves replacing the natural lens with an intraocular lens?

A) PRK

B) Phacoemulsification

C) Trabeculectomy

D) Vitrectomy

E) Corneal Cross-Linking

Correct Answer: B

7. What physical principle is used in phacoemulsification?

A) Ultrasonic Cavitation

B) Photoablation

C) Plasma-Mediated Ablation

D) Thermal Conduction

E) Mechanical Cutting

Correct Answer: A

8. What does FLACS stand for?

A) Femtosecond Laser-Assisted Cataract Surgery

B) Focused Laser-Assisted Corneal Surgery

C) Fast Laser-Assisted Cataract Surgery

D) Fine Lens-Assisted Cataract Surgery

E) Femtosecond Laser-Assisted Corneal Stabilization

Correct Answer: A

9. What interaction does a femtosecond laser use in FLACS?

A) Cavitation
B) Plasma-Mediated Ablation
C) Ultrasonic Vibrations
D) Thermal Coagulation
E) Photochemical Reaction
Correct Answer: B

10. Which of the following is NOT a retinal surgery technique?

A) Vitrectomy

B) Trabeculectomy

C) Laser Photocoagulation

D) Retinal Detachment Repair

E) Pneumatic Retinopexy

Correct Answer: B

11. Which fluid governs the replacement process in vitrectomy?

A) Blood Plasma

B) Aqueous humor

C) Silicone oil or gas bubble

D) Vitreous gel

E) Saline Solution

Correct Answer: C

12. What principle is used in laser photocoagulation for retinal repairs?

A) Photoablation

B) Ultrasonic Vibrations

C) Thermal Coagulation

D) Plasma-Mediated Ablation

E) Mechanical Cutting

Correct Answer: C

13. What condition is treated by trabeculectomy?

A) Retinal Detachment
B) Myopia
C) Glaucoma
D) Cataracts
E) Astigmatism
Correct Answer: C

14. What is the purpose of laser trabeculoplasty?

A) Reshape the cornea

B) Improve fluid drainage from the trabecular meshwork

C) Replace the natural lens

D) Seal retinal tears

E) Strengthen corneal collagen

Correct Answer: B

15. What energy is delivered by the laser in trabeculoplasty?

A) Plasma Energy

B) Mechanical Energy

C) Thermal Energy

D) Ultrasonic Waves

E) UV Light

Correct Answer: C

16. In DSAEK, What is replaced during the procedure?

A) Entire cornea

B) Corneal stroma only

C) Endothelium with donor tissue

D) Epithelium and Bowman's layer

E) Lens and cornea

Correct Answer: C

17. What principle is involved in corneal cross-linking?

A) Cavitation

B) Photochemical Reactions

C) Photoablation

D) Thermal Coagulation

E) Mechanical Bonding

Correct Answer: B

18. What activates riboflavin during corneal cross-linking?

A) Ultrasound Waves
B) UV Light
C) Thermal Energy
D) Visible Light
E) Laser Pulses
Correct Answer: B

19. What technology customizes wavefront-guided LASIK?

A) Riboflavin activation

B) Aberrometry

C) Femtosecond lasers

D) Ultrasonic imaging

E) Endothelial analysis

Correct Answer: B

20. What aspect of physics is most important in robotic-assisted surgery?

A) Fluid Dynamics

B) Motion Tracking

C) Ultrasonic Cavitation

D) Photoablation

E) Plasma-Mediated Ablation

Correct Answer: B

21. What condition does SMILE primarily treat?

A) Cataracts
B) Astigmatism
C) Glaucoma
D) Retinal Detachment
E) Myopia
Correct Answer: E

22. What process does an excimer laser rely on?

A) Cavitation

B) Plasma-Mediated Ablation

C) Photochemical Reactions

D) Thermal Energy

E) Photoablation

Correct Answer: E

23. What type of laser creates precise corneal incisions in LASIK?

A) Nd:YAG

B) Excimer

C) CO_2

D) Femtosecond

E) Argon

Correct Answer: D

24. What material replaces vitreous gel in vitrectomy?

A) Synthetic Gel

B) Plasma

C) Silicone oil or gas bubble

D) Saline Solution

E) None; left empty

Correct Answer: C

25. Which is an emerging technique in eye surgery?

A) PRK

B) DSAEK

C) Wavefront-guided LASIK

D) Phacoemulsification

E) Trabeculectomy

Correct Answer: C