# Intro to Iris Biometrics

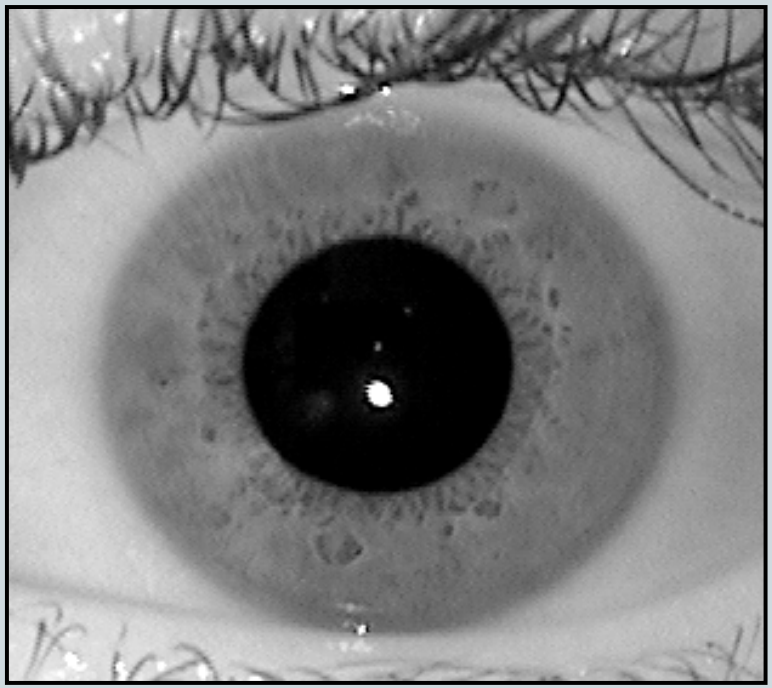

## Kevin W. Bowyer

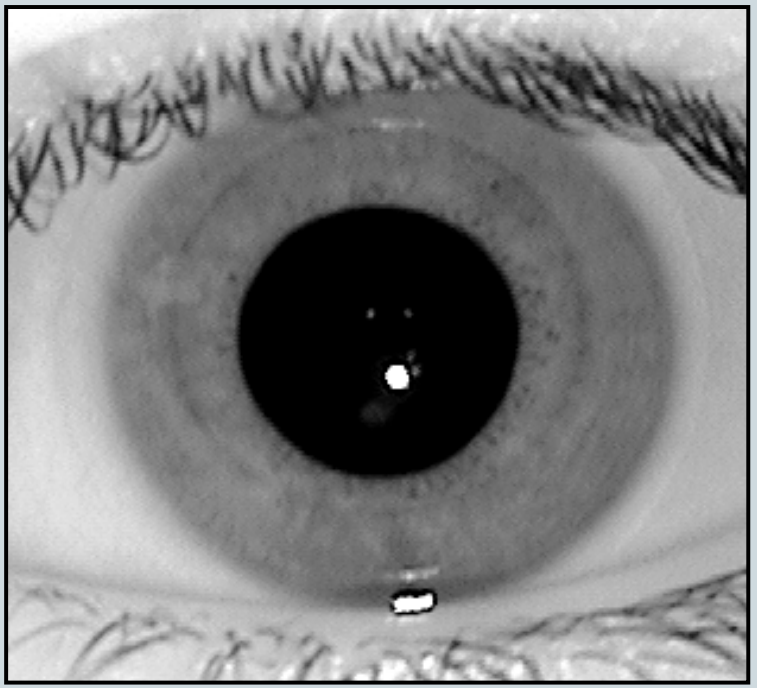
**Schubmehl-Prein Professor**
**Chair, Computer Science & Engineering**
**University of Notre Dame**

**kwb@cse.nd.edu**

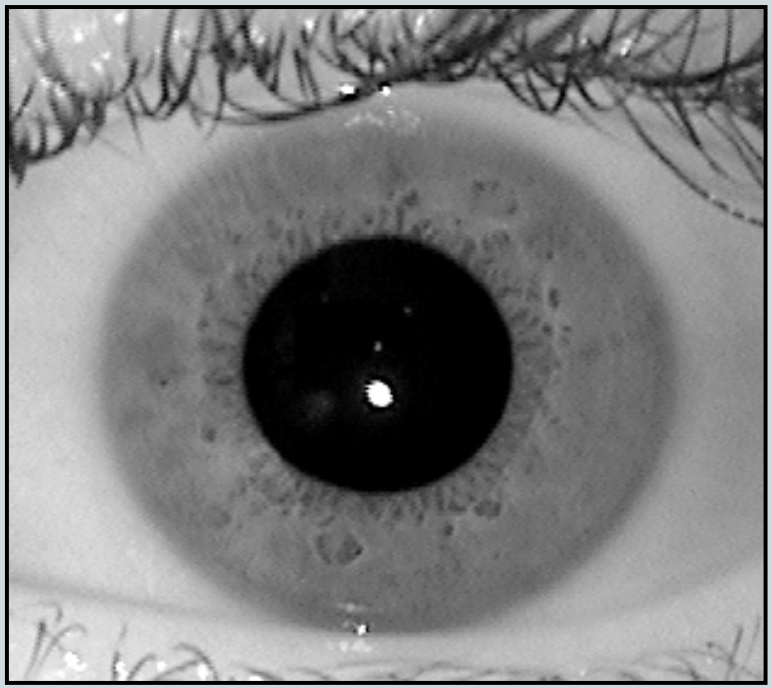
# Our goal for today –

## to appreciate the various kinds of contact lenses that people wear and understand how they affect the performance of iris biometrics.

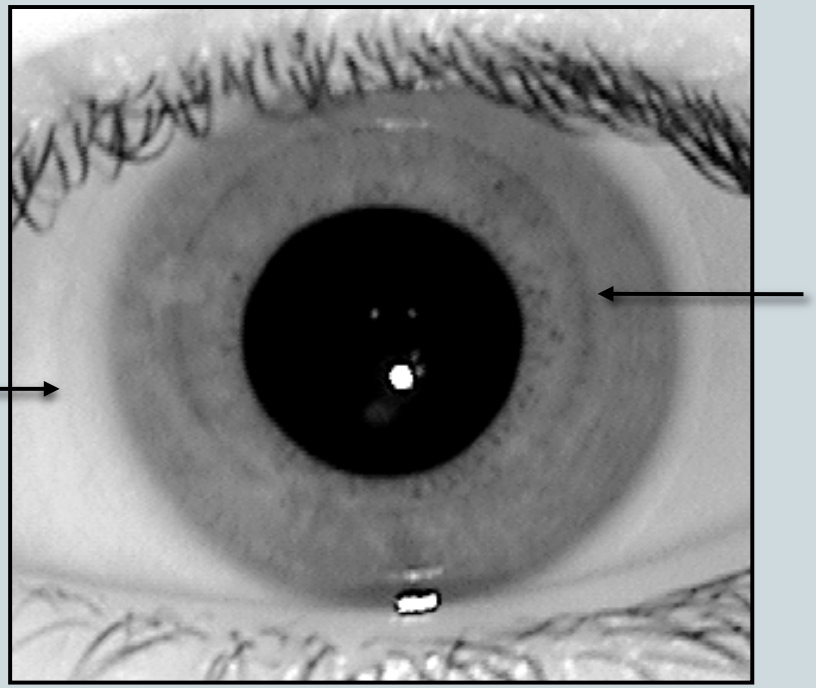




# Which eye is wearing a contact lens?



iris **without** contact lens



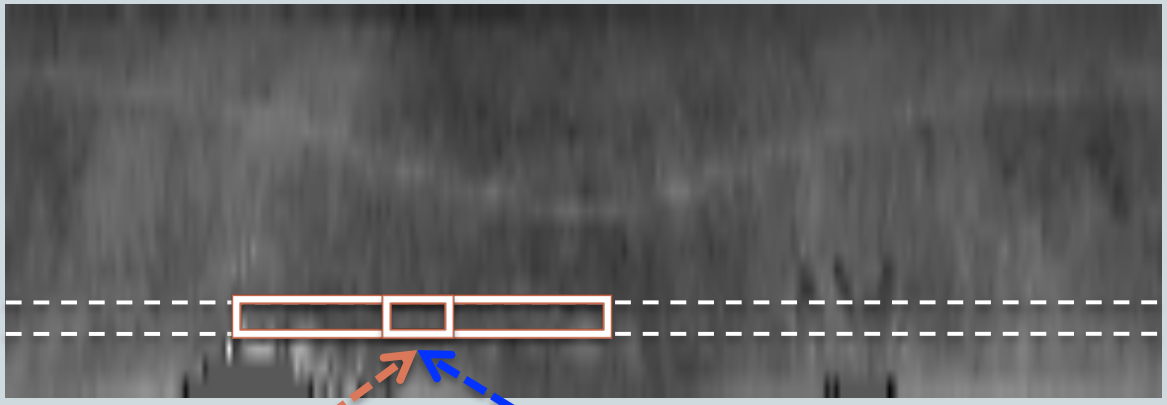
iris **with** contact lens

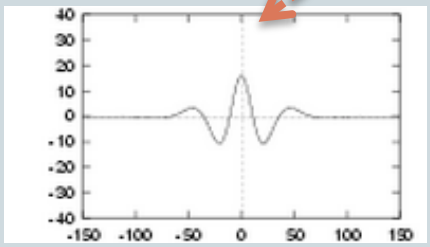
**Even normal, transparent, contact lenses do result in visible artifacts in iris images.**

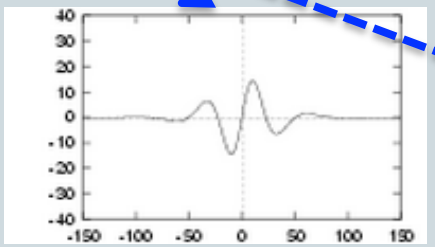
# Today's Outline

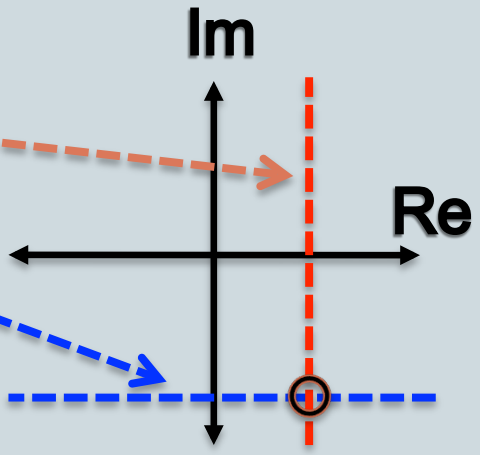
- **Review – iris code matching**
- Contact lens technology
- Example iris images
- Effects of contact lenses
- Research questions

# Iris Code Matching

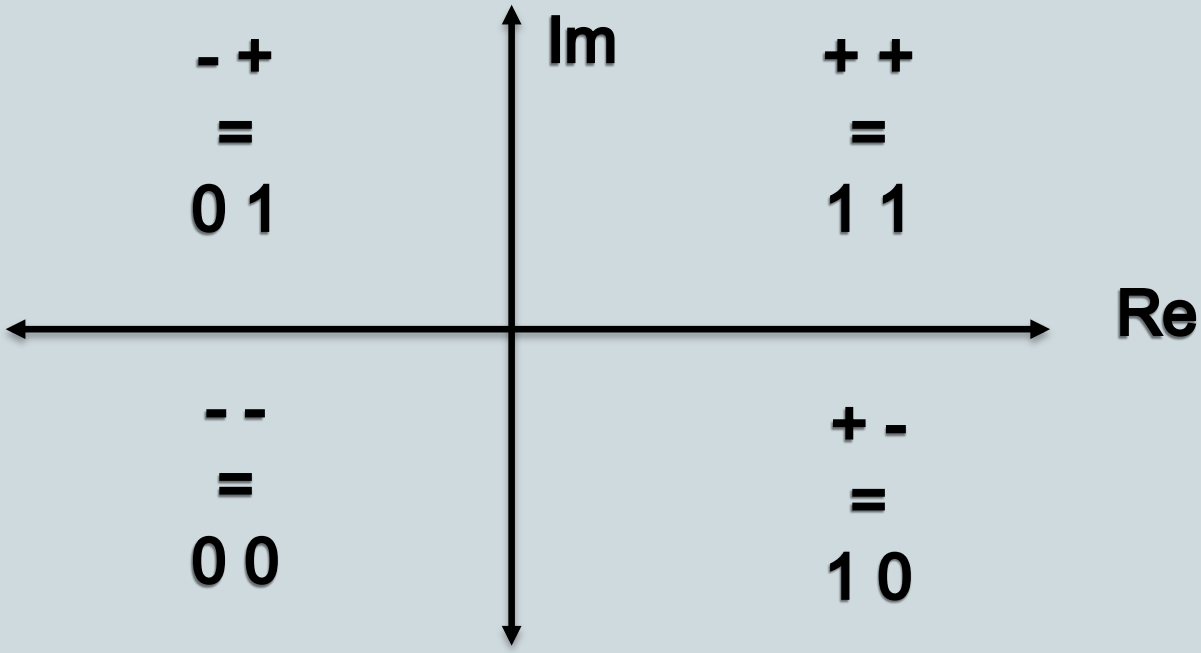




# Iris Code Matching




**The quadrant in which the result lies – its phase – gives two bits of iris code.**

# Iris Code Matching

enrolled

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 |
| 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 |

probe

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 |

XOR

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |

FHD is the fraction of bits that differ; here, FHD = 0.5

# Iris Code Matching

One complication:

There is a mask with each iris code.

If 1 means iris and 0 means occlusion, the two masks are ANDed, and the result is ANDed with the XOR result.

$$\frac{| (Mask_1 \text{ AND } Mask_2) \text{ AND } (Code_1 \text{ XOR } Code_2) |}{| \text{Mask1 AND Mask2} |}$$

# Today's Outline

- Review – creating iris codes
- **Contact lens technology**
- Example iris images
- Effects of contact lenses
- Research questions

# Contact Lens Technology

- About 34 M contact lens wearers in the US in 2008 (J&J press release)
- Big categories are soft and rigid gas permeable, but many types exist
- New lens types introduced often
- Driven by cosmetic considerations now, as well as vision correction

# Contact Lens Technology

- About 34 M contact lens wearers in the US in 2008 (J&J press release)
- Big categories are soft and rigid gas permeable, but many types exist
- New lens types introduced often
- Driven by cosmetic considerations now, as well as vision correction

# Contact Lens Technology

**Historical development of materials used to make contact lenses:**

**"Contact Lens Materials" (about 2 minutes)**
**http://www.youtube.com/watch?v=tKG4imG3KRk&feature=related**

***Showing this video does not imply any endorsement of any company, lens, etc.***

# Contact Lens Technology

**Background on one way that lenses have been made:**

**"Making Contact Lenses" (about 5 minutes)**
**http://www.youtube.com/watch?v=AXRGRyqSRao&NR=1**

***Showing this video does not imply any endorsement of any company, lens, etc.***

# Contact Lens Technology

**Lenses to correct for astigmatism:**

**“Contact Lenses for Astigmatism” (about 2 minutes)**
**http://www.youtube.com/watch?v=86a7OmCPerY**

***Showing this video does not imply any endorsement of any company, lens, etc.***

# Contact Lens Technology

**More on lenses designed to correct for astigmatism:**

**"Accelerated Stabilisation Design Lenses" (about 3 minutes)**
**http://www.youtube.com/watch?v=Z4JewQawPY8**

***Showing this video does not imply any endorsement of any company, lens, etc.***

# Contact Lens Technology

## Lenses to correct for presbyopia:

**"Presbyopia: Synergeyes Multifocal Contact Lenses Available at Wing Eyecare" (about 3 minutes)**
**http://www.youtube.com/watch?v=JtsZZzTOUqo**

***Showing this video does not imply any endorsement of any company, lens, etc.***

# Contact Lens Technology

## Specialty – colored contact lenses:

**"Pros /cons of colored contacts" (about 2 minutes)**
**http://www.youtube.com/watch?v=h7NdXDJfE1k**
**"Colored contact lenses for dark eyes" (about 2 minutes)**
**http://www.youtube.com/watch?v=D_gDa7-ZpzM**

***Showing this video does not imply any endorsement of any company, lens, etc.***

# Contact Lens Technology

## Specialty – lenses tinted for sports:

**"Nike Sports Contact Lens Test" (about 4 minutes)**
**http://www.youtube.com/watch?v=b82BCZ_QmRg&feature=related**

***Showing this video does not imply any endorsement of any company, lens, etc.***

# Contact Lens Technology

## Specialty – scleral lenses:

**"Scleral Contact Lenses-Mayo Clinic" (about 2 minutes)**
**http://www.youtube.com/watch?v=SGdhHAZHwmI&feature=related**

***Showing this video does not imply any endorsement of any company, lens, etc.***

# Contact Lens Technology

**Specialty – sensing / computing:**

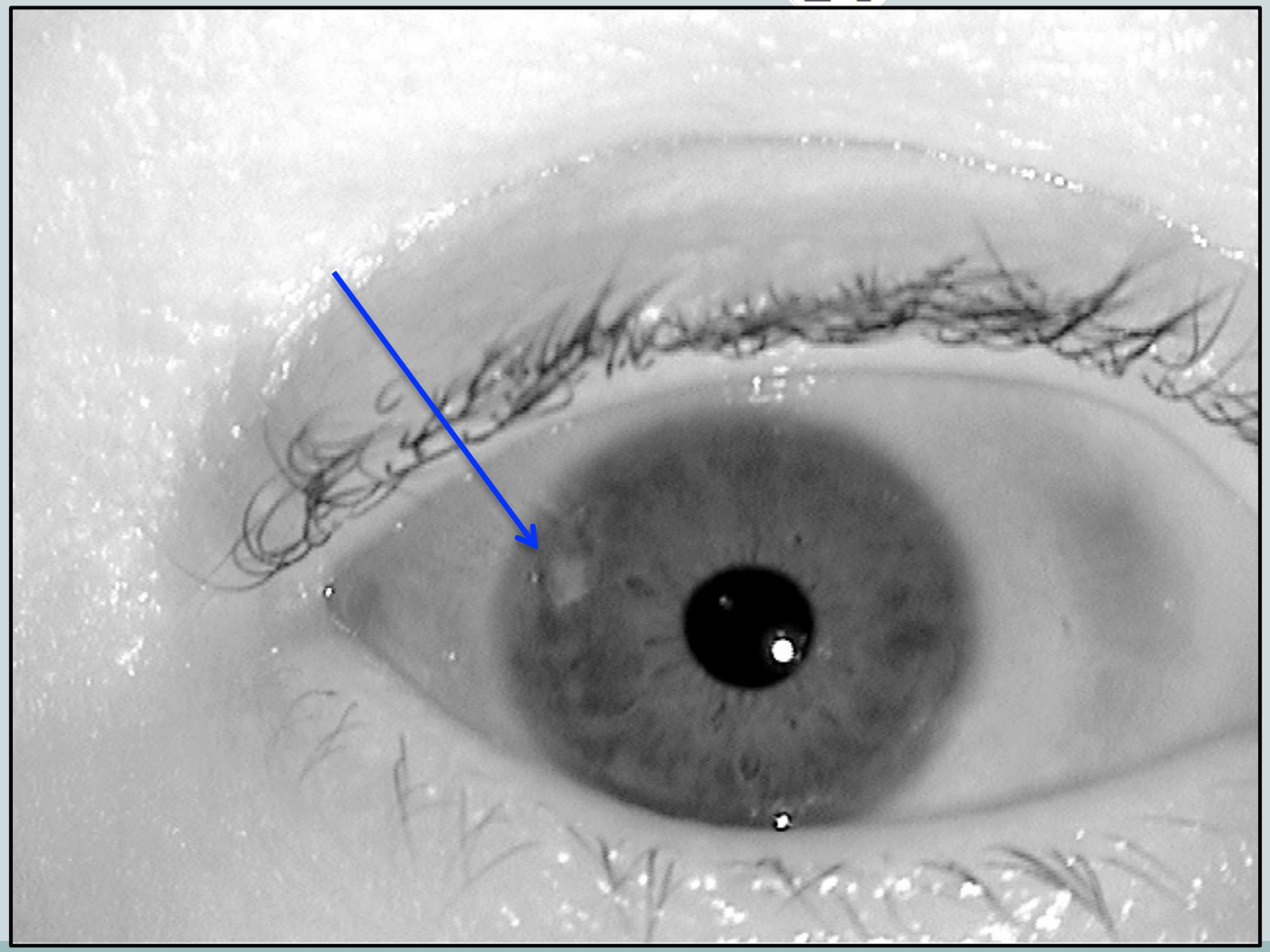
**"Bionic Contact Lenses" (about 2 minutes)**
**http://www.youtube.com/watch?v=qdILVMGXSQk&feature=more_related**

***Showing this video does not imply any endorsement of any company, lens, etc.***

# Today's Outline

- Review – creating iris codes
- Contact lens technology
- **Example iris images**
- Effects of contact lenses
- Research questions

# Example Iris Images

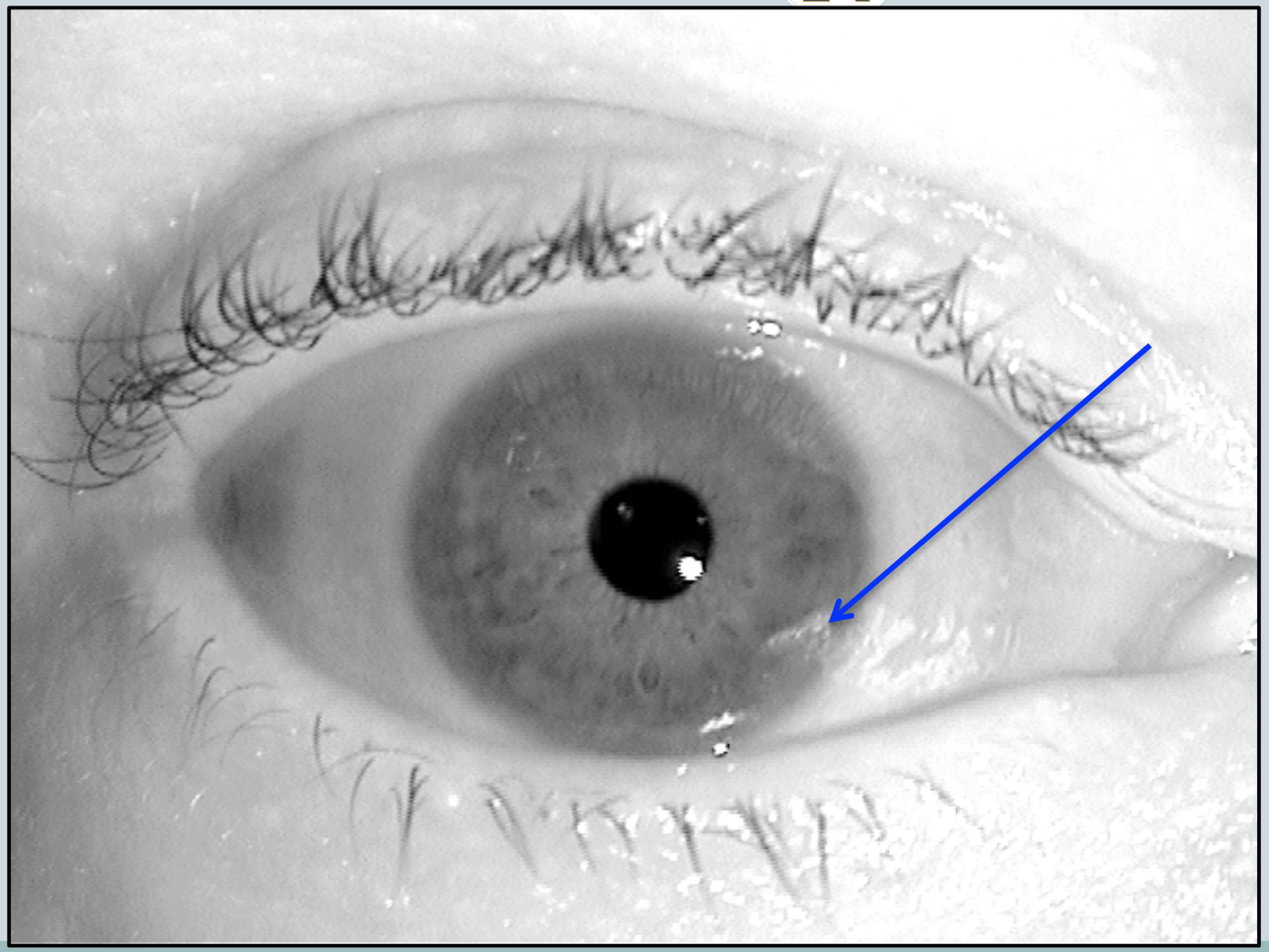


02463d900.

No contact lens.

Lighting highlights / reflections.

# Example Iris Images

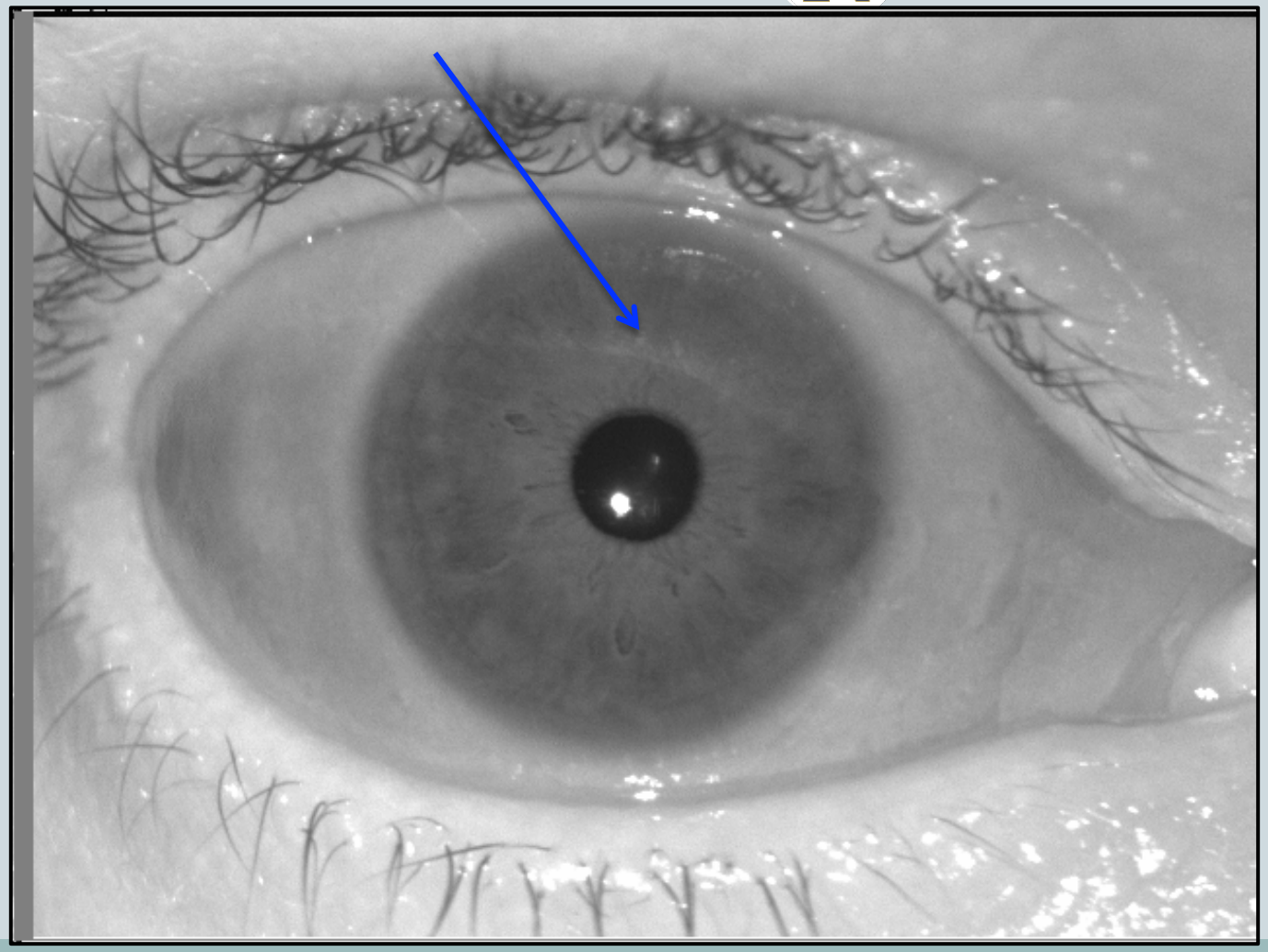


02463d1348.

No contact lens.

Lighting highlights / reflections.

# Example Iris Images

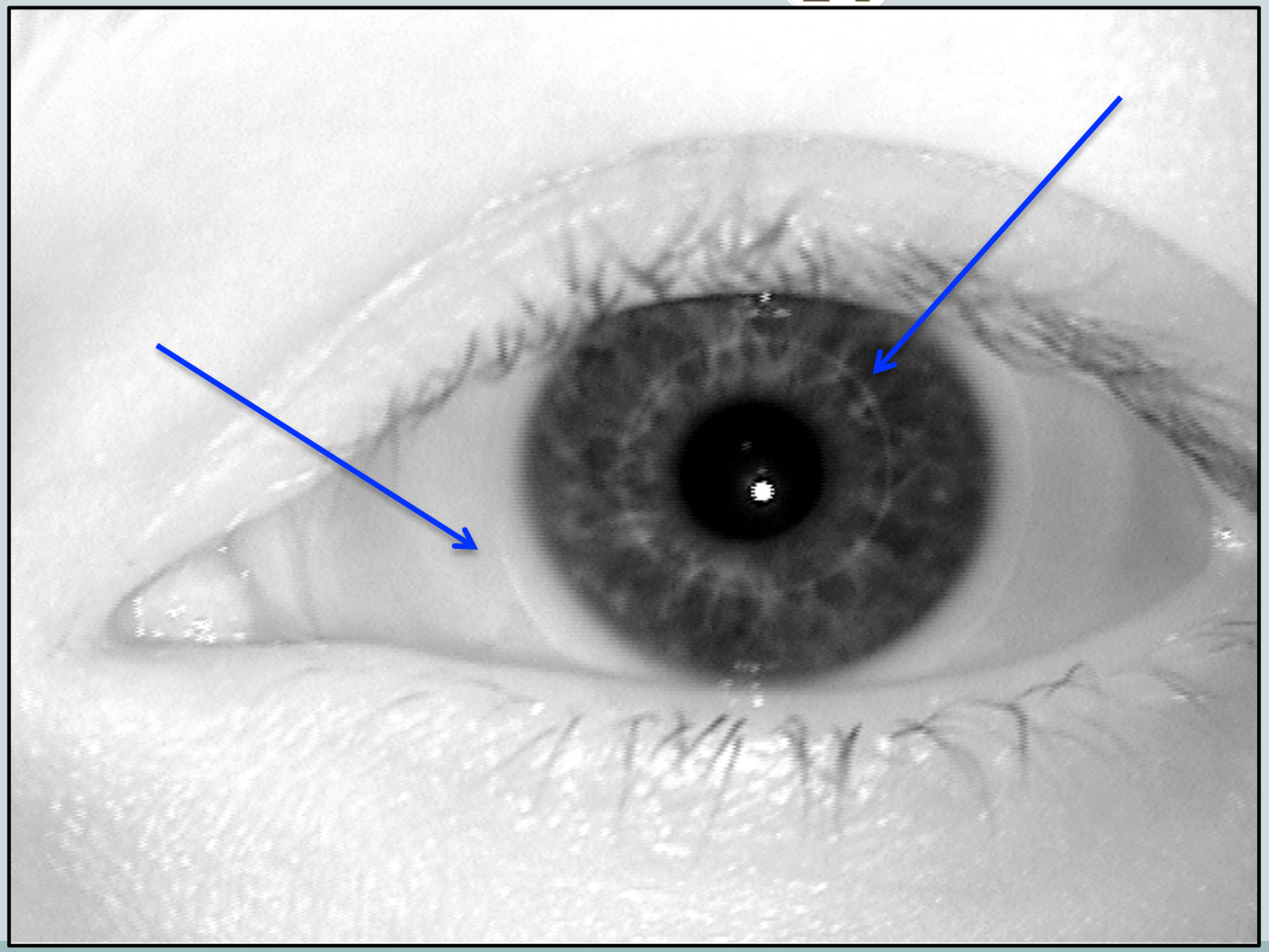


02463d2876.

No contact lens.

Lighting highlights / reflections.

# Example Iris Images



**04201d450.**

**Contact lens.**

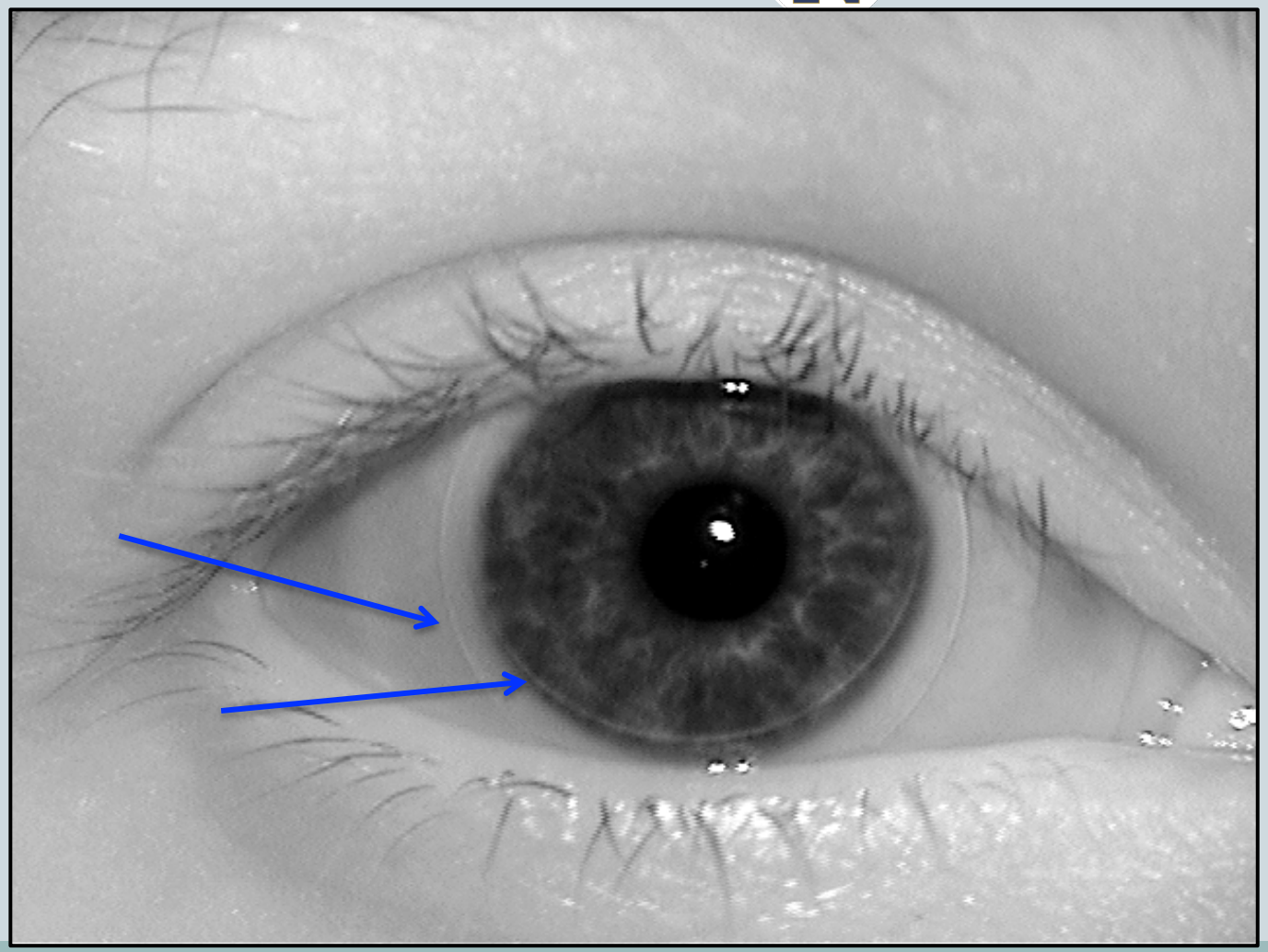
**Thin, light concentric circles.**

# Example Iris Images

**04201d450.**

**Same eye but with no contact lens.**

# Example Iris Images

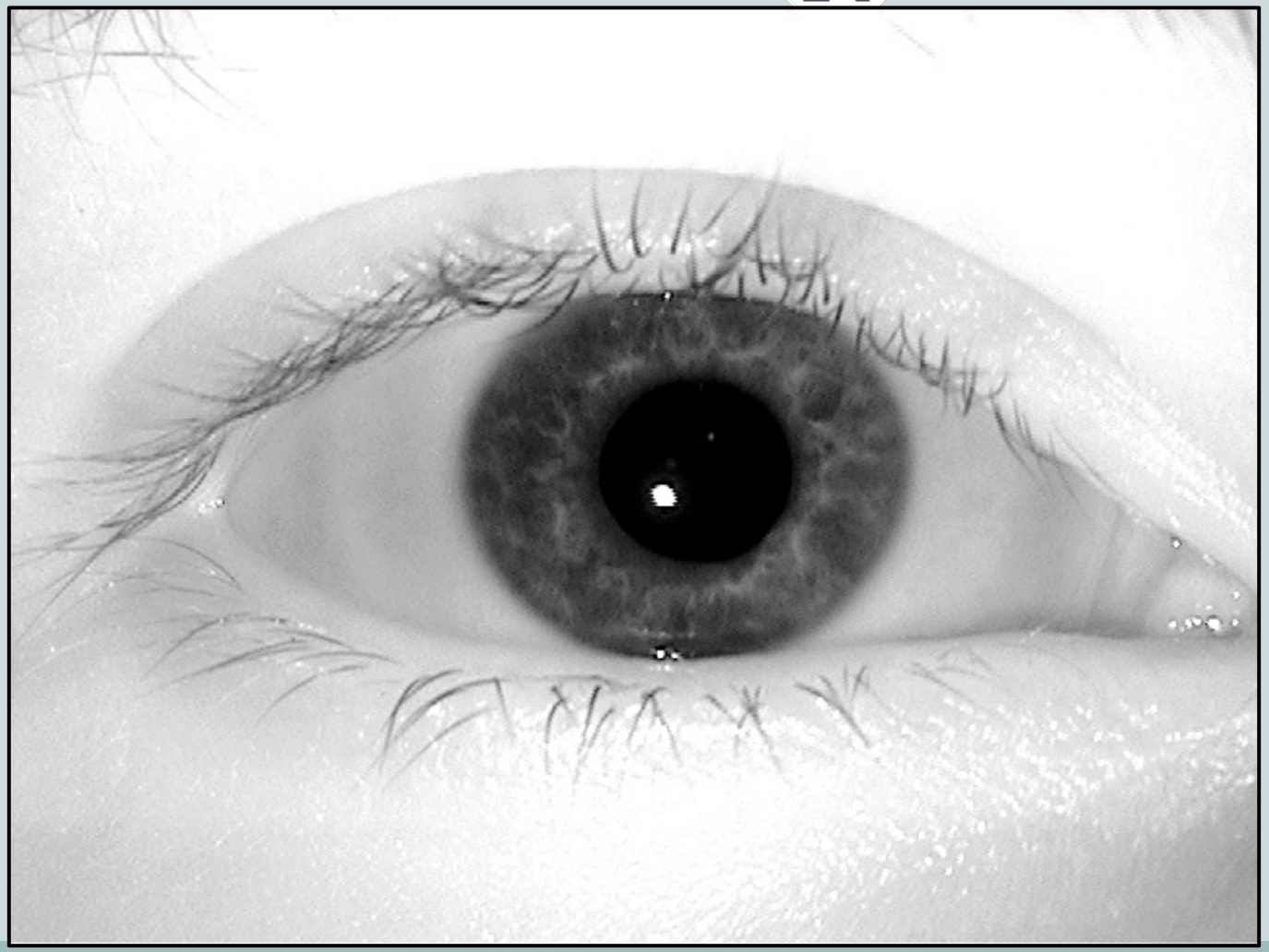


**04201d451.**

**Contact lens.**

**Thin light circle that is NOT concentric.**

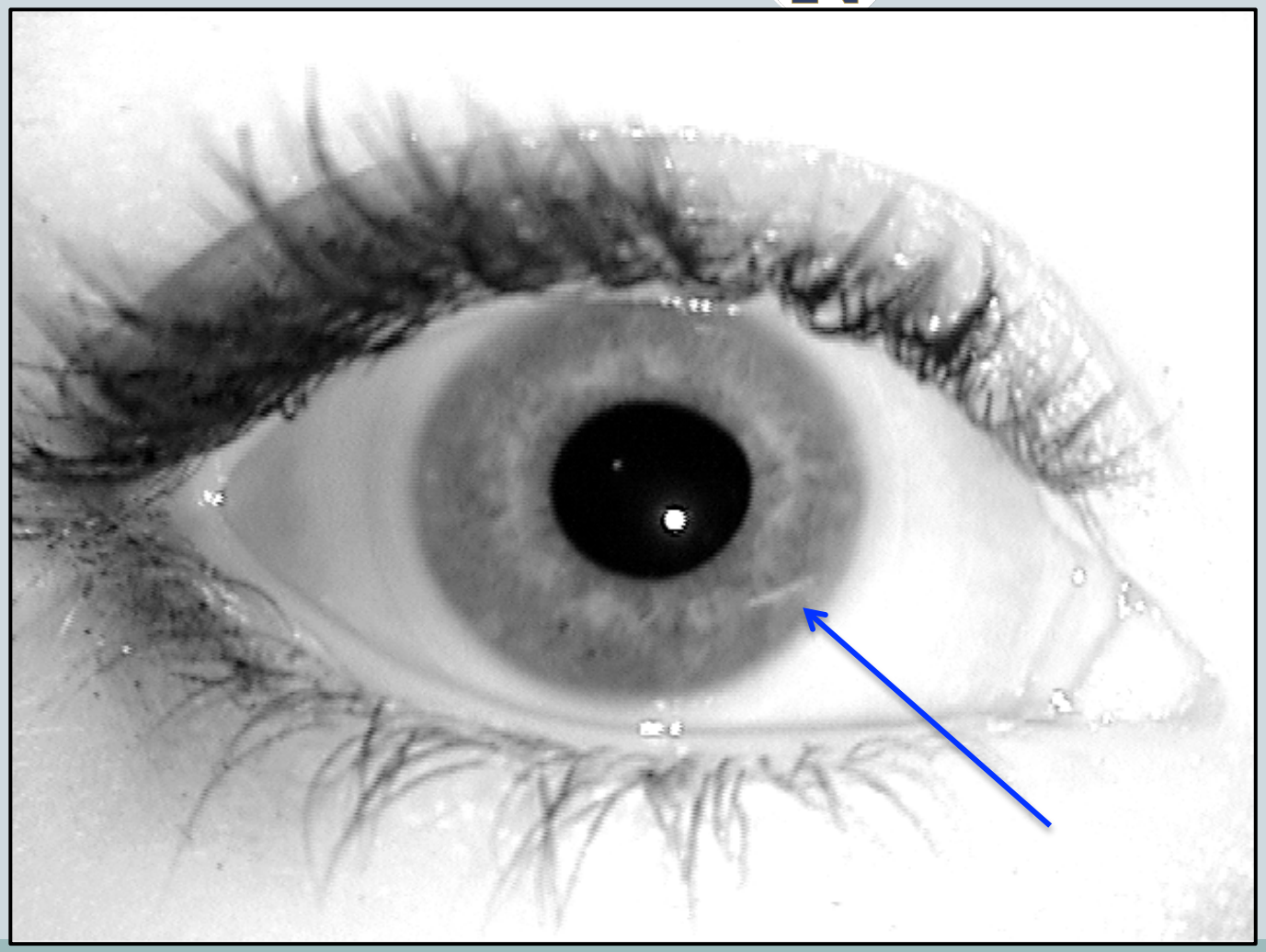
# Example Iris Images



**04201d575.**

**Same eye without contact lens.**

# Example Iris Images



04213d378.

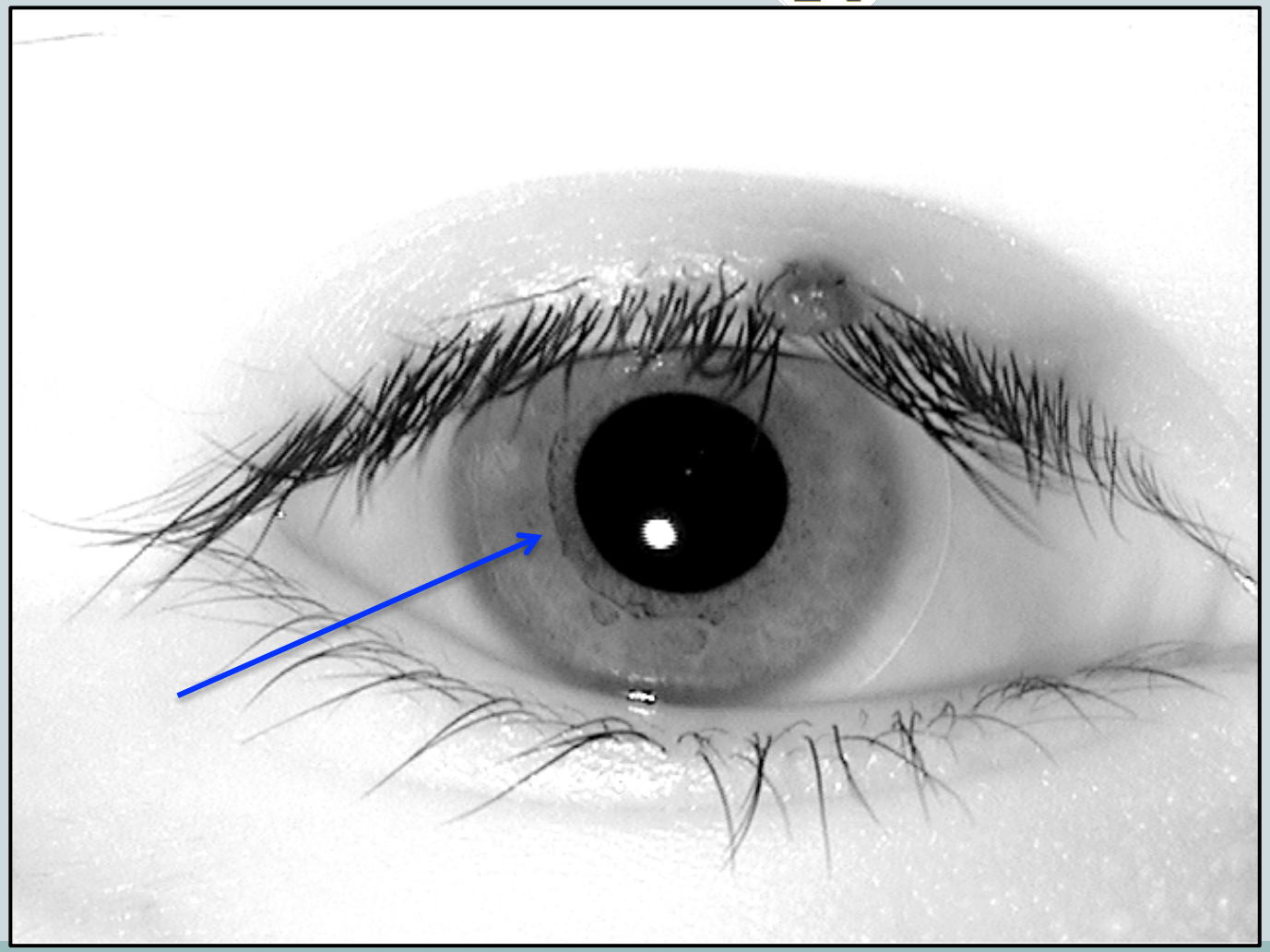
Contact lens and apparent specular highlight, but we can see similar highlights in eyes without contacts.

# Example Iris Images

**04213d379.**

**Contact lens and NO apparent specular highlight.**

# Example Iris Images

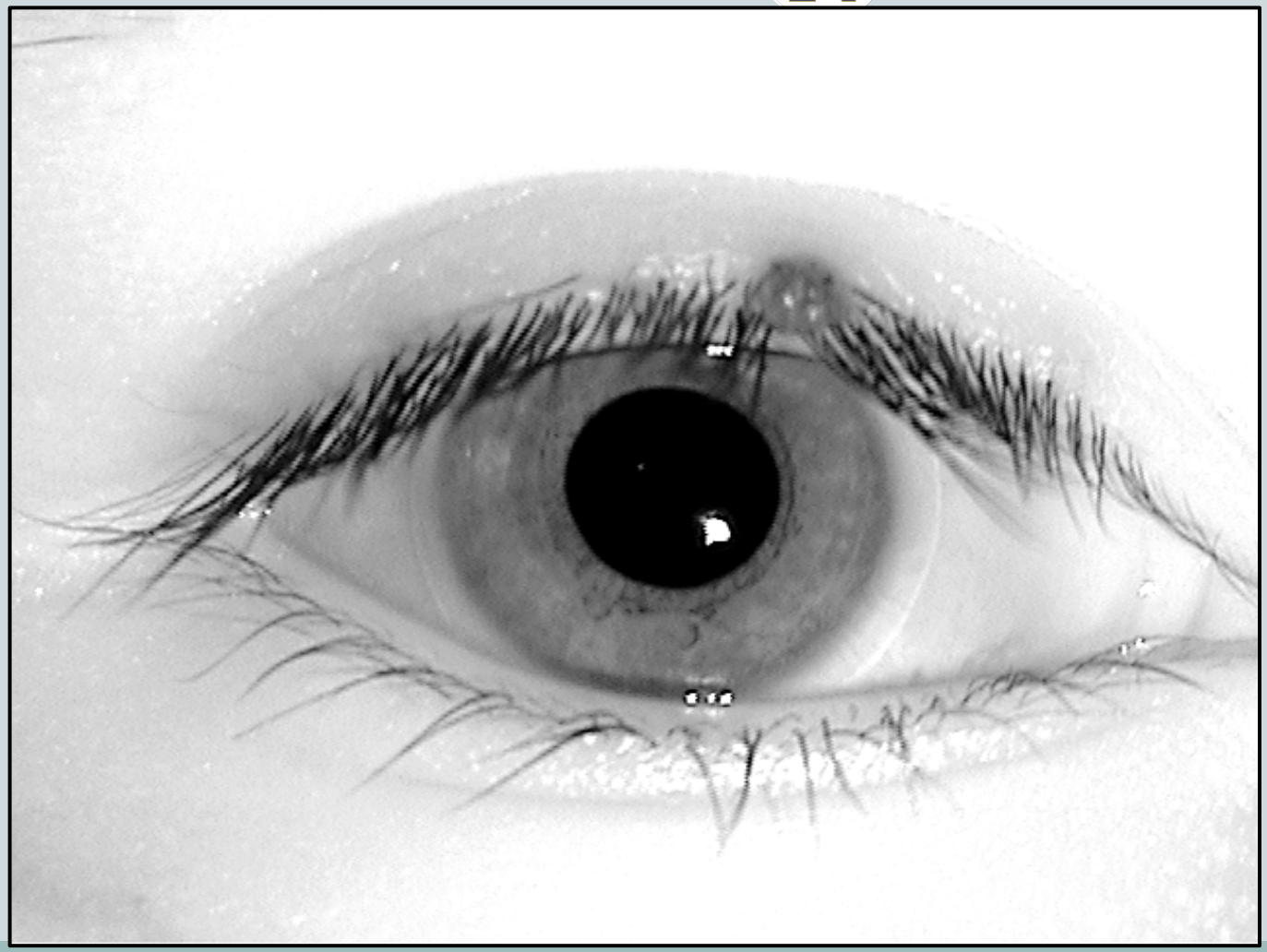


04320d396.

Contact lens.

Effects of lighting direction; look at left and right side of pupillary fringe region.

# Example Iris Images

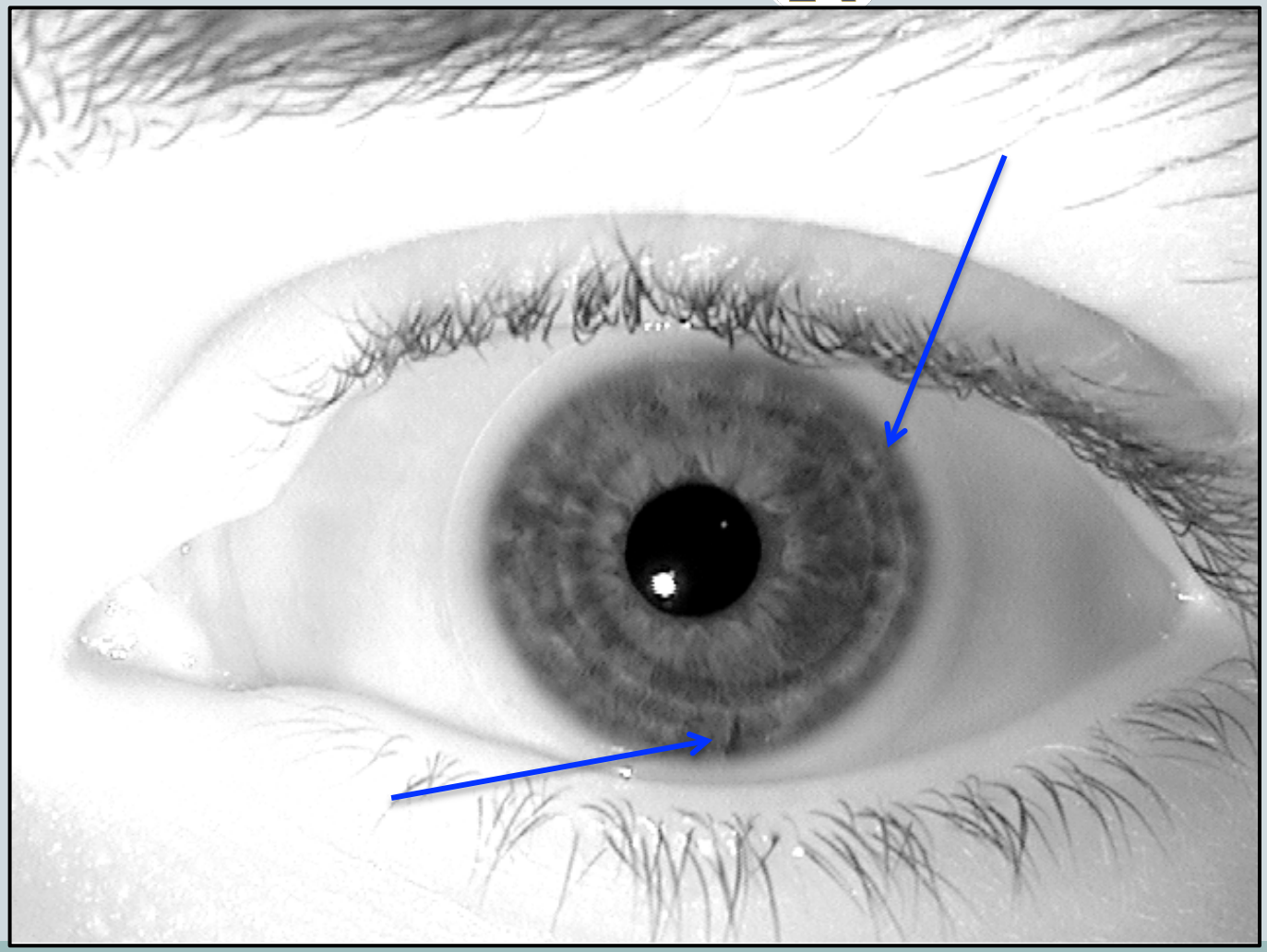


**04320d397.**

**Contact lens.**

**Effects of lighting direction; look at left and right side of pupillary fringe region.**

# Example Iris Images



**04456d373.**

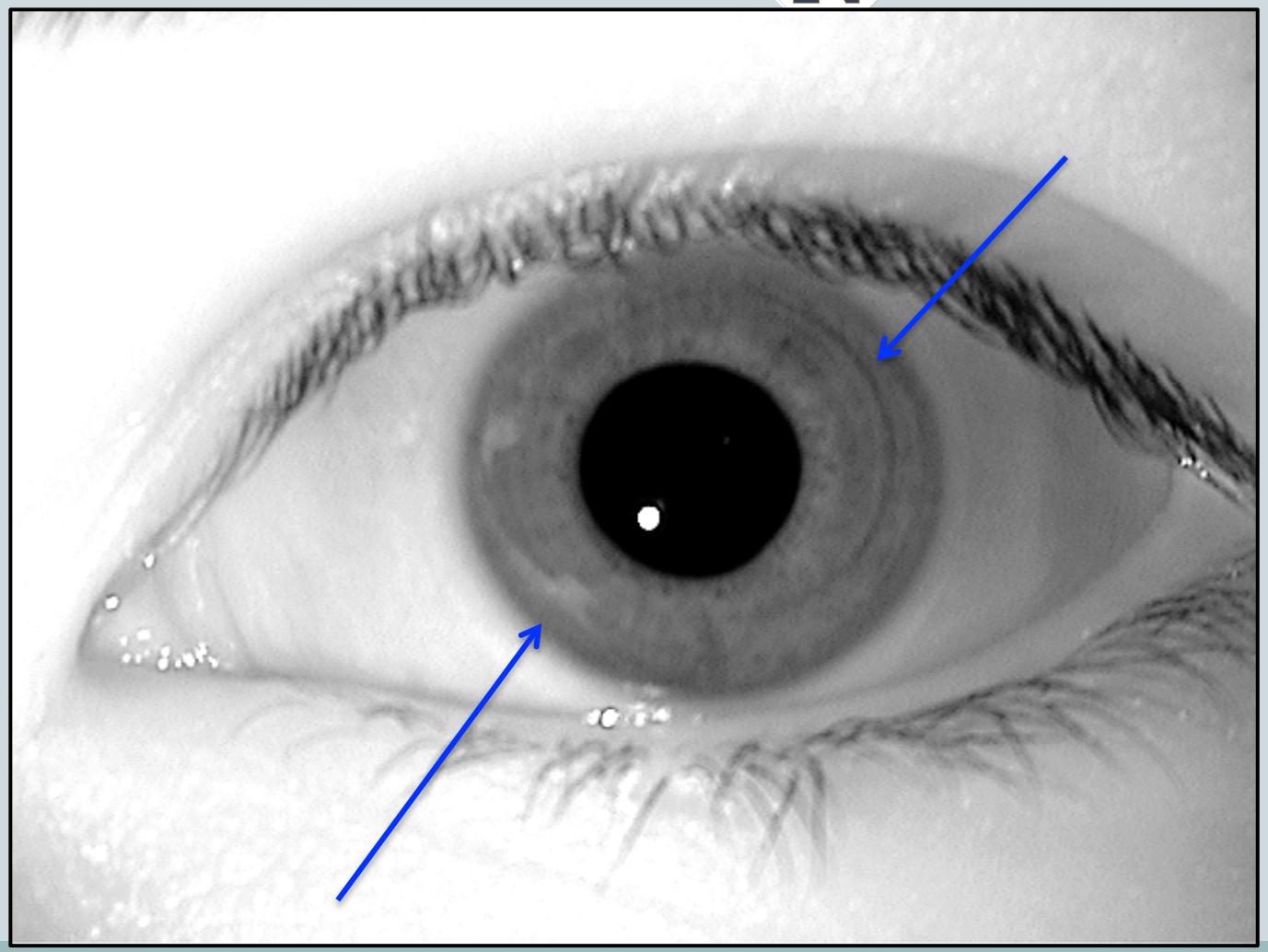
**Contact lens with light outer circle and inner bands.**

# Example Iris Images

**04456d375.**

**Contact lens with light outer circle and inner bands.**

# Example Iris Images



**04598d378.**

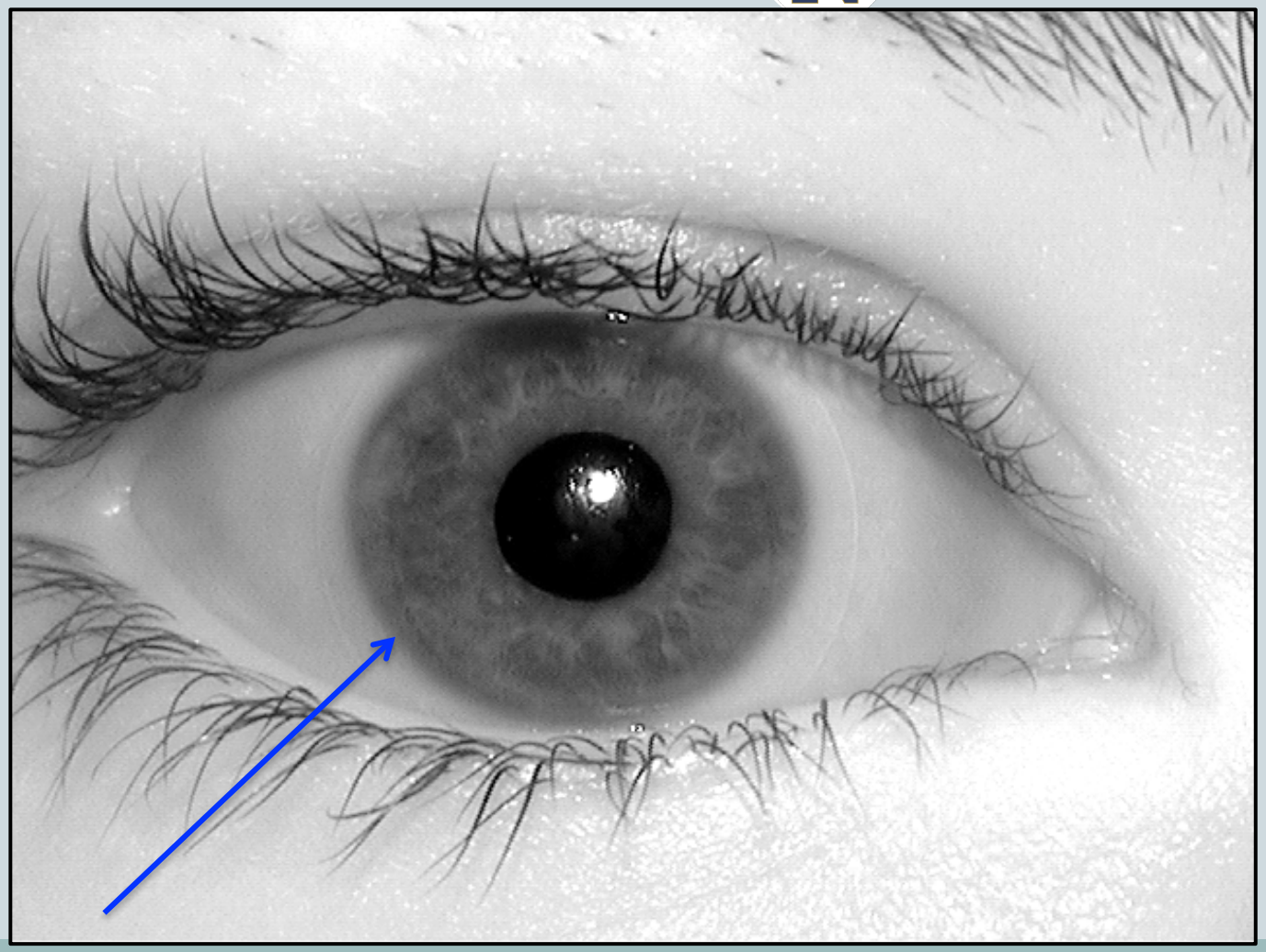
**Contact lens with dark inner circle.**

# Example Iris Images

**04598d380.**

**Contact lens with dark inner circle.**

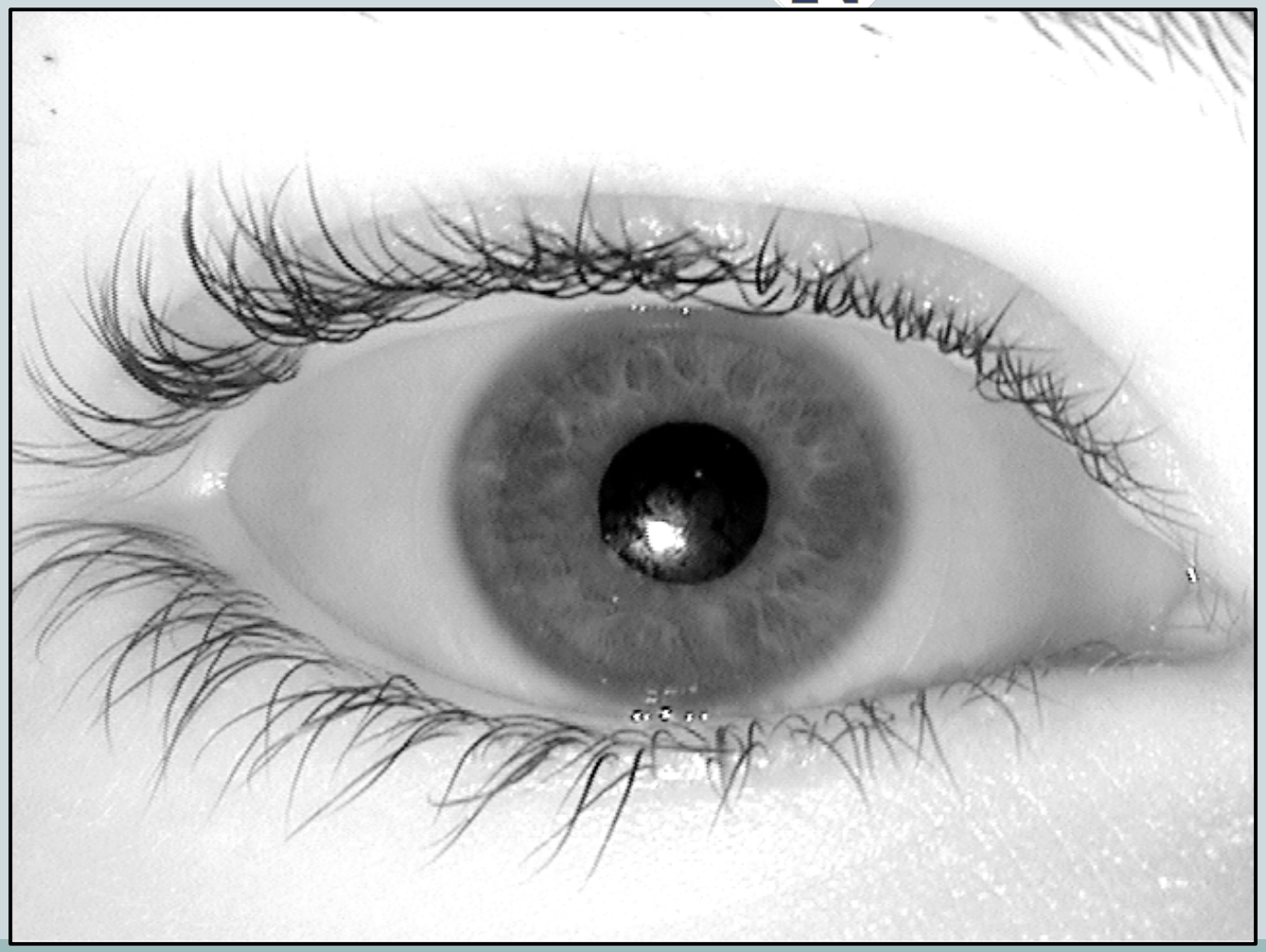
# Example Iris Images



**04692d190.**

**Contact lens with dark inner circle and diffuse specular highlights.**

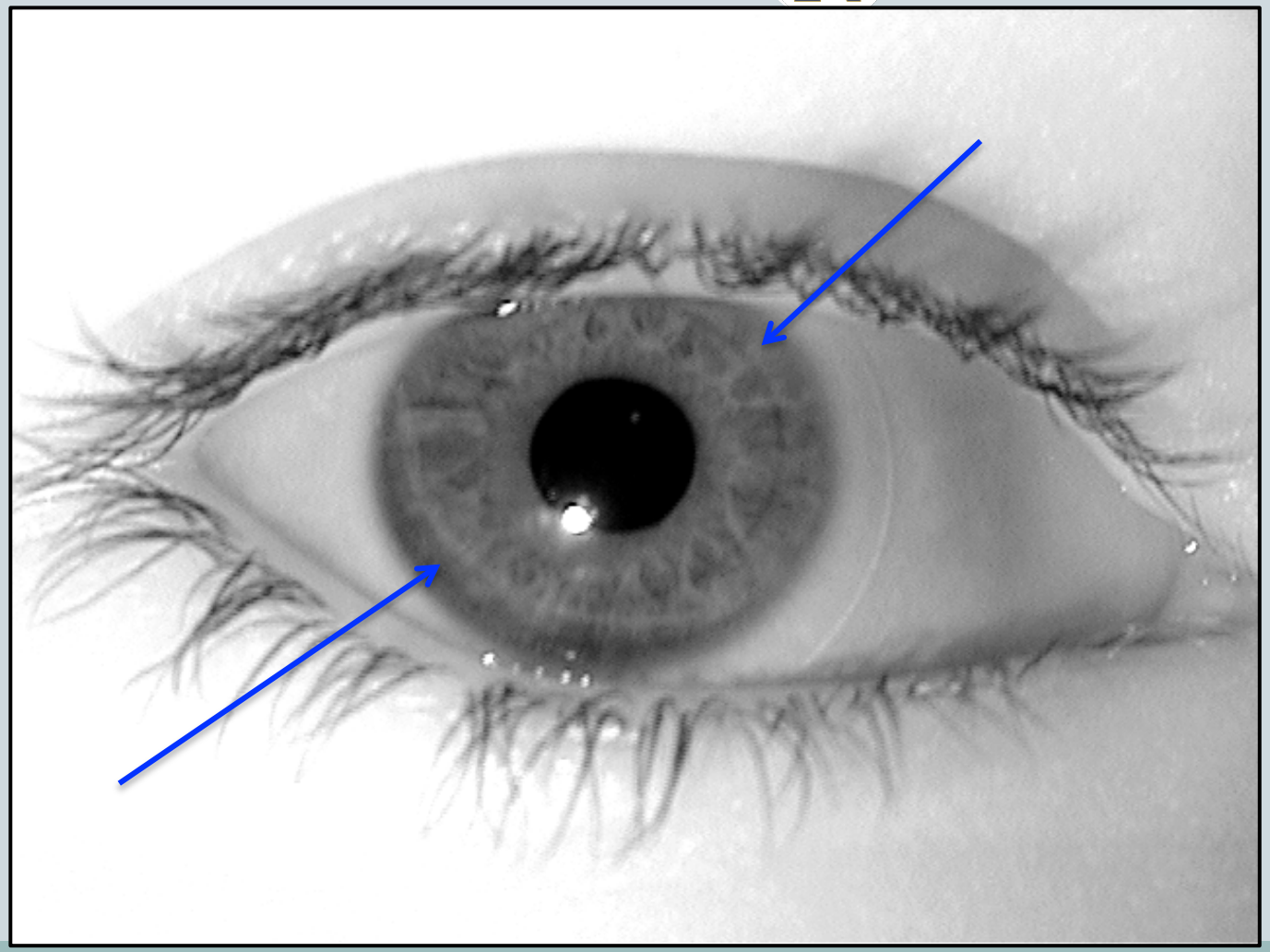
# Example Iris Images



**04692d191.**

**Contact lens with dark inner circle and diffuse specular highlights.**

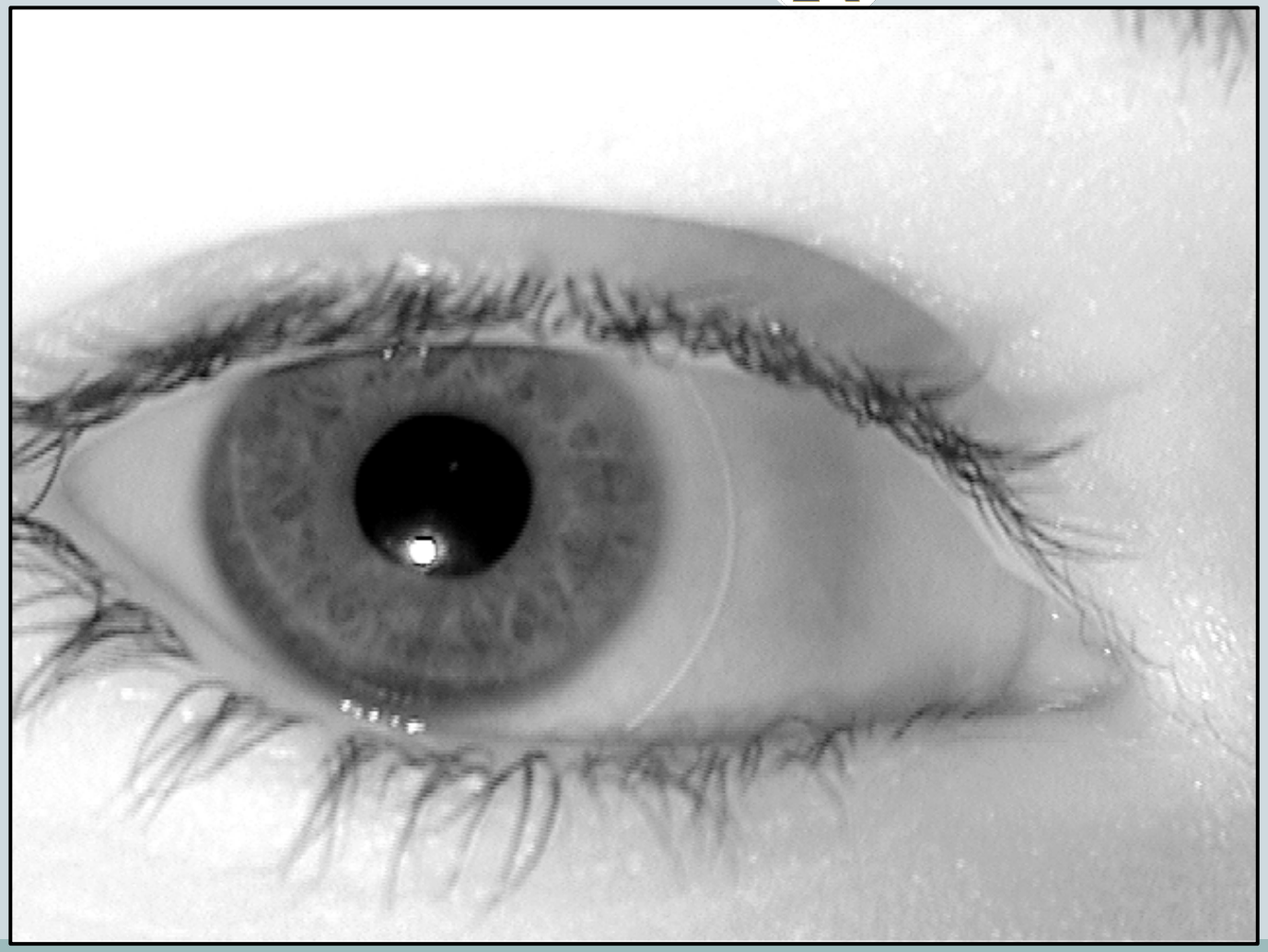
# Example Iris Images



04856d127.

Contact lens with dark and light inner circles.

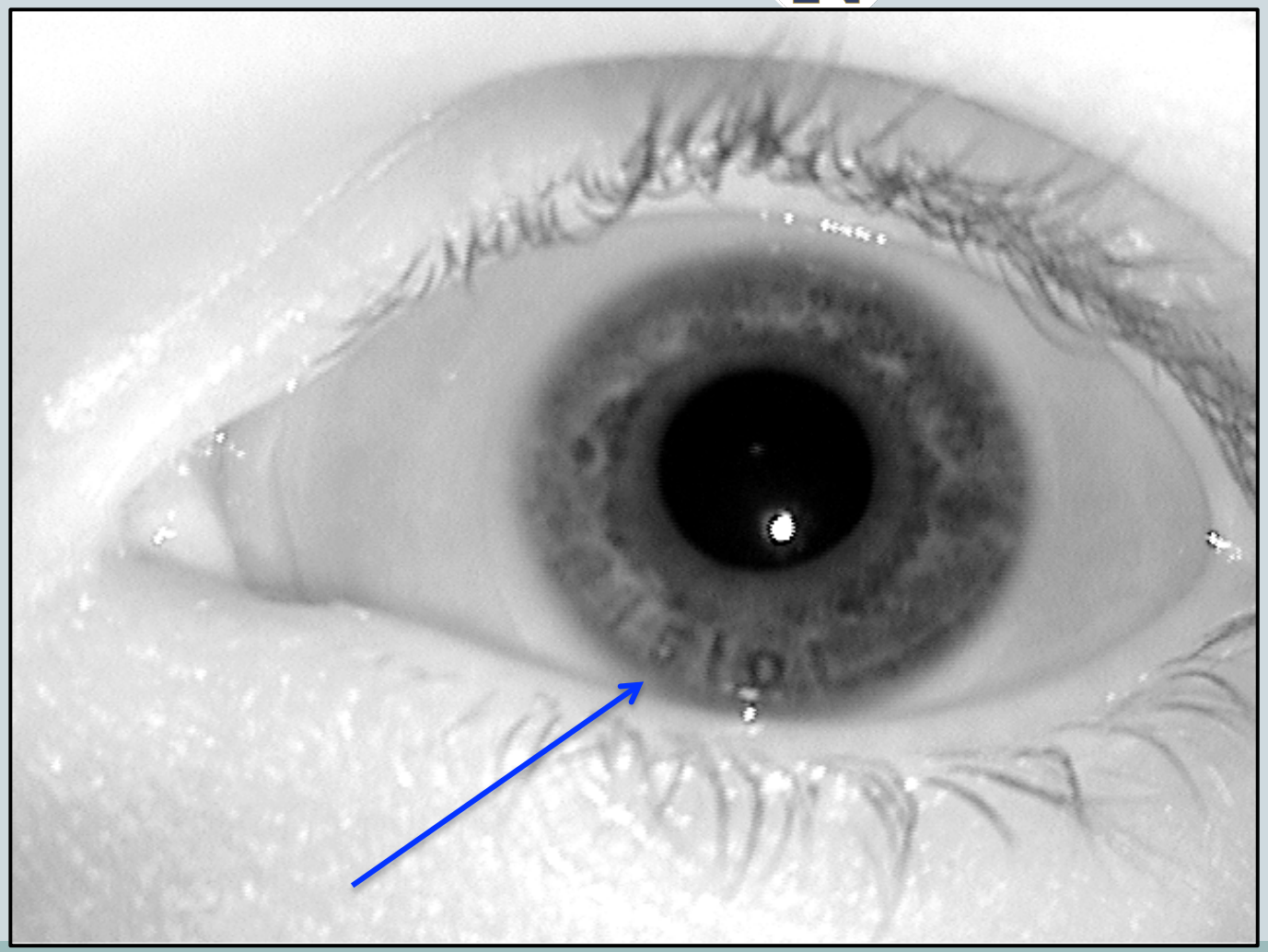
# Example Iris Images



04856d131.

Contact lens with dark and light inner circles.

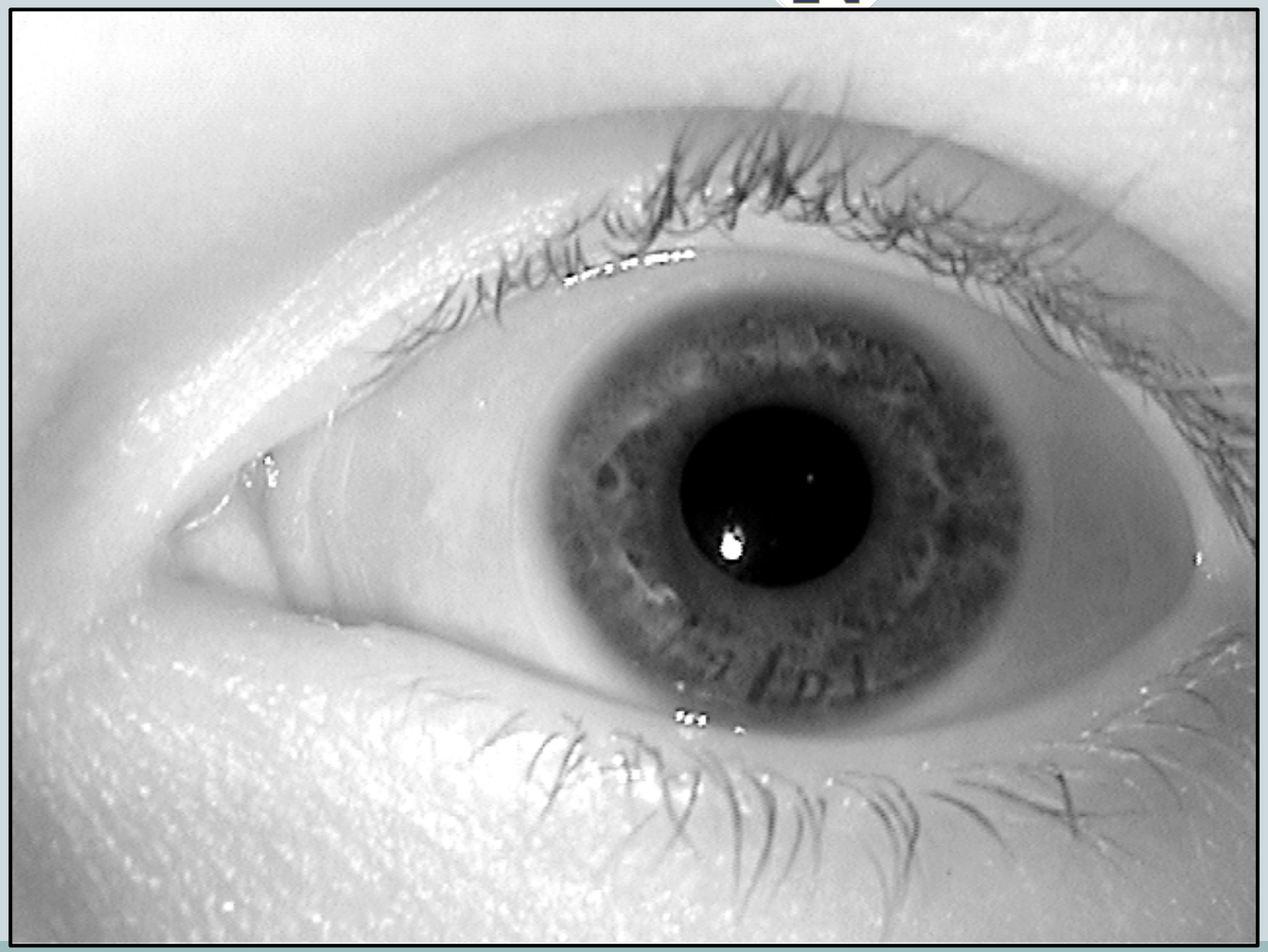
# Example Iris Images



**04869d84.**

**Lettering and circles.**

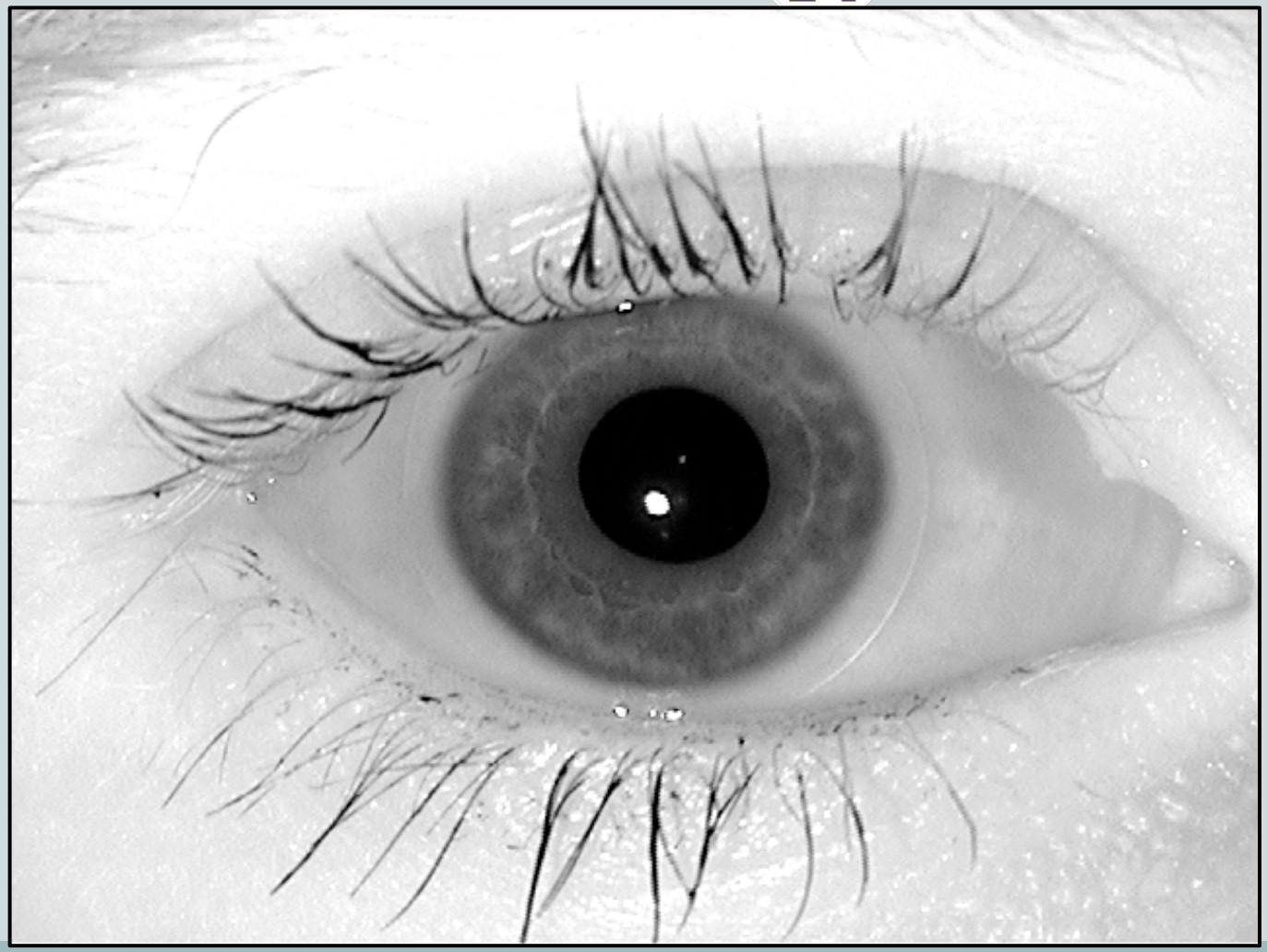
# Example Iris Images



**04869d86.**

**Lettering and circles.**

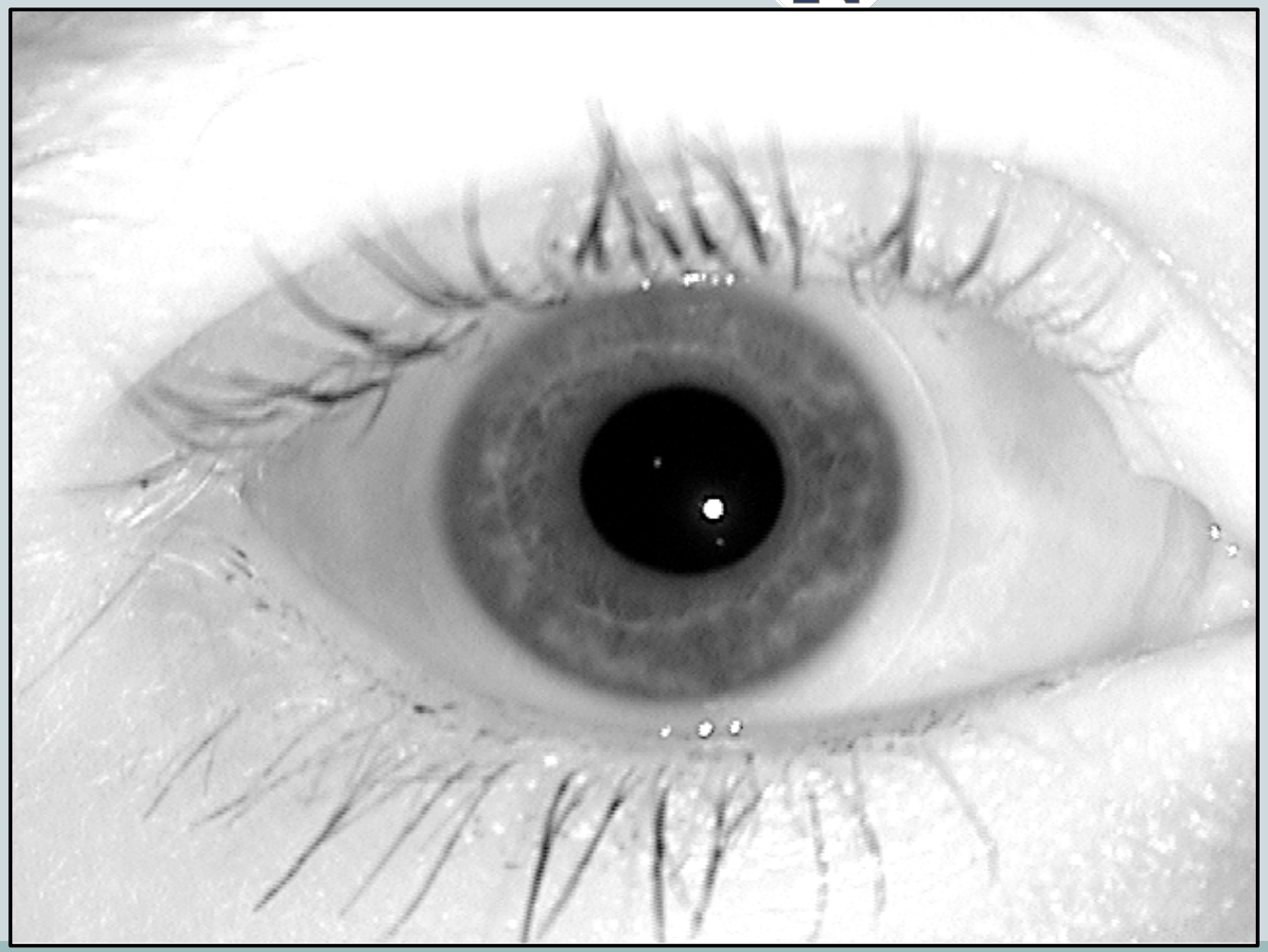
# Example Iris Images



**04885d97.**

**Circle blending with natural texture.**

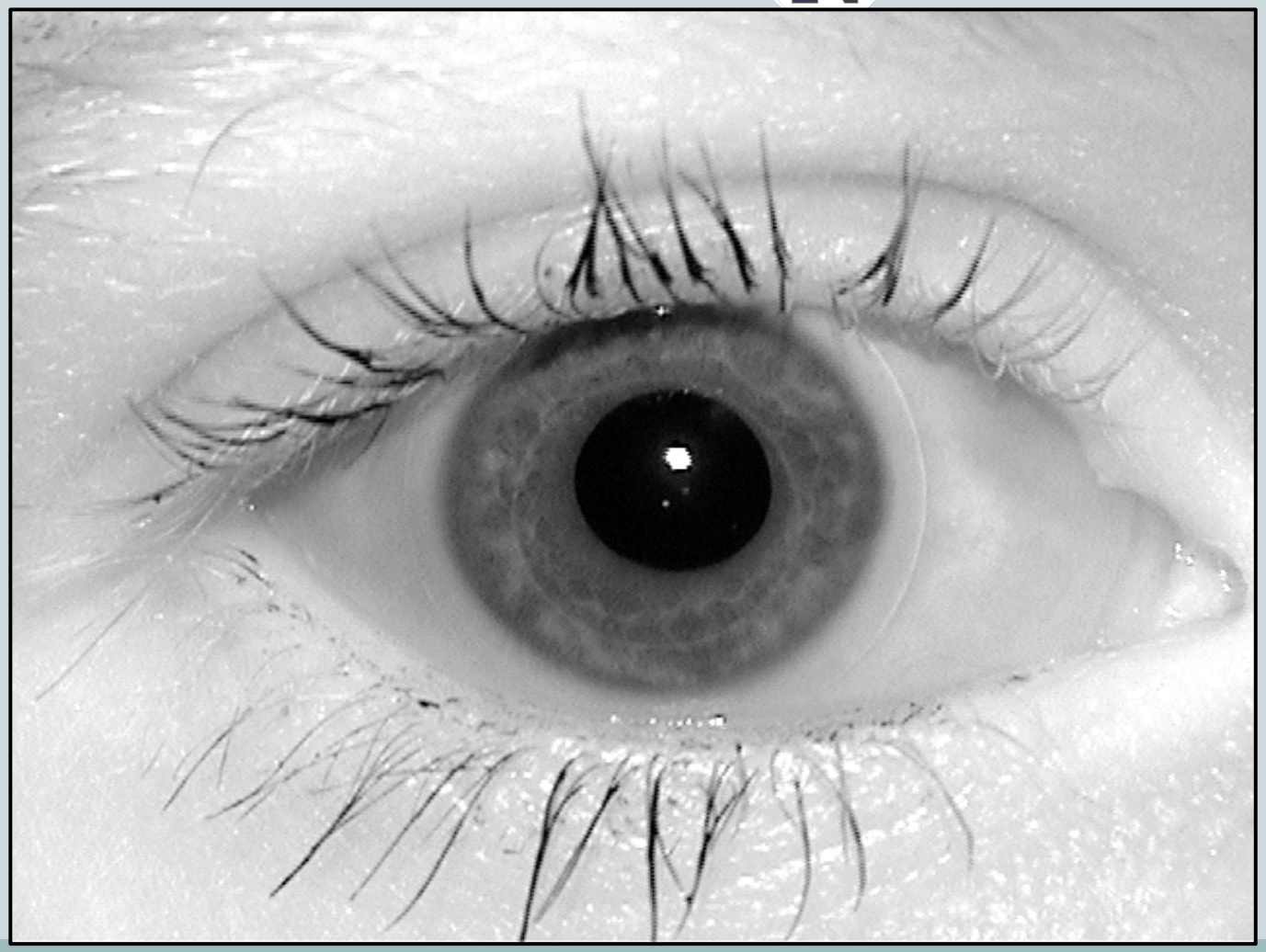
# Example Iris Images



**04885d98.**

**Circle blending with natural texture.**

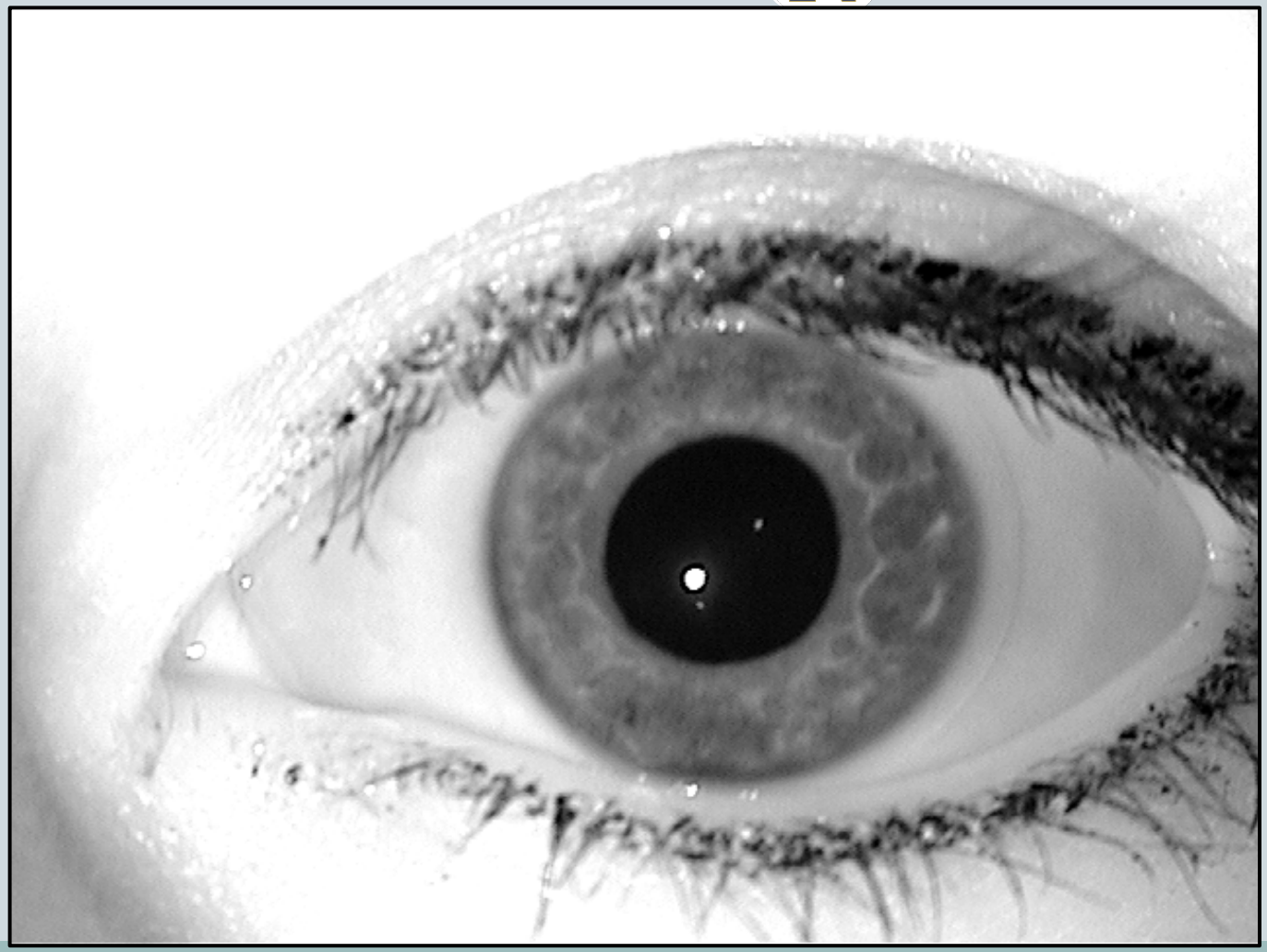
# Example Iris Images



04885d99.

Circle blending with natural texture.

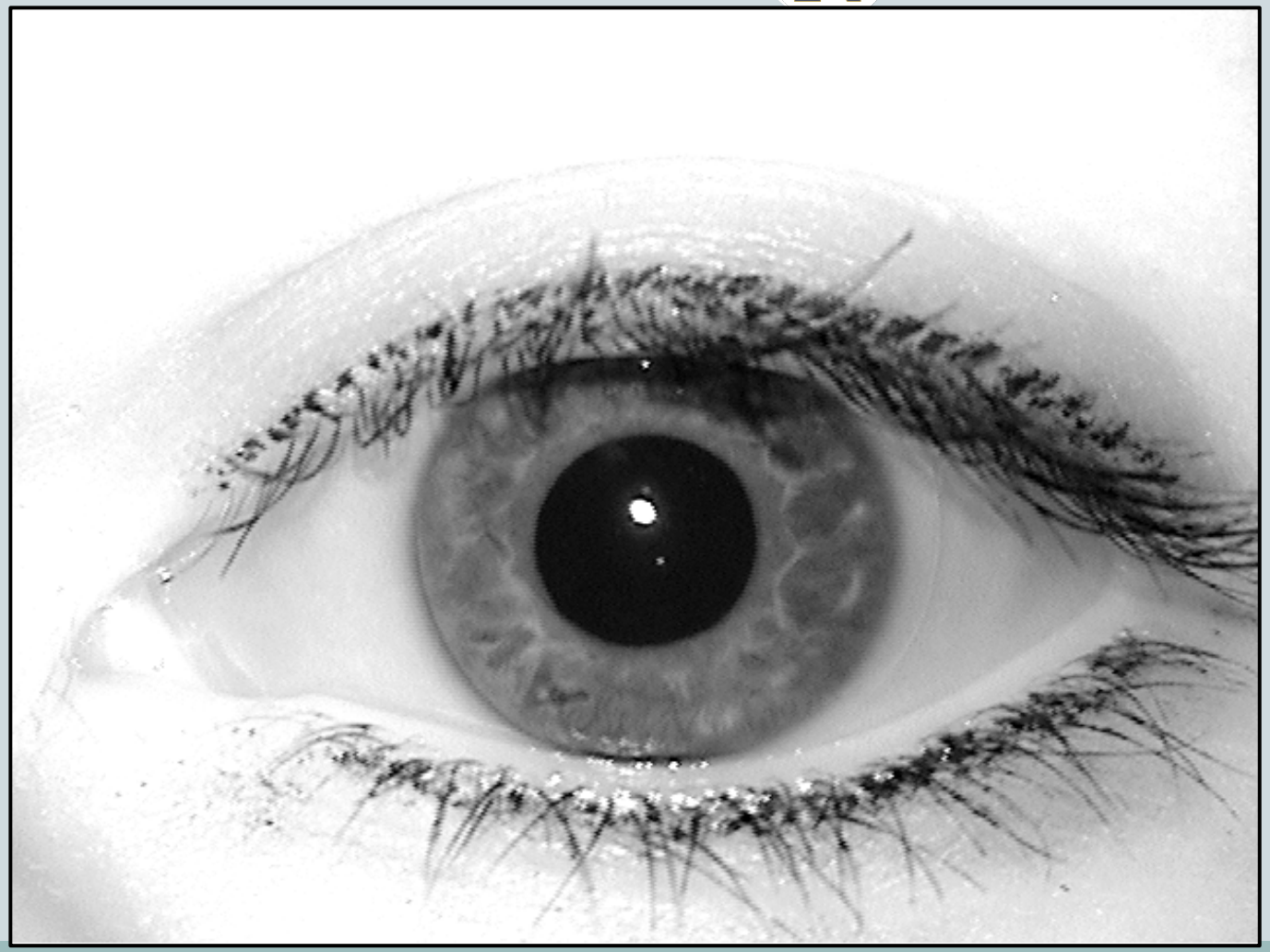
# Example Iris Images



04887d96.

Shifting “AV”.

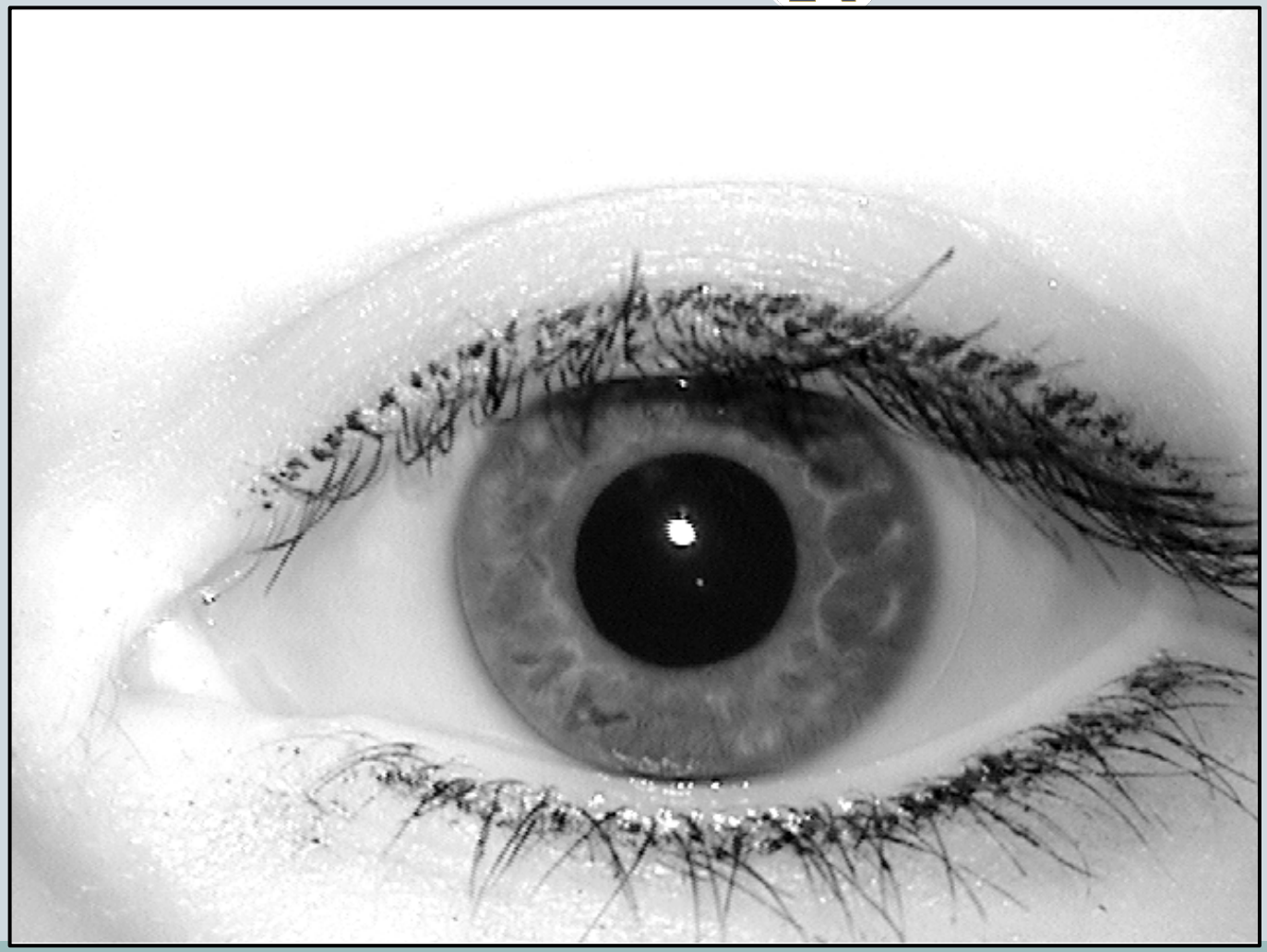
# Example Iris Images



04887d99.

Shifting “AV”.

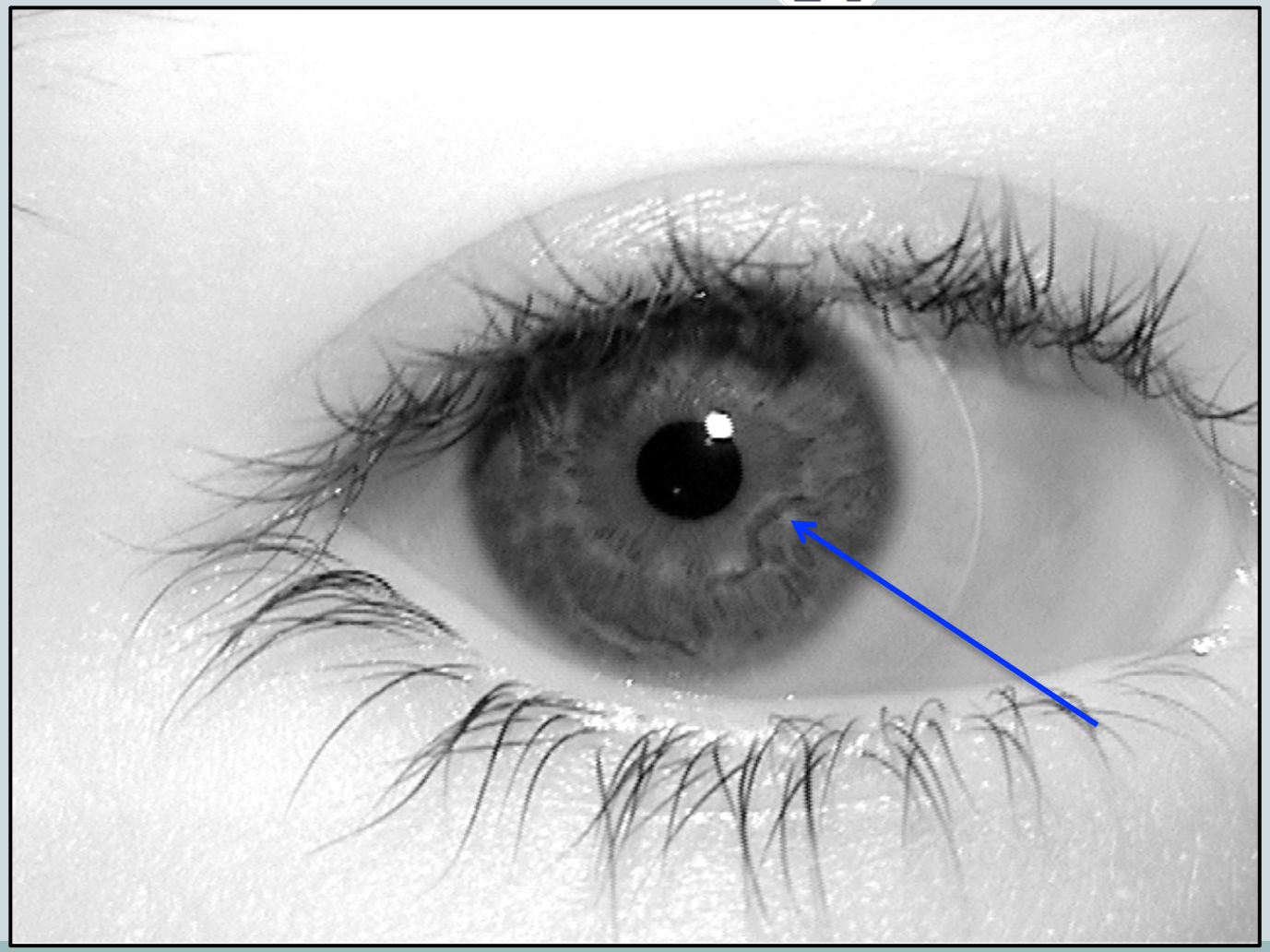
# Example Iris Images



**04887d102.**

**Shifting “AV”.**

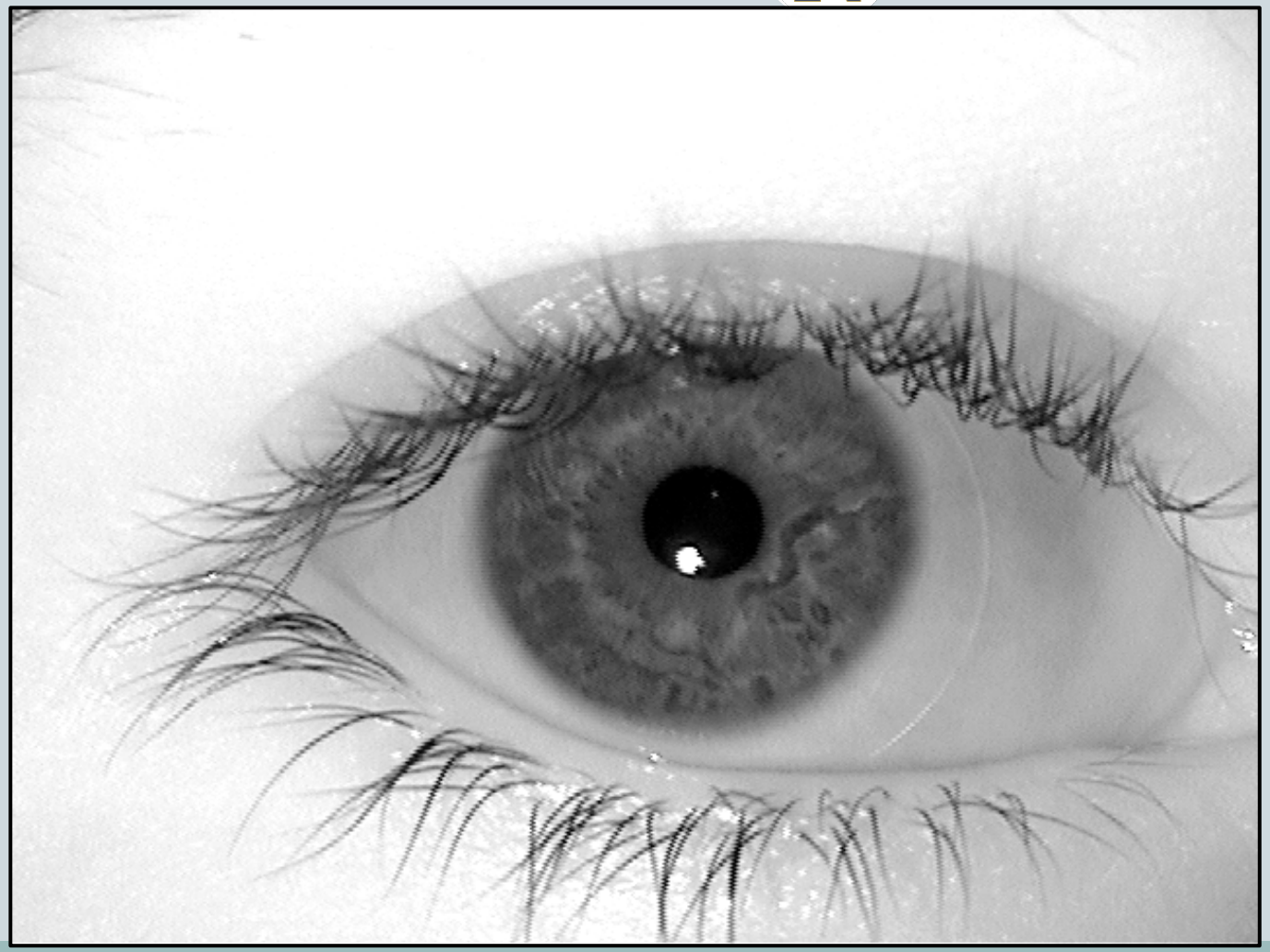
# Example Iris Images



**04888d74.**

**Shifting squiggle and lettering.**

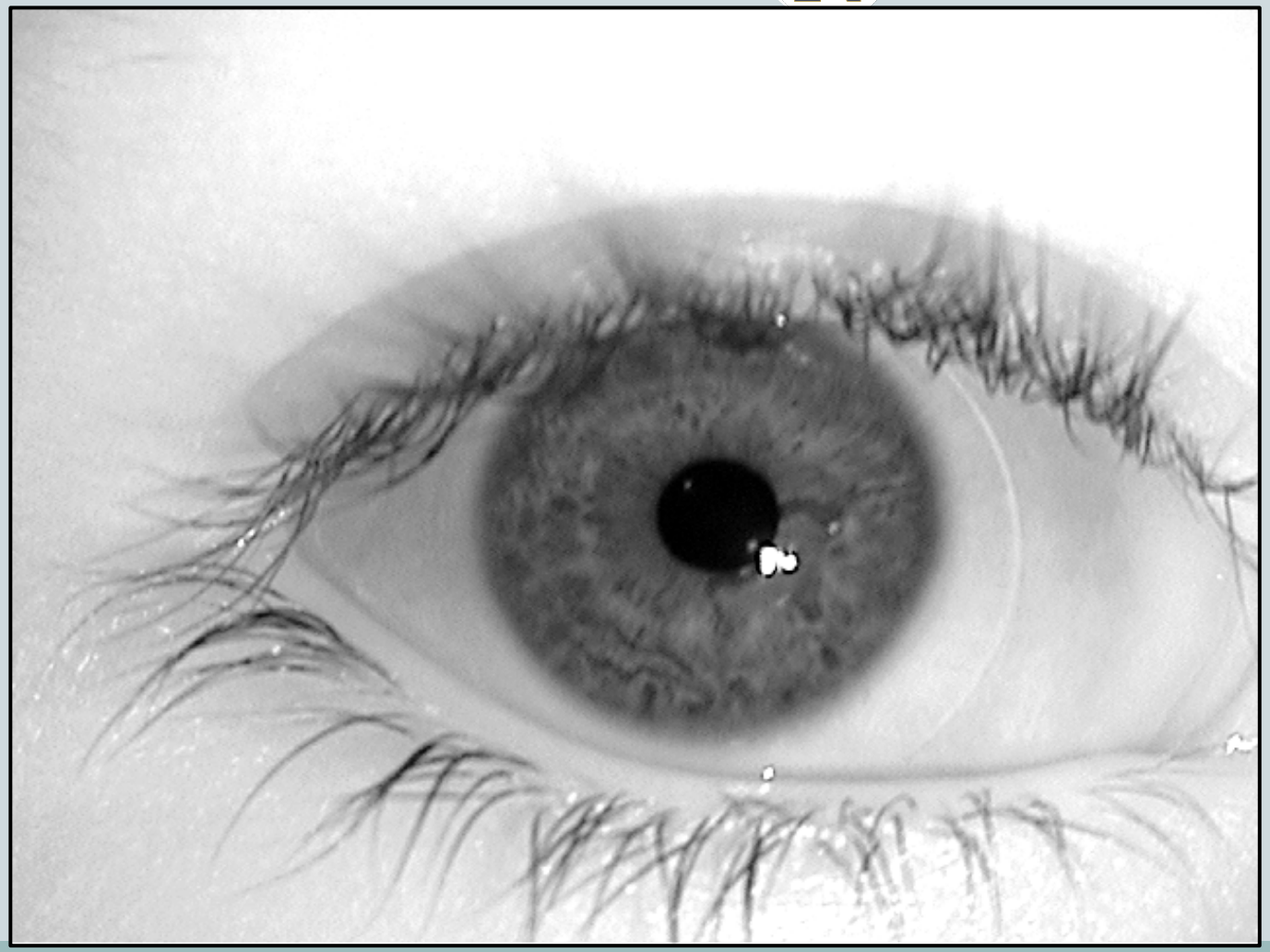
# Example Iris Images



**04888d75.**

**Shifting squiggle and lettering.**

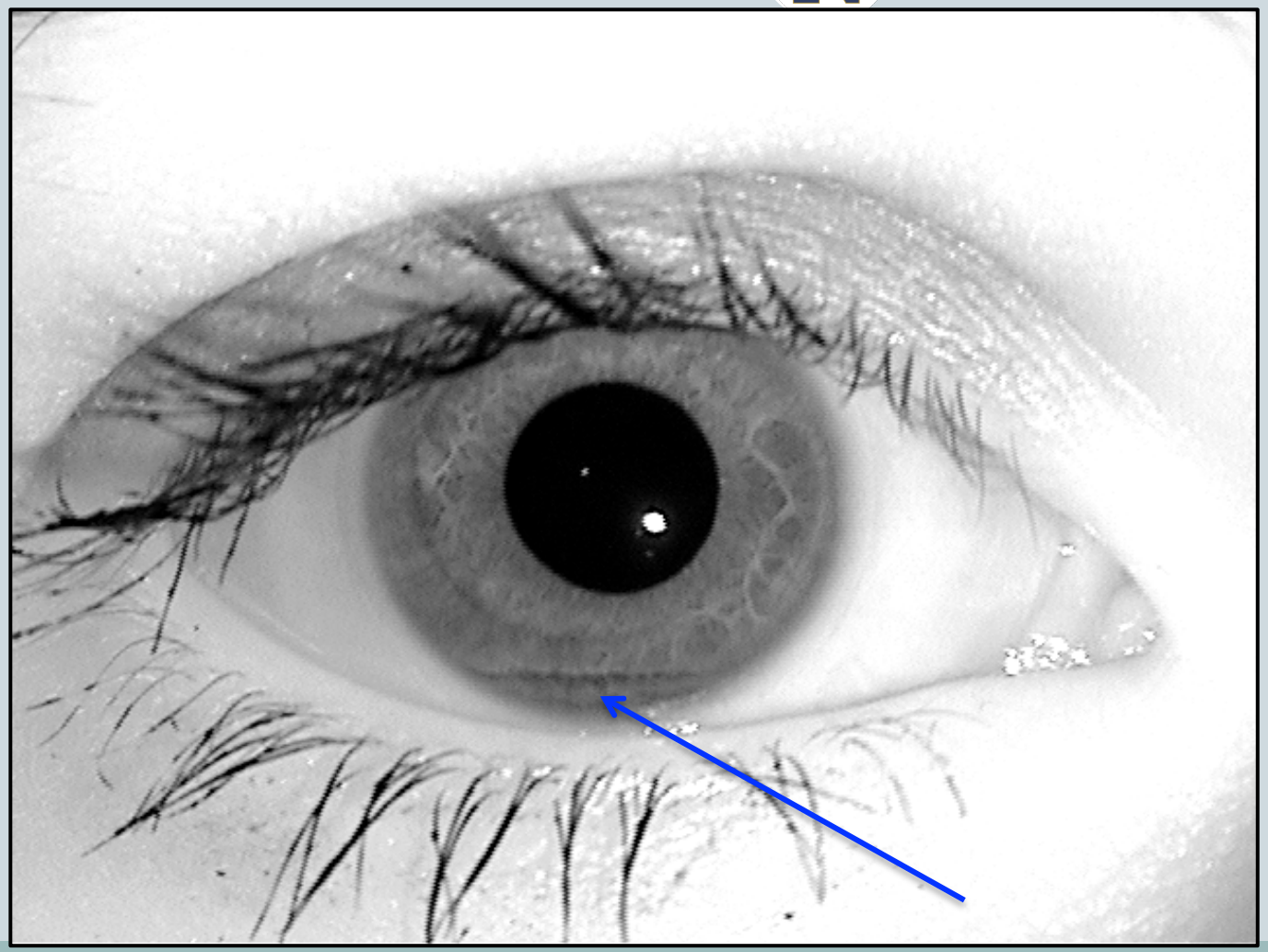
# Example Iris Images



**04888d76.**

**Shifting squiggle and lettering.**

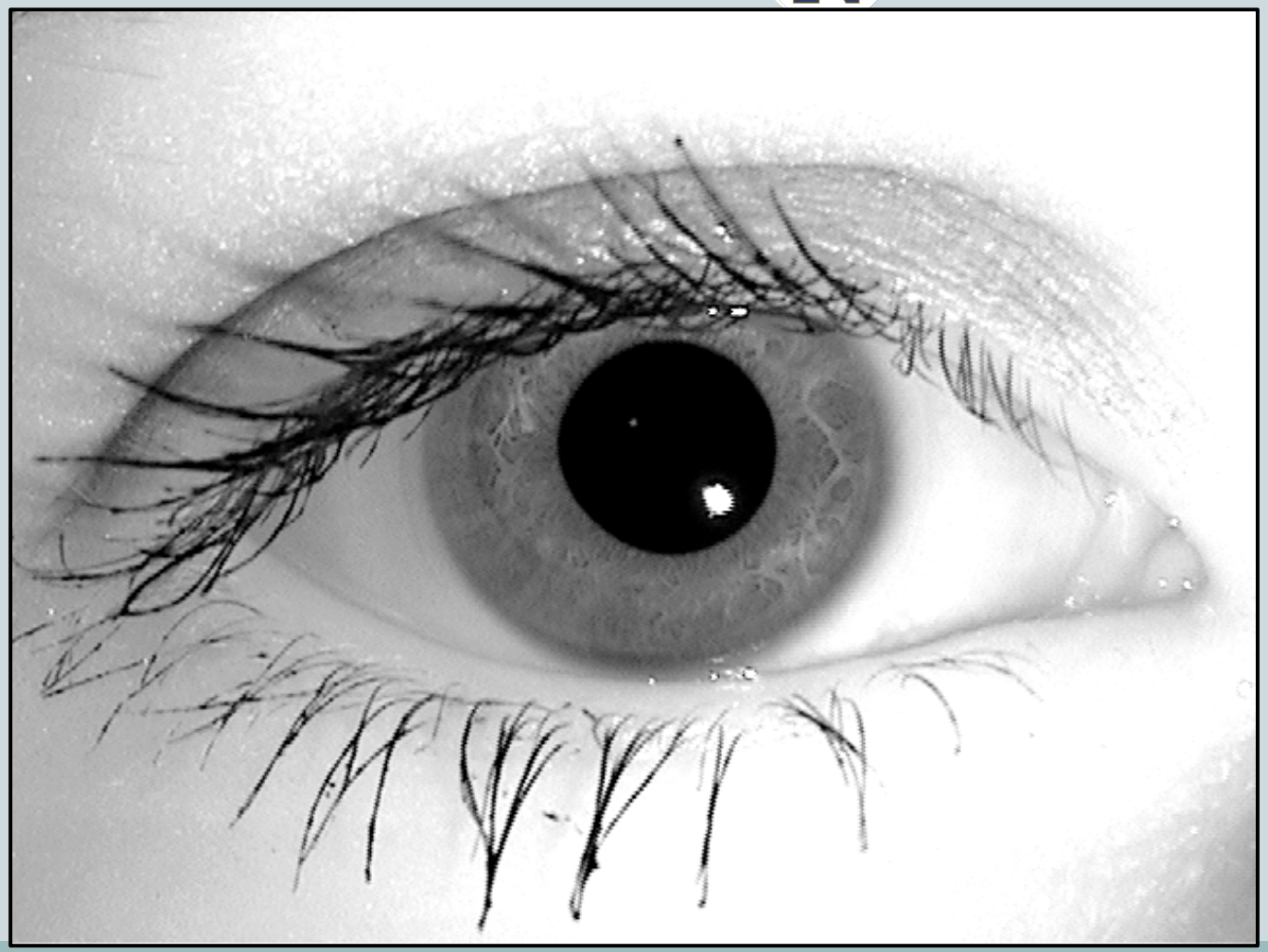
# Example Iris Images



**04926d17.**

**Shifting dark circle and line.**

# Example Iris Images



**04926d22.**

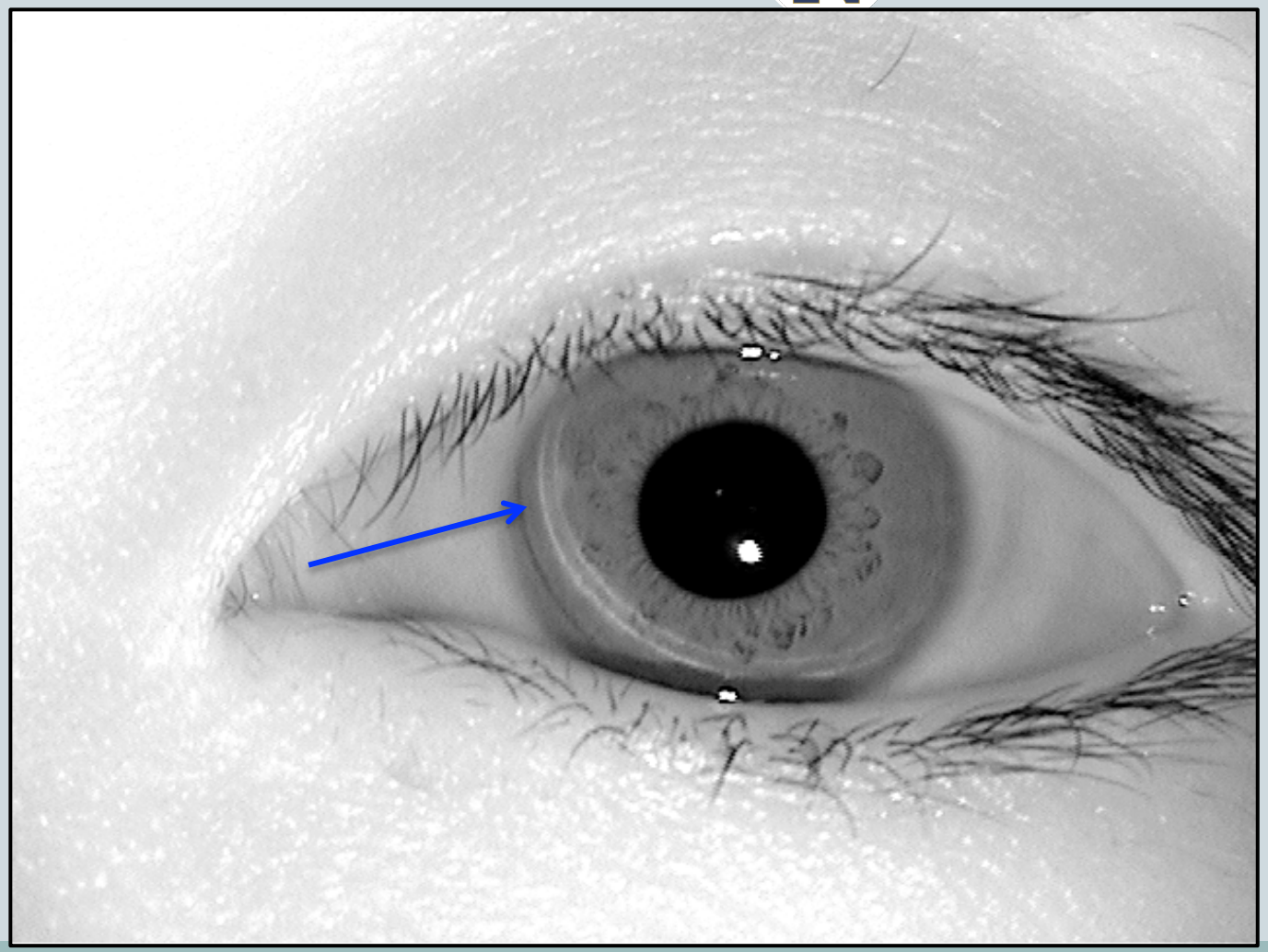
**Shifting dark circle and line.**

# Example Iris Images

**04926d23.**

**Shifting dark circle and line.**

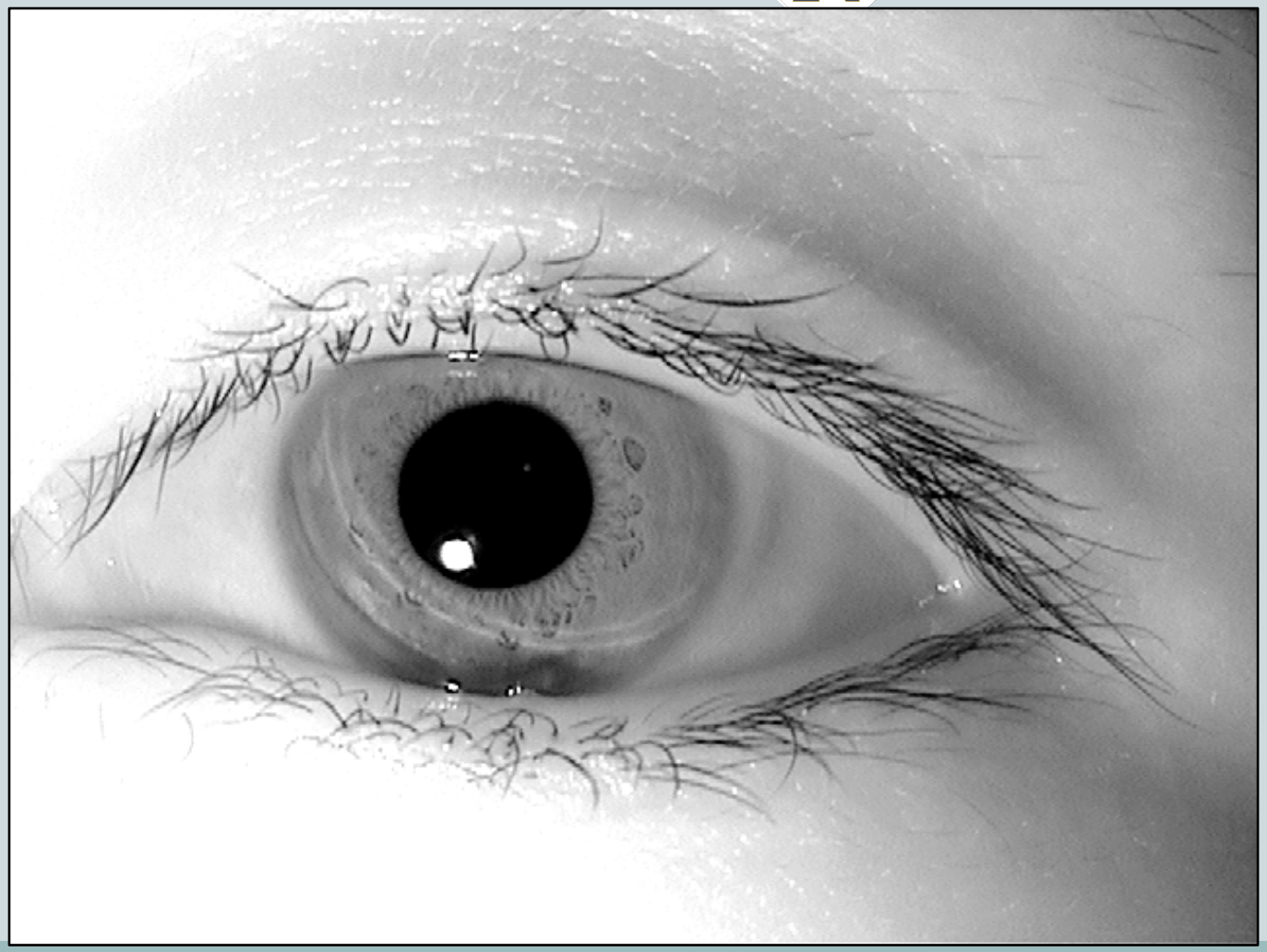
# Example Iris Images



**04221d1060.**

**Contacts lens that does not fit well.**

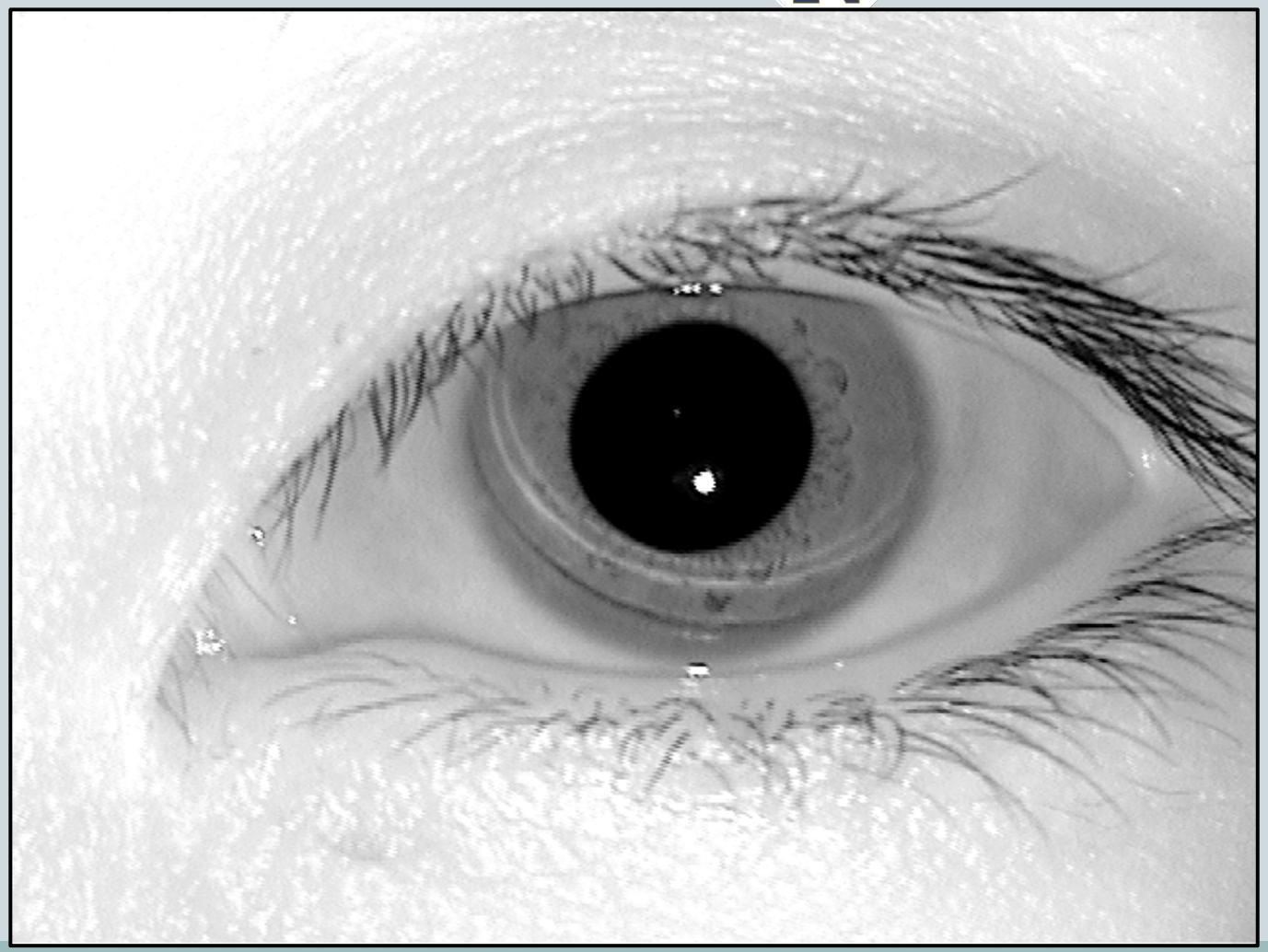
# Example Iris Images



**04221d1070.**

**Contacts lens that does not fit well.**

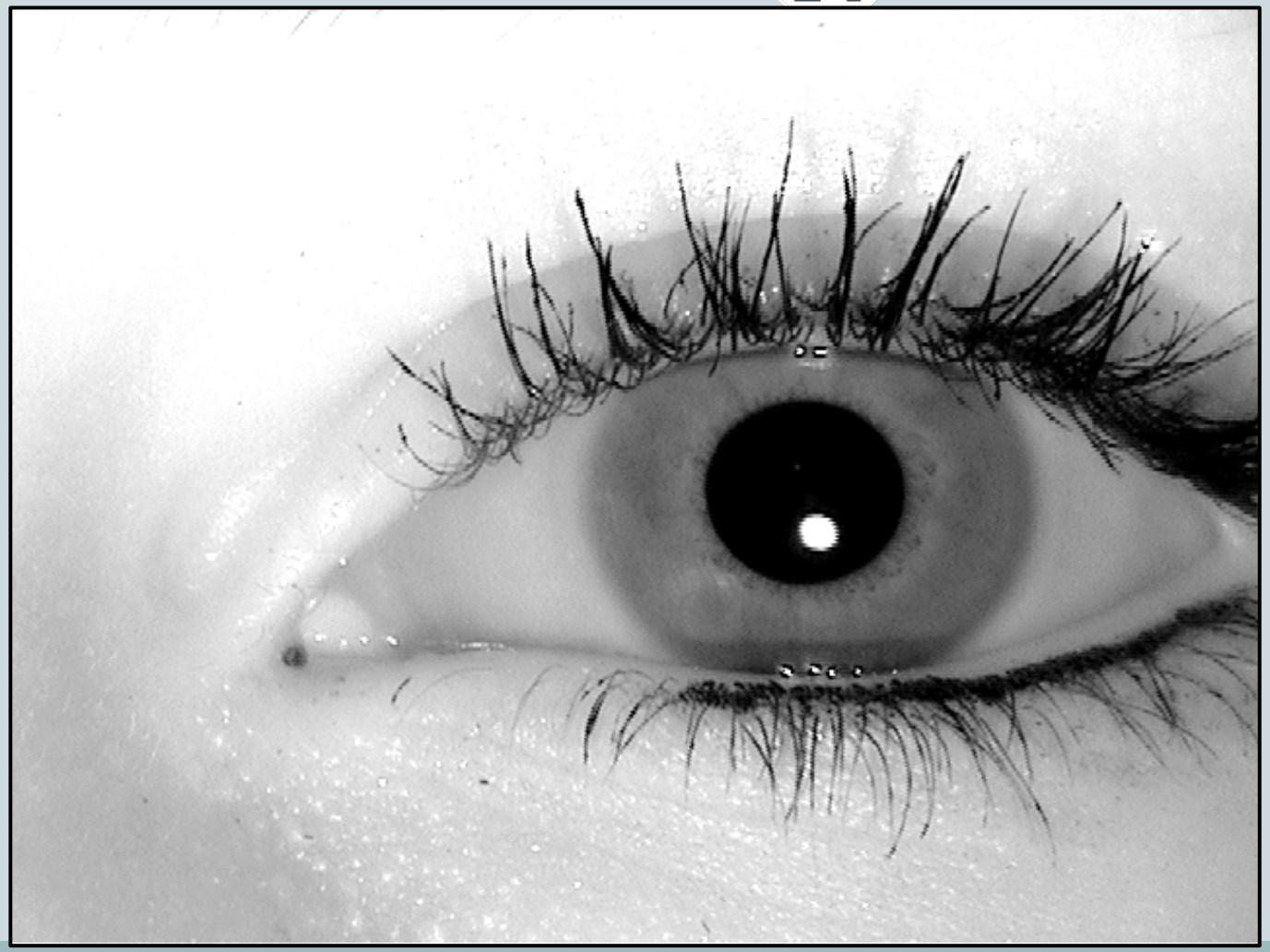
# Example Iris Images



**04221d1225.**

**Contacts lens that does not fit well.**

# Example Iris Images



**04780d143.**

**No contact lens.**

# Example Iris Images

**04780d112.**

**Cosmetic contact lens.**

# Example Iris Images

**04780d121.**

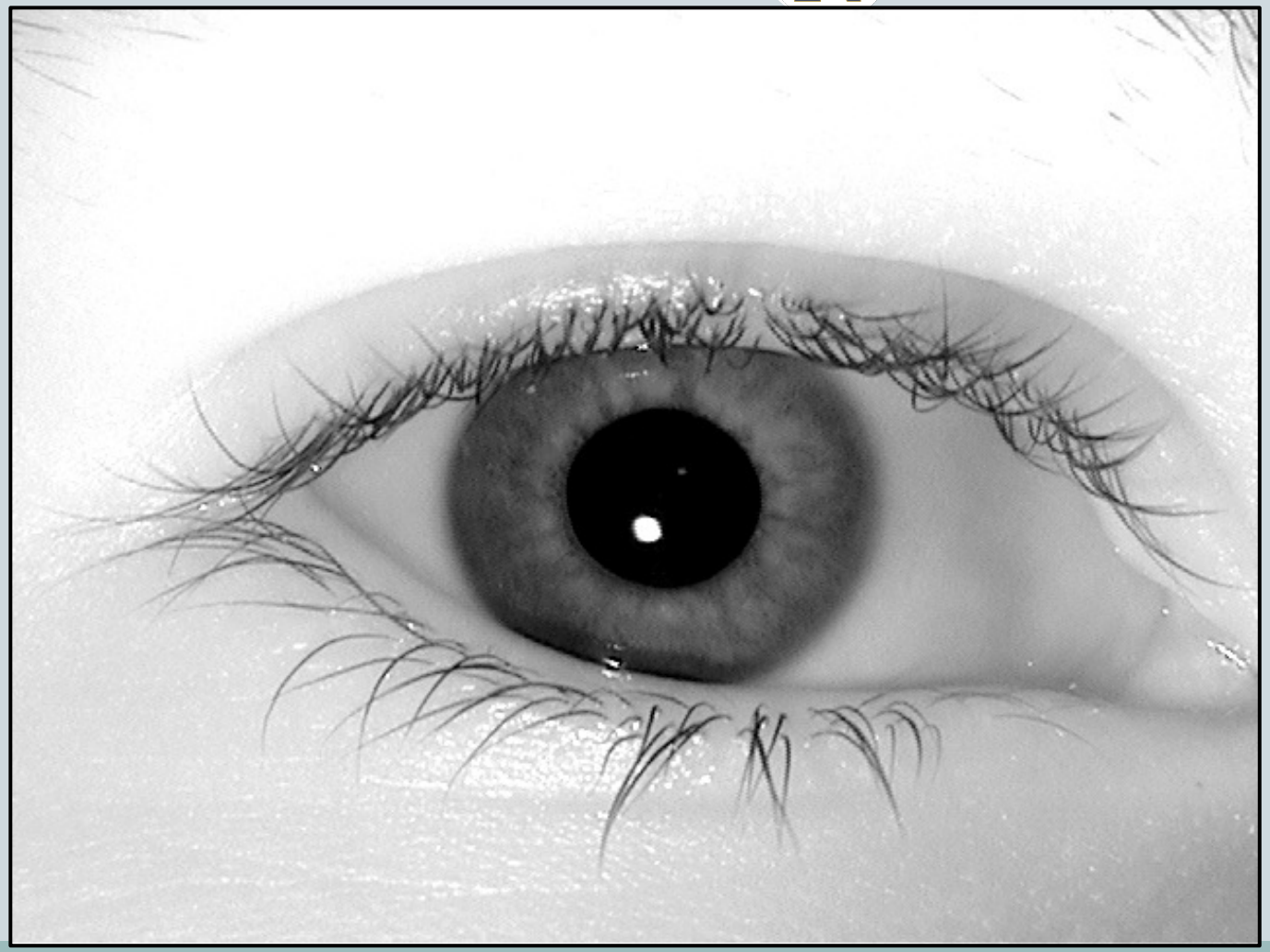
**Cosmetic contact lens.**

# Example Iris Images

**04780d159.**

**Cosmetic contact lens.**

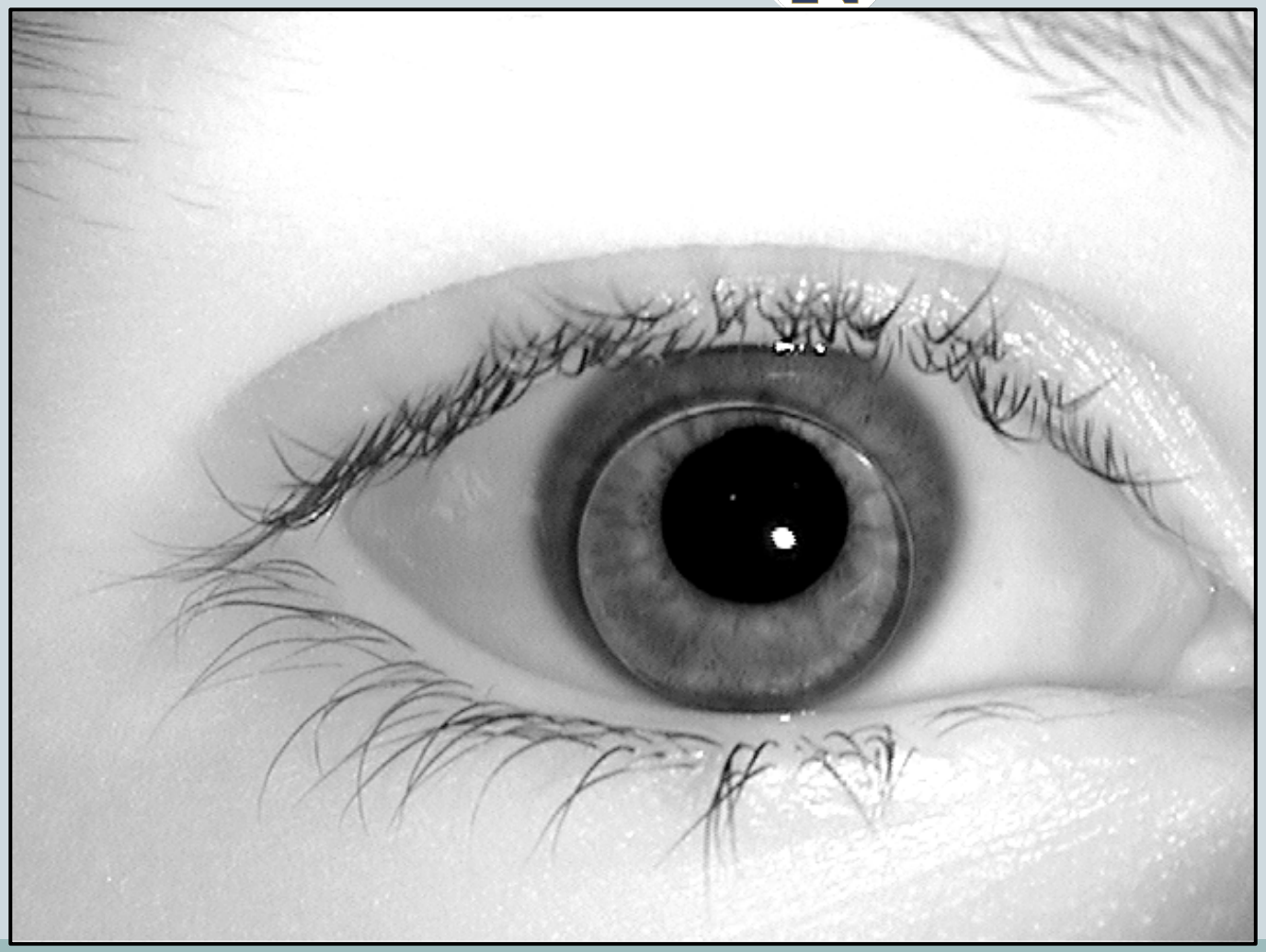
# Example Iris Images



**04622d653.**

**No contact lens.**

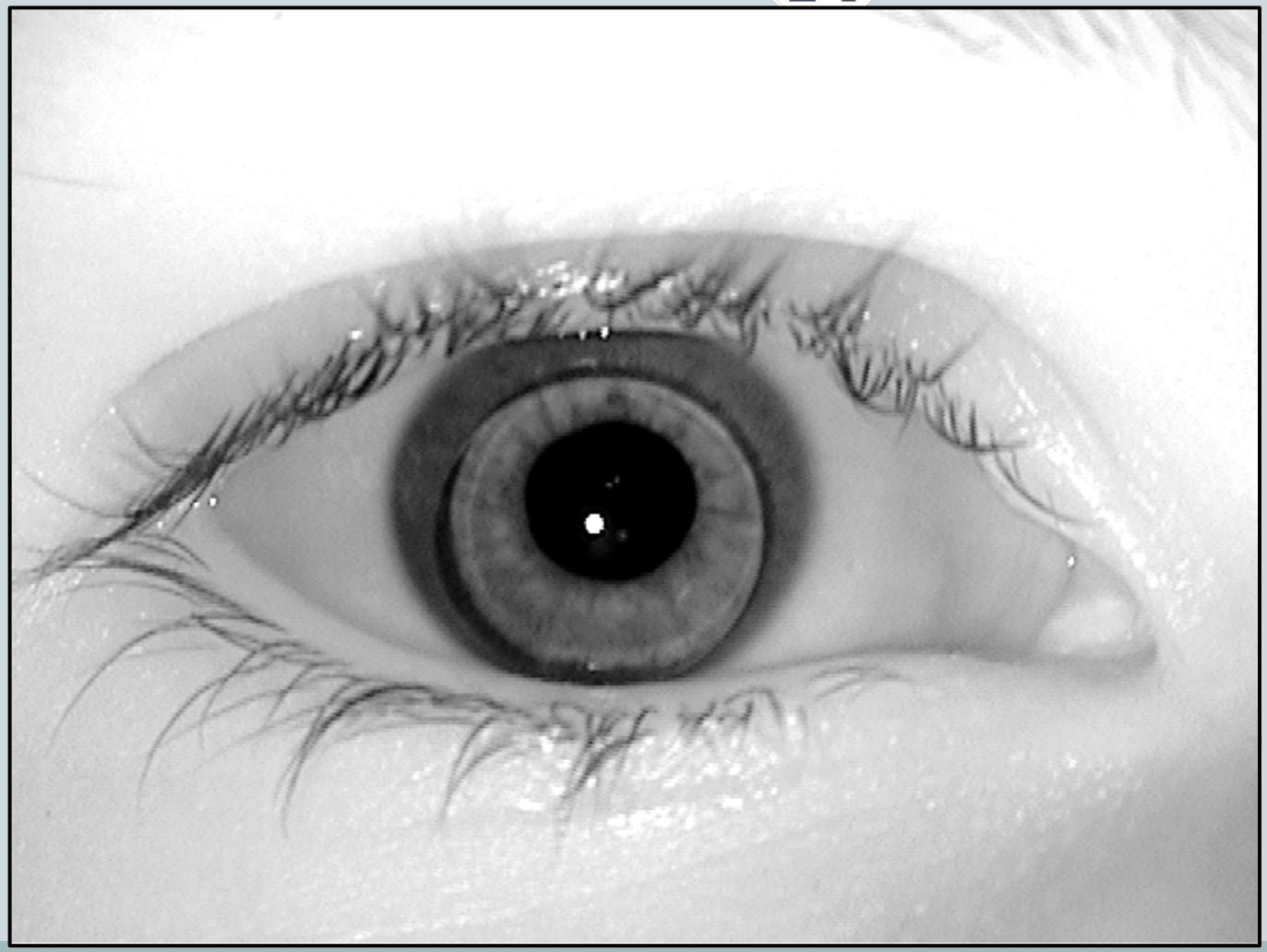
# Example Iris Images



**04622d660.**

**Rigid Gas Permeable (RGP) lens.**

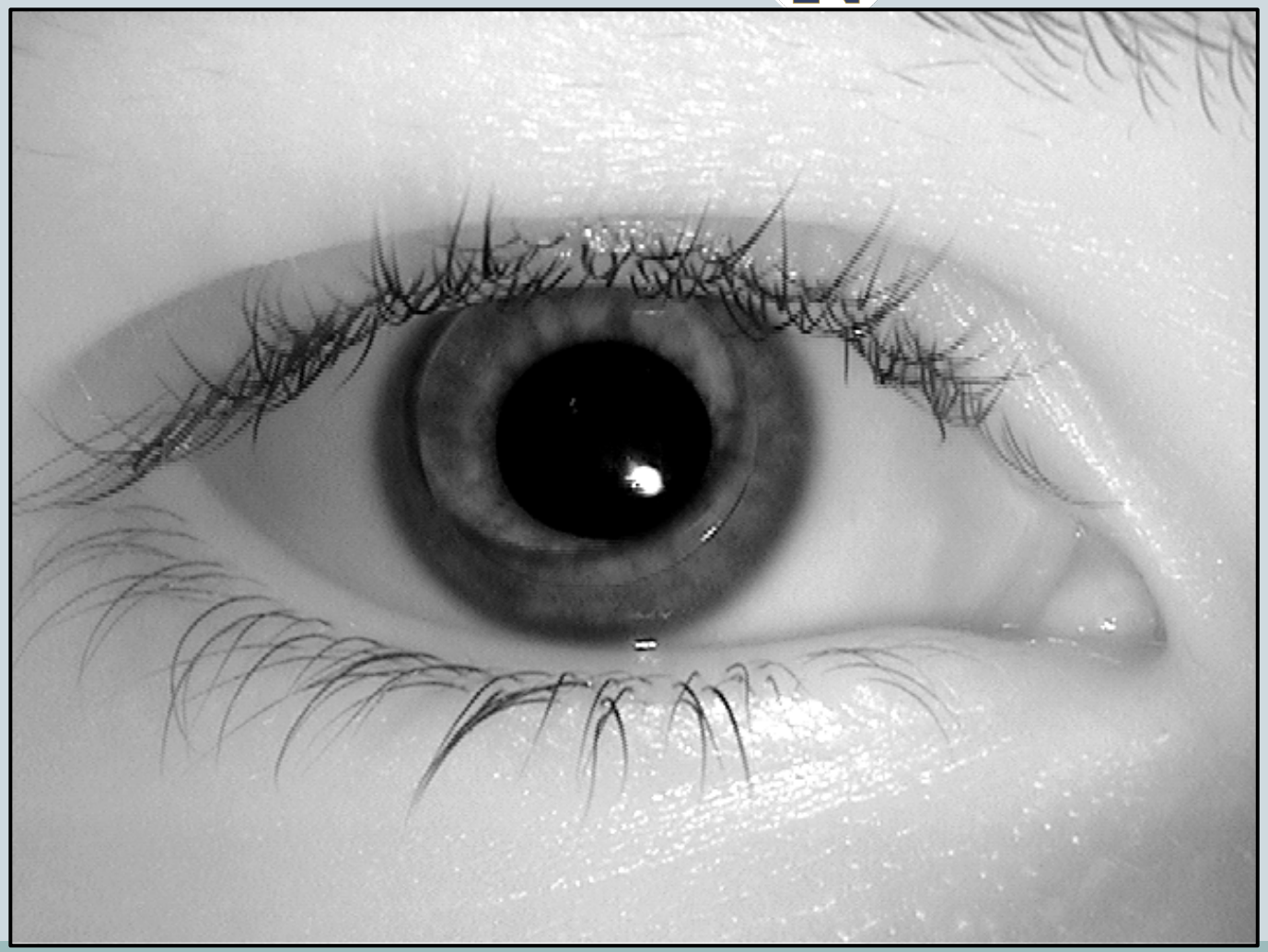
# Example Iris Images



**04622d665.**

**Rigid Gas Permeable (RGP) lens.**

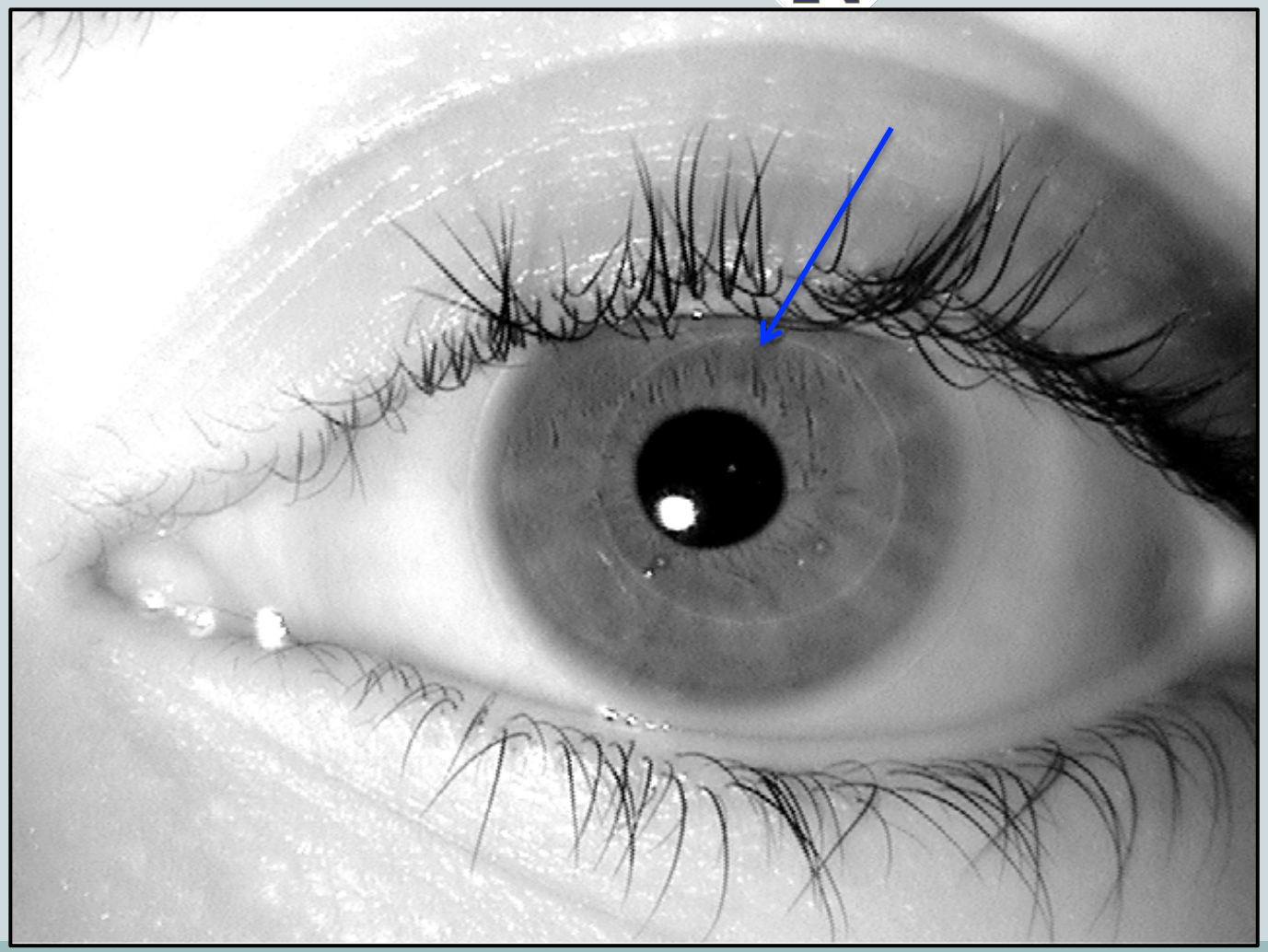
# Example Iris Images



**04622d741.**

**Rigid Gas Permeable (RGP) lens.**

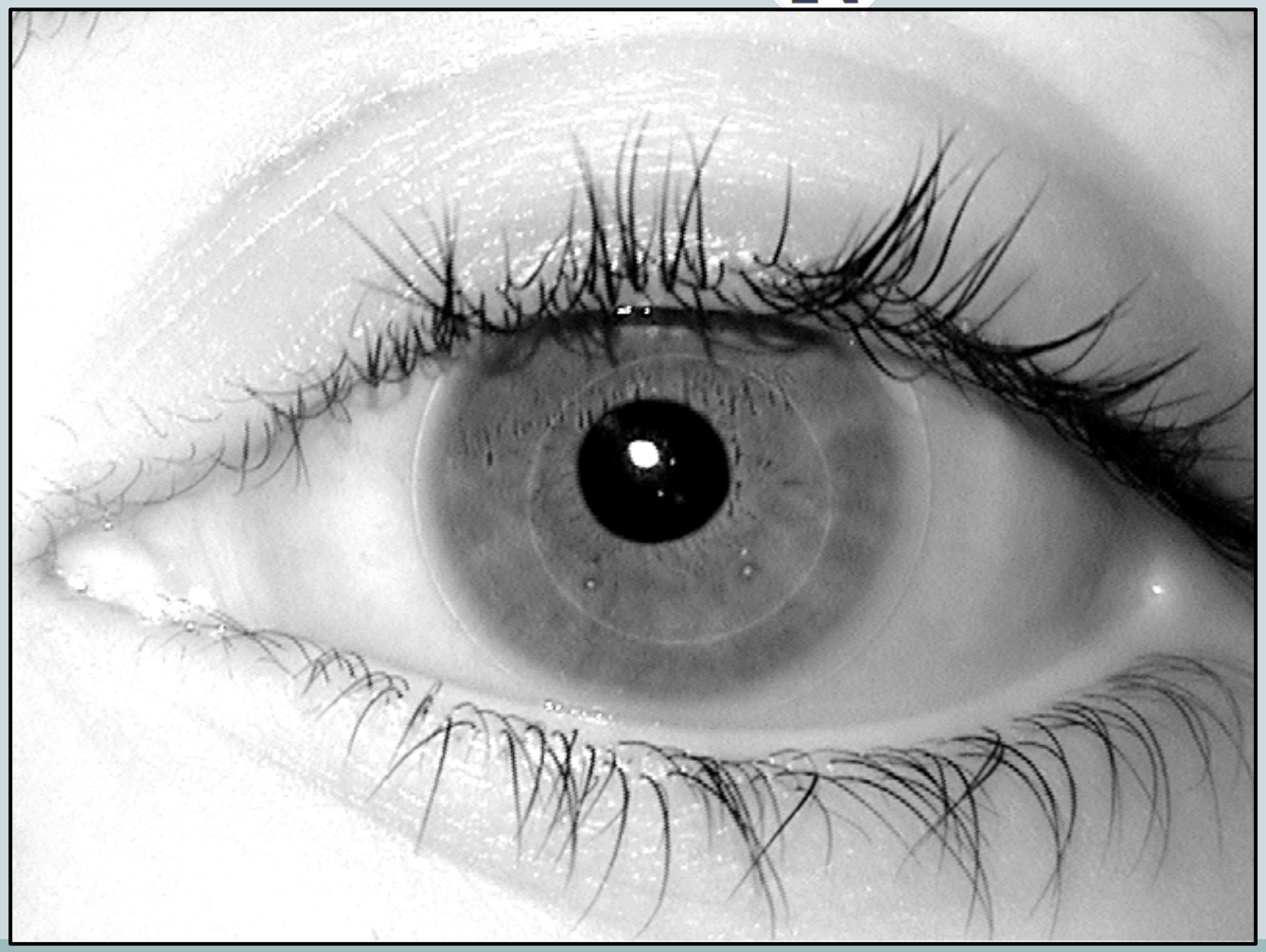
# Example Iris Images



**05271d21.**

**Contact lens, clusters of streaks that move around.**

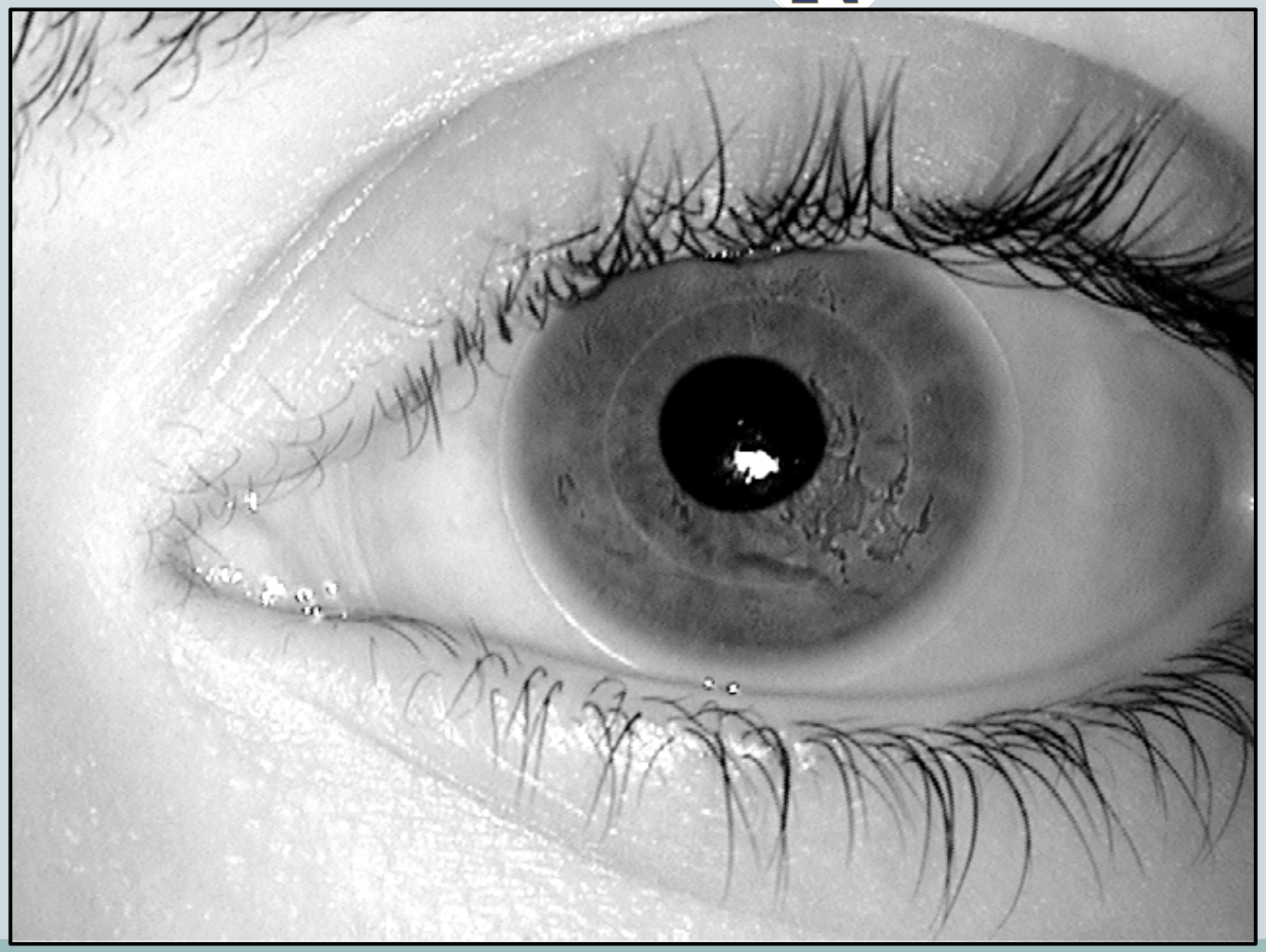
# Example Iris Images



**05271d23.**

**Contact lens, clusters of streaks that move around.**

# Example Iris Images



**05271d37.**

**Contact lens, clusters of streaks that move around.**

# Example Iris Images

**Contact lenses can contribute to a very broad variety of different effects in iris biometric images, all of which potentially effect iris biometric performance.**

# Today's Outline

- Review – creating iris codes
- Contact lens technology
- Example iris images
- **Effects of contact lenses**
- Research questions

# Effects of Contacts

**Conventional wisdom –**

***"Successful identification can be made through eyeglasses and contact lenses …"***

**"An Iris Biometric System for Public and …,"**
**M. Negin et al, *IEEE Computer*, Feb. 2000.**

# Effects of Contacts

## Conventional wisdom –

## "Iris recognition efficacy is rarely impeded by glasses or contact lenses."

**Wikipedia's article on "Iris Recognition", accessed October 25, 2010.**

# Effects of Contacts

**Conventional wisdom –**

**"Glasses, contact lenses, and even eye surgery does not change the characteristics of the iris."**

http://www.biometricnewsportal.com/iris_biometrics.asp, accessed Oct. 25, 2010.

# Effects of Contacts

## Conventional wisdom –

## "This type of biometric scanning works with glasses and contact lenses in place."

http://www.globalsecurity.org/security/systems/biometrics-eye_scan.htm, accessed Oct. 25, 2010.

# Effects of Contacts

## Two experiments:

- One with data from 15 persons wearing contacts, 15 no contacts, in *Int'l Conf. on Biometrics* in 2009
- Larger study with 87 persons wearing contacts and 124 not, published in *CVIU* in September 2010

# Effects of Contacts

## Experimental dataset:

- Images from ND_Iris_0405 dataset
- Acquired with LG 2200 system
- Visually inspected for image quality, IrisBEE segmentation quality
- Screened to not have large rotation
- Manually tagged for type of contacts

# Effects of Contacts

## Experimental dataset:

- 92 persons never wearing contacts
- 52 who wore same type of contacts
- 32 sometimes wore contacts
- 3 visibly changed type of contacts

= 87 subjects wearing contacts + 124 not wearing contacts.

# Effects of Contacts

## Experimental dataset:

- Age: 19 – 58; 75% are 19 – 25
- Gender: 85 female, 86 male
- 122 Caucasian, 36 Asian, 13 other
- Do not have stats on prescriptions for types of contact lenses

# Effects of Contacts

## Experimental dataset:

- 124 no-contacts subjects; 248 irises; total of 9,697 images = about 40 images per iris
- 87 contacts-wearing subjects; 174 irises; total of 12,003 images = about 70 images per iris

# Effects of Contacts

Images categorized as:

0. Not wearing contacts
   (124 subjects; 9,697 images)
1. No artifact visible on iris region
   (47 subjects; 5,867 images)
2. Thin light or dark circle on iris
   (26 subjects; 3,602 images)

# Effects of Contacts

3. Larger visible artifact on iris; eg, AV (11 subjects, 1,802 images)
4. Rigid gas permeable (RGP) lenses (4 subjects, 732 images)

Plus one subject who wore various cosmetic contacts at different times.

# Effects of Contacts

## Experimental materials:

- IrisBee with 25% fragile bit masking, +/- 15 degree rotation, …
- VeriEye with similar rotation range

# Effects of Contacts

## IrisBEE FRR in % with 0.32 Threshold

| Category | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 0 | 1.17 | 5.66 | 6.02 | * | * |
| 1 | | 1.67 | * | * | |
| 2 | | | 3.72 | * | |
| 3 | | | | 5.77 | |
| 4 | | | | | 40.1 |

* = less than 15,000 matches in this category

# Effects of Contacts

**VeriEye FRR in % with Threshold = 43**

| Category | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 0 | 0.04 | 0.44 | 3.20 | * | * |
| 1 | | 0.05 | * | * | |
| 2 | | | 0.08 | * | |
| 3 | | | | 0.70 | |
| 4 | | | | | 2.02 |

* = less than 15,000 matches in this category

# Effects of Contacts

**Huge difference in FRR with IrisBee versus VeriEye, across the board.**

**But there is also a huge difference between wearing contacts and not wearing contacts, with both systems.**

# Effects of Contacts

- Going from category 0 to 1:
  - about 50% increase in IrisBee FRR
  - about 25% in VeriEye FRR
- Going from category 0 to 2:
  - about triple FRR with IrisBEE
  - about double FRR with VeriEye

# Effects of Contacts

- Going from category 0 to 3:
  - about 5x increase with IrisBee
  - about 17.5x in VeriEye FRR
- Going from category 0 to 4:
  - about 40x increase with IrisBEE
  - About 50x increase with VeriEye

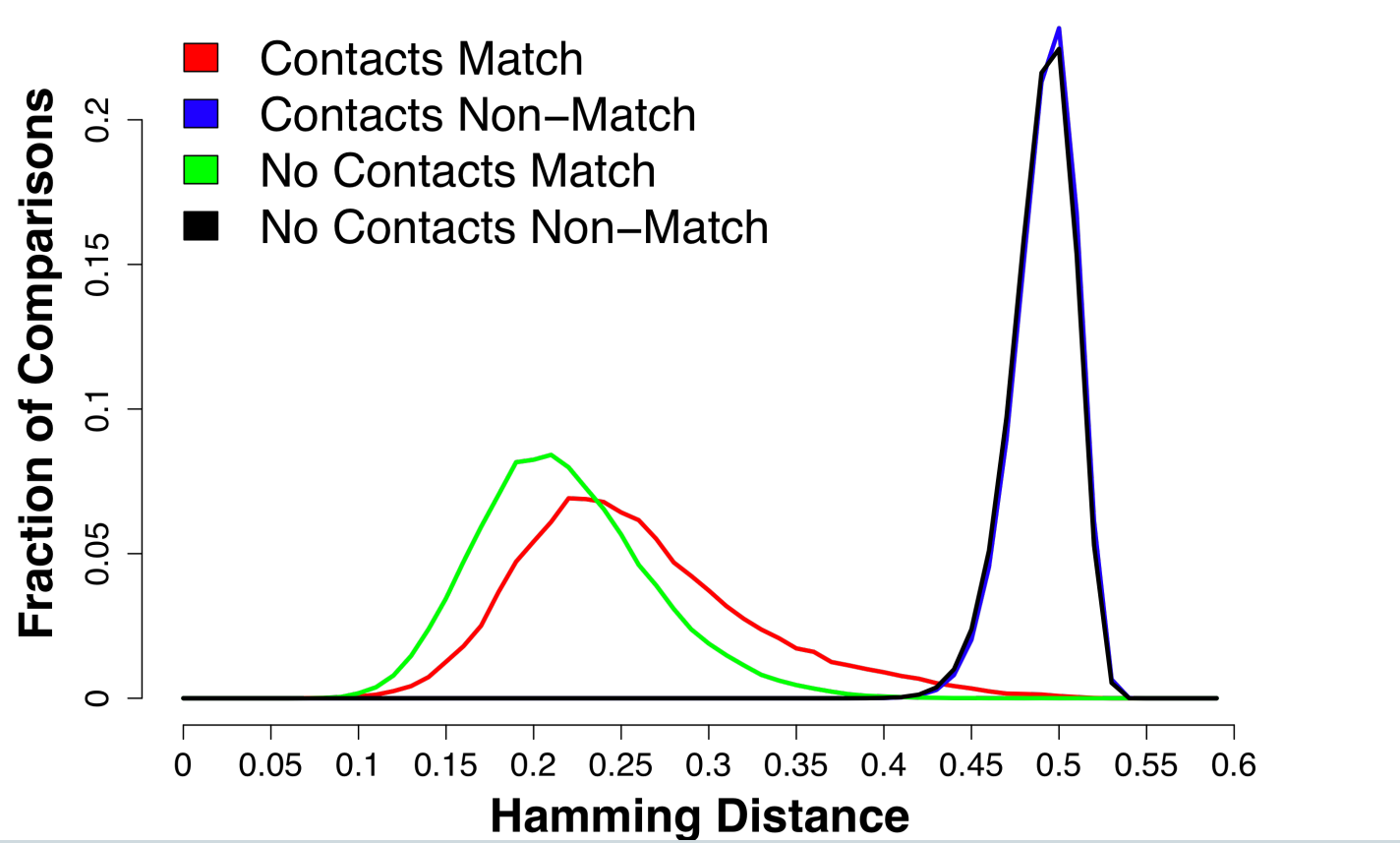
# Effects of Contacts

**Depending on the type of lenses and the biometrics software used:**

***Contact lens wearers are from 25% more likely to 50 times more likely to experience a false reject!***

# Effects of Contacts

## The general situation is something like …



# Effects of Contacts

**Above results do not include cosmetic lenses.**

**Matching cosmetic lens images across sessions gave 100% FRR.**

**Matching cosmetic to no contacts images across sessions gave 95% FRR.**

# Effects of Contacts

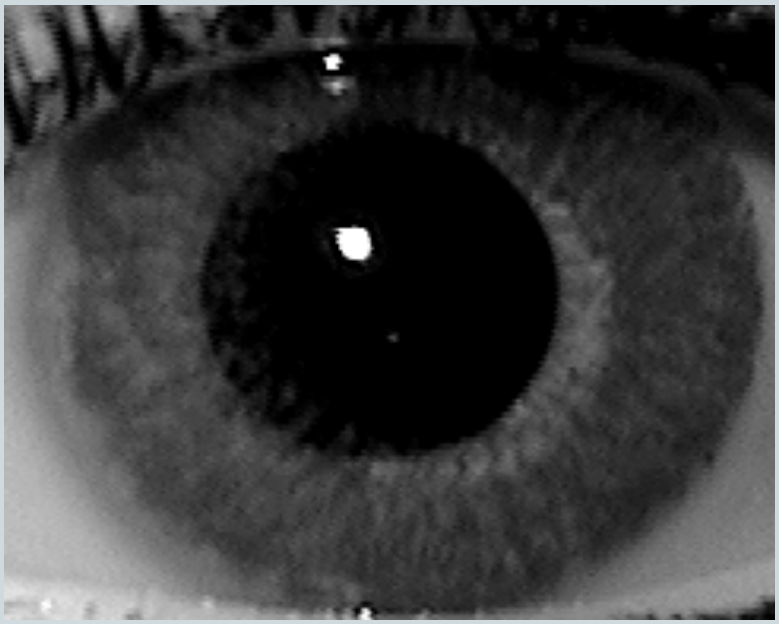
**Caution –**

**We have a very small number of cosmetic lens iris images, and the variety of cosmetic lenses is large.**

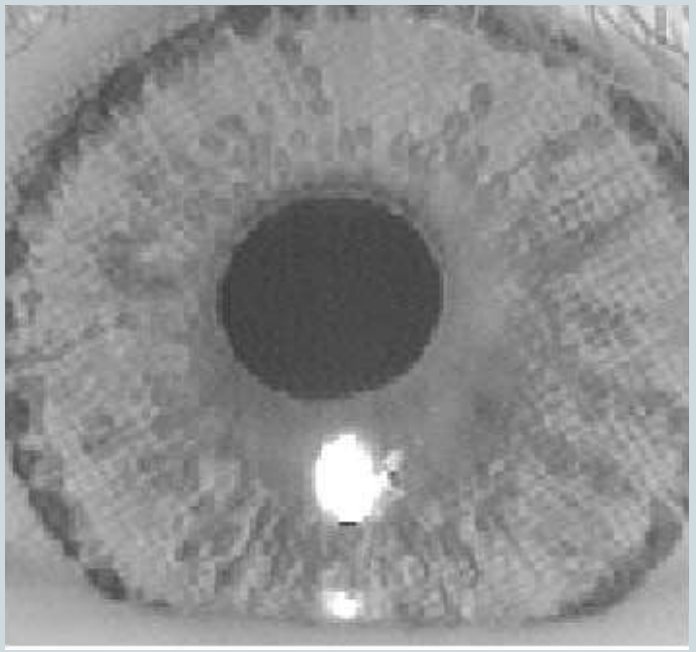
**It is possible that there are different effects that we have not yet seen.**

# Effects of Contacts

There are >= 2 types of cosmetic contacts.



“pad printing”



“dot matrix”

(Thanks to John Daugman for use of his iris image.)

# Today's Outline

- Review – creating iris codes
- Contact lens technology
- Example iris images
- Effects of contact lenses
- **Research questions**

# Research Questions

Larger experimental studies to better understand the basic phenomena:

by type of prescription lens, and

especially with cosmetic lenses.

# Research Questions

**Detect when a person is wearing contact lenses:**

- **using a single still image?**
- **using a video stream?**
- **using added illumination?**

# Research Questions

Compensate for a person wearing contact lenses:

- by masking out lens artifacts?
- by integrating parts of several images from a video sequence?

# Research Questions

**Identity theft question –**

**Can custom-made contacts be used to allow Person A to match to Person B's enrolled iris template?**

# End of sixth class.