DOT/FAA/AM-99/6

Office of Aviation Medicine
Washington, D.C. 20591

Refractive Surgery in the Civil Airman Population by Class of Medical Certificate And by Aviation Occupation

Van B. Nakagawara
Kathryn J. Wood
Ronald W. Montgomery
Civil Aeromedical Institute
Federal Aviation Administration
Oklahoma City, OK 73125

February 1999

Final Report

U.S. Department of Transportation
Federal Aviation Administration

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/AM-99/6		

4. Title and Subtitle	5. Report Date
Refractive Surgery in the Civil Airman Population by Class of Medical Certificate and by Aviation Occupation	February 1999
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Nakagawara, V.B., Wood, K.J., and Montgomery, R.W.	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
FAA Civil Aeromedical Institute P.O. Box 25082 Oklahoma City, OK 73125	
	11. Contract or Grant No.
12. Sponsoring Agency name and Address	13. Type of Report and Period Covered
Office of Aviation Medicine Federal Aviation Administration 800 Independence Ave, S.W. Washington, D.C. 20591	
	14. Sponsoring Agency Code

15. Supplemental Notes

This work was performed under task AM-B-98-TOX-203

16. Abstract

Introduction. Refractive surgical procedures performed in the United States have increased in recent years and continued growth is projected in the near future. These procedures have been associated with numerous side-effects, including glare, reduced contrast sensitivity, and fluctuating visual acuity. The quality of vision after refractive surgery may be unacceptable in a cockpit environment. This report reviews the aeromedical certification experience with the refractive surgery population.

Methods. Active airmen with FAA-specific pathology codes 130 (radial keratotomy) and 5179 (general eye pathology with surgical prefix), during the period 1 January 1994 through 31 December 1996, were identified in the Consolidated Airman Information System medical database. The medical records of airmen with pathology code 5179 were reviewed. Airmen identified by records review as having had refractive surgery, and those with pathology code 130 were collated into a database and analyzed against demographic data extracted from Federal Aviation Administration (FAA) publications. Airmen with refractive surgery were further stratified by aviation occupation (pilot, copilot, first and second officer, and flight engineer).

Results. There were 3,761 airmen identified as having had some type of refractive surgical procedure during the study period. The prevalence rate of refractive surgery in the total civil airman population was 6.21/1,000 airmen. By class of airman medical certificate, the prevalence rate was 3.60/1,000 for first-class, 6.26/1,000 for second-class, and 7.43/1,000 for third-class holders. A total of 133 airmen (125 pilots and 8 flight engineers) with refractive surgery was identified as employees of scheduled and nonscheduled airlines.

Conclusions. Airmen who have had refractive surgery are present in all classes of civil aeromedical certificate holders, including a substantial number of crewmembers who fly for commercial airlines. The substantial presence and the anticipated increased incidence of such procedures in the airman population warrant special monitoring and evaluation of operational problems involving these pilots.

17. Key Words	18. Distribution Statement
Aviation Vision, Refractive Surgery, Radial Keratotomy (RK), Photorefractive Keratectomy (PRK)	Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	12	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

ACKNOWLEDGMENTS

The authors gratefully acknowledge the assistance provided by Dr. Stephen L Carpenter and Leslie E. Downey, of the Medical Appeals Branch, and the consultation and technical support provided by Dr. Henry K. Boren, of the Medical Review Branch, Aeromedical Certification Division.

Refractive Surgery in the Civil Airman Population by Class of Medical Certificate and by Aviation Occupation

INTRODUCTION

Optimum vision is essential for pilots who must detect and identify airborne traffic as well as hazards that may be on runways and taxi lanes. Printed materials, such as flight manifests, charts and maps, and cockpit instruments need to be clearly visible to ensure that proper flight procedures and safety are maintained.

Refractive error is an optical defect that prevents light rays from being focused as a clear, single image on the retina. Refractive conditions include myopia (nearsightedness), hyperopia (farsightedness), and astigmatism that are normally corrected with ophthalmic lenses (eyeglasses, contact lenses). There are approximately 145 million Americans (54.6% of the U.S. population) who are dependent upon spectacles or contact lenses to achieve a quality of vision satisfactory for their daily needs. With the advent of refractive surgical procedures there is considerable marketing pressure to induce those with a refractive error to free themselves from their dependence on glasses or contact lenses.

Civil airmen with radial keratotomy (RK) refractive surgical procedures have been allowed to obtain Federal Aviation Administration (FAA) medical certificates since the early 1980s. Currently, newer refractive surgical procedures, such as photorefractive keratectomy (PRK) and laser-assisted in situ keratomileusis (LASIK), are available for airmen (see Figure 1). At this time, applicants with refractive surgical procedures may obtain a medical certificate without a waiver if they meet the visual acuity standards for the class of medical certificate applied, and an eye specialist verifies that healing is complete, their visual acuity is stable, and no significant glare intolerance is present (1).

Refractive surgical procedures performed in the United States have increased and continued growth is projected. A survey of refractive laser manufacturers and service providers predicted a 100% increase in U.S. laser refractive procedures from 1996 to 1997, with LASIK representing 29% of these procedures (2). It is estimated about 1 million laser refractive procedures will be performed annually in the U.S. by the year 2000 (3).

There have been reports of numerous side-effects associated with refractive surgical procedures. These include: glare (4,5,6), halos around lights (7,8), reduced contrast sensitivity (9,10), refractive regression (11), fluctuating visual acuity (9,12), reduced best corrected visual acuity (13,14), and post-operative corneal haze (15). These signs and symptoms suggest that the quality of vision after refractive surgery may prove unacceptable in a cockpit environment. In addition, it is not known if post-refractive surgery problems could be compounded by the normal age-related decline in vision.

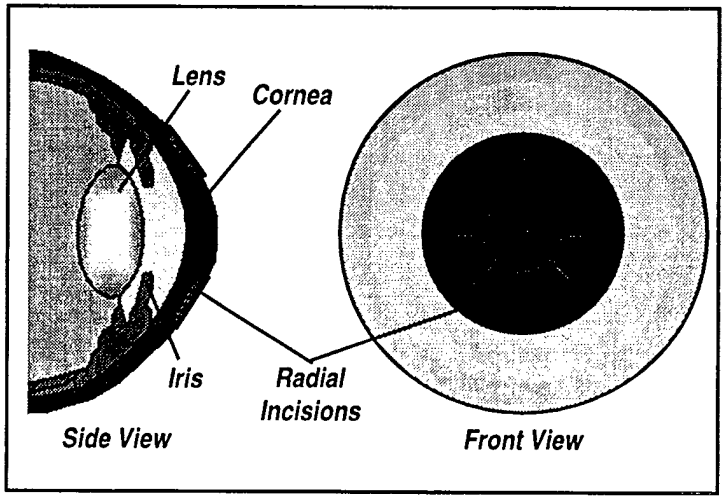
A Triservice Working Group on Refractive Surgery requested the FAA's Civil Aeromedical Institute in Oklahoma City, OK, study demographic and operational data of civil airmen with refractive surgery. The armed services are interested in the future application of refractive surgery in selected military occupational groups, including aviators. This report discusses the initial findings of an epidemiology study that reviewed the aeromedical certification experience of airmen with refractive surgery. It specifically examines the prevalence of refractive surgery in the civil airman population by class of medical certificate and by aviation occupation for the study period 1994-96.

METHODS

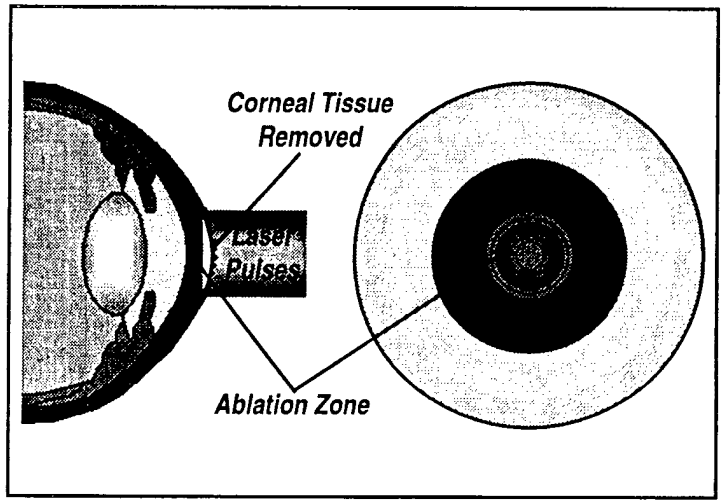
A list of active airmen with FAA-specific pathology codes 130 (radial keratotomy) and 5179 (general eye pathology with surgical prefix) during the period 1 January 1994 through 31 December 1996 was generated. This information was extracted from the Consolidated Airman Information System medical database, maintained by the FAA's Application Systems Division at the Mike Monroney Aeronautical Center in Oklahoma City, OK. Medical records of those airmen with pathology code 5179 were reviewed, to identify those airmen who had refractive

REFACTIVE SURGERY PROCEDURES

Radial Keratotomy (RK)



Photorefractive Keratectomy (PRK)



Laser-Assisted in Situ Keratomileusis (LASIK)

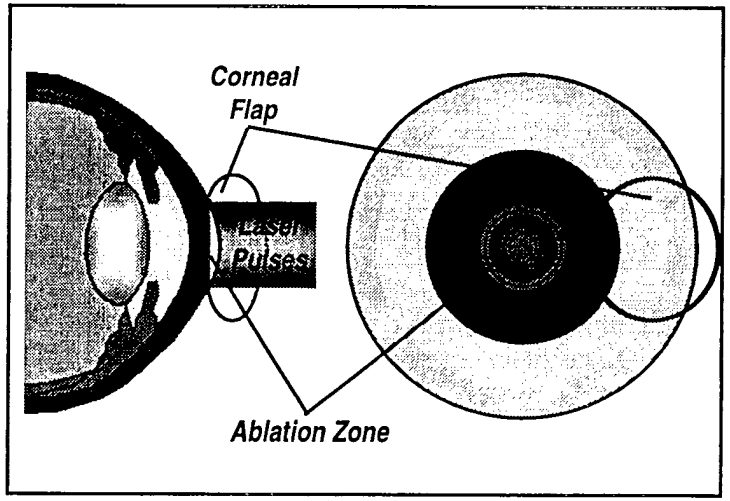


FIGURE 1

surgery. (Note: The 5179 code is assigned to applicants with various eye surgeries, including refractive surgery.) Data from airmen identified as having had refractive surgery through a record review and those airmen with pathology code 130 were collated into a database. This refractive surgery database was compared to the average of the total, first-, second-, and third-class civil airman populations during the study period. This data was extracted from the Aeromedical Certification Statistical Handbook, which is published annually by the Civil Aeromedical Institute's Aeromedical Certification Division (16).

Airmen with refractive surgery were further stratified by aviation occupation according to aeromedical certification guidelines. The captain, co-pilot, and first and second officers of scheduled and nonscheduled airlines are identified as first-class medical certificate holders that have an occupational code 1 designation in their medical records. Flight engineers are first- or second-class medical certificate holders who carry occupational code 2 designation (17).

RESULTS

Review of the 202 medical records of airmen carrying pathology code 5179 revealed that 53 airmen had refractive surgical procedures. Combining these records with the 3,708 airmen that carried pathology code 130 resulted in a total of 3,761 airmen who had some form of refractive surgery during the study period. The total average civil airman population for the period was 605,296. Figure 2 illustrates the division of the total average civil airman and refractive surgery population by class for 1994-96. The prevalence rate for refractive surgery in the total average civil airman population was 6.21/1,000 airmen for the study period. By class of medical certificate, the prevalence rate was 3.60/1,000 for first-class, 6.26/1,000 for second-class, and 7.43/1,000 for third-class airmen (see Table 1).

The average age of the refractive surgery population was 43.1 years. By class of medical certificate, the average age of airmen with refractive surgery was 38.6 years for first-class, 43.0 years for second-class, and 44.2 years for third-class (see Table 1).

THE PREVALENCE RATE PER 1,000 AIRMEN FOR REFRACTIVE SURGERY BY CLASS OF MEDICAL CERTIFICATE HELD

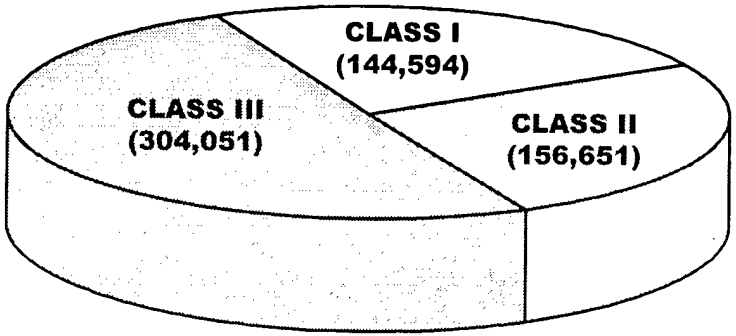
CLASS I	3.60/1,000
CLASS II	6.26/1,000
CLASS III	7.43/1,000
TOTAL	6.21/1,000

TOTAL AVERAGE CIVIL AIRMAN AND REFRACTIVE SURGERY POPULATION BY CLASS AND AGE 1994-96

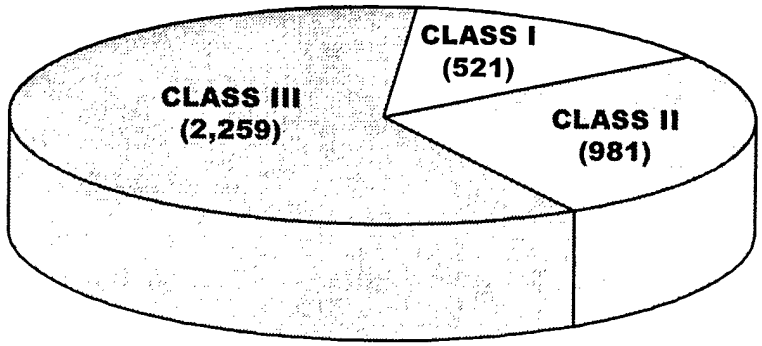
	TOTAL	REFRACTIVE
CLASS I	39.0	38.6
CLASS II	43.0	43.0
CLASS III	43.6	44.2
TOTAL	42.2	43.1

TABLE 1

TOTAL AVERAGE CIVIL AIRMAN & REFRACTIVE SURGERY POPULATIONS BY CLASS: 1994-96



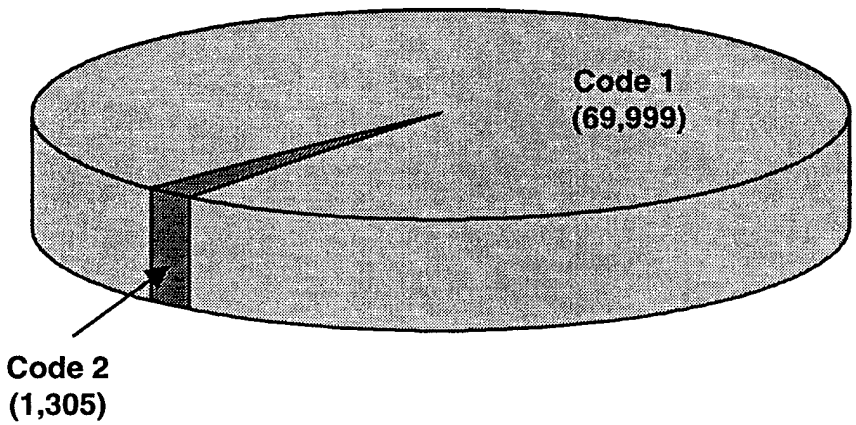
TOTAL CIVIL AIRMEN (n = 605,296)



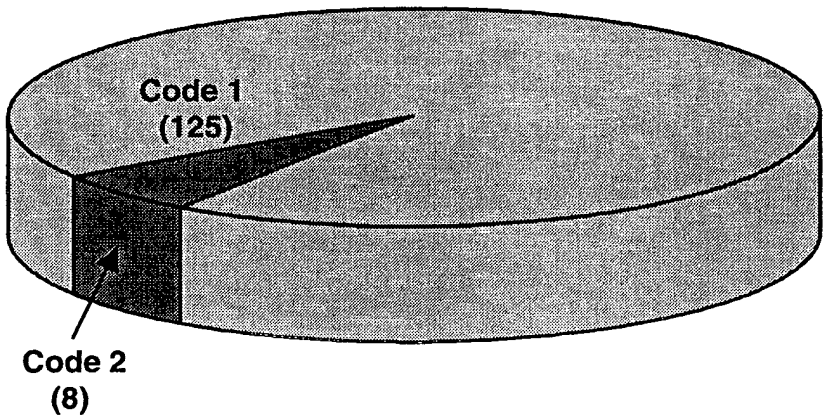
TOTAL REFRACTIVE SURGERY (n = 3,761)

FIGURE 2

TOTAL AVERAGE CIVIL AIRMAN &
REFRACTIVE SURGERY POPULATIONS
BY OCCUPATION CODE: 1994-96



TOTAL CIVIL AIRMEN (n = 71,304)



TOTAL REFRACTIVE SURGERY (n = 133)

PREVALENCE RATE PER 1,000 AIRMEN	
CODE 1	1.79/1,000
CODE 2	6.13/1,000
TOTAL	1.87/1,000

FIGURE 3

A total of 125 airmen was identified as being employed as a captain, co-pilot, or first and second officer (code 1), and 8 airmen were identified as flight engineers (code 2). Of those airmen who carried an aviation occupation code 1 or 2, the prevalence rate for refractive surgery was 1.79/1,000 airmen for code 1, 6.13/1,000 airmen for code 2 and 1.87/1,000 airmen for the total population (see Figure 3).

Table 2 identifies those airmen with refractive surgery by aviation occupation code, by employer, and by gender (see Table 2).

DISCUSSION

The use of eyeglasses to correct refractive problems may have disadvantages for pilots. Spectacle frames can reduce the field of vision, be uncomfortable when not properly fit, displaced during flight maneuvers (G-forces), and are often incompatible with communication and protective breathing equipment. Spectacle lenses may also be dislodged in-flight and fogging can occur with changes in air temperature.

TABLE 2

TOTAL REFRACTIVE SURGERY POPULATION BY OCCUPATION, BY EMPLOYER, AND GENDER: 1994-96

EMPLOYER	CODE 1		CODE 2	
	Males	Females	Males	Females
American Airlines (AAL)	3			
American Eagle (AEA)	2			
America West (AMW)	12			
Alaska Airlines (ASA)	3			
Atlantic Southeast (ASE)	1			
Business Express (BEX)	1			
Continental Airlines (CAL)	13	1		
China Airline (CHIN)	1		2	
Delta Airlines (DAL)	6		1	
Evergreen Airlines (EVR)	1		1	
Federal Express (FDX)	3			
Hawaiian Airlines (HAI)	2			
Horizon Airlines (HZA)	3	1		
Mesa Airlines (MSA)	2	1		
Midway Airlines (MWA)	1			
National Aeronautical Space Administration (NASA)	1			
Northwest Airlines (NWA)	6			
Piedmont Aviation (PAI)	2			
Saudi Arabian Airlines (SAA)	8		2	
Simmons (SIM)	1			
Southwest Airlines (SWA)	7			
Aloha Airlines (TPA)	1			
Trans World Airlines (TWA)	6			
United Airlines (UAL)	9	2		1
United Parcel Post (UPS)	4			
U.S. Air (USA)	21			
Air Force, Military (MIAF)			1	
Total	**120**	**5**	**7**	**1**

Contact lenses can have inherent advantages for pilots over spectacle correction, including, more natural vision, entire field of vision in focus, no lens fogging or water droplet accumulation, no discomfort due to weight, and no annoying obstruction from the frame or distracting reflections from the lenses. However, contact lenses have been displaced and even lost in flight. Airmen have also reported removing a contact lens in-flight, primarily due to dryness or a foreign body beneath the lens (18). Furthermore, the aviation environment includes low barometric pressure and relative humidity, which may affect contact lens wear. Corneal edema has been reported in seemingly well-fit contact lens wearers with altitude hypoxia (19). There is evidence of less lens movement and increased conjunctival injection, both indications of a tighter fit, with soft contact lenses in the 10-15% relative humidity of an aircraft (20). Soft contact lenses can dehydrate in low humidity, resulting in visual performance (low-contrast acuity) loss (21).

This study shows that refractive surgery is prevalent in all classes of civil aeromedical certificate holders. The highest prevalence rate is in third-class airmen, predominately private pilots, while the lowest prevalence rate is found in first-class airmen, normally airline pilots. A substantial complement (n=133) of flight crewmembers for commercial carriers were found to have had refractive surgery. Based on the increase in the number of surgical procedures performed in the United States and the growth projected in the near future, the prevalence rate of refractive surgery is expected to increase in the civil airman population for the next several years.

Civilian pilots may be more likely to opt for eye surgery to correct refractive error due to an actual or perceived operational concern with spectacles and contact lenses in the aviation environment. In addition, pilots need to meet occupational or recreational vision standards, not normally required for the general population. Professional pilots' medical standards are not only more stringent, their physical examinations must be performed more frequently. However, before a pilot elects to have refractive surgery performed, he/she should be aware of the possible side-effects associated with refractive surgery procedures (4-15). Such visual side-effects could compromise a pilot's ability to safely fly an aircraft in some situations. Reportedly, visual problems from refractive surgery in one eye have persuaded patients not to have the surgery performed on the other eye (22). Others patients have discontinued driving at night as a result of vision problems resulting from refractive surgery (7,8,23). Although these cases are infrequent, for the professional pilot a poor refractive surgical result could jeopardize his/her aeromedical certification and aviation career.

The long-term effects of newer refractive surgery techniques, such as PRK and LASIK, are not known. How these procedures interact with the normal age-related changes in vision requires further investigation. Since the average age of airmen with refractive surgery was only 43.1 years, suggesting that these pilots could continue to fly for three decades or longer, it is recommended that special monitoring and evaluation of possible operational problems involving pilots with refractive surgery be performed.

Prior studies of vision deficiencies and aviation accidents by the FAA have not specifically investigated an association between refractive surgery and operational problems in-flight. A search of the National Transportation Safety Board Aviation/Incident Database, and the FAA Incident Data System and Near Midair Collisions System Database from 1 January 1980 to 31 December 1996 did not identify refractive surgery as a probable cause or contributing factor in any aviation accident or incident. However, since post-accident investigations rarely focus on sensory deprivation as a factor in aviation accidents this data could be misleading.

In conclusion, airmen who have had refractive surgery are present in all classes of civil aeromedical certificate holders, including a substantial number of crewmembers who fly for commercial airlines. If the increase in the number of civilian pilots who elect to have refractive surgical procedures follows that projected for the general population, such procedures will become more prevalent in the civil airman population. This presence and the anticipated increased incidence of refractive procedures in the airman population warrant special monitoring. Monitoring would provide a means for evaluating whether known, and potential unknown, side-effects associated with refractive surgery lead to operational problems in the aviation environment.

REFERENCES

1. Department of Transportation/Federal Aviation Administration: Guide for aviation medical examiners. Washington, DC:1996; FAA Office of Aviation Medicine.
2. Editor. Laser procedures to double this year, survey projects. *AOA News.* Sep 29, 1997; **36**(6):8.
3. Myeroff WJ. Patients of the future, marketing to the post-RK/PRK patient. *Optom Econ.* Sum 1997; 7(2):20-3.
4. Lavenburg DJ. The state of the art radial keratotomy. *Rev Optom.* Mar 1994; **131**(3):45-51.
5. Veraart HG, van den Berg TJ, IJspeert JK, Cardozon OL. Stray light in radial keratotomy and the influence of pupil size and stray light angle. *Am J Ophthalmol.* Oct 1992; **114**(4):424-8.
6. Braunstein RE, Jain S, McCally RL, Stark WJ, Connolly PJ, Azar DT. Objective measurement of corneal light scattering after excimer laser keratectomy. *Ophthalmol.* Mar 1996; **103**(3):439-43.
7. Gimbel HV, Van Westenbrugge JA, Johnson WH, Willerscheidt AB, Sun R, Ferensowicz M. Visual, refractive, and patient satisfaction results following bilateral photorefractive keratectomy for myopia. *Refract Corneal Surg.* Mar-Apr 1993; 9(suppl):S5-10.
8. Gartry DS, Kerr-Muir MG, Marshall J. Excimer laser photorefractive keratectomy: 18 month follow-up. *Arch Ophthalmol.* Aug 1992; **99**(8):1209-19.
9. Bullimore MA, Sheedy JE, Owen D, Refractive Surgery Study Group. Diurnal visual changes in radial keratotomy: implications for visual standards. *Optom Vis Sci.* Aug 1994; **71**(8):516-21.
10. Ficker LA, et al. Excimer laser photorefractive keratectomy for myopia: 12 month follow-up. *Eye.* 1993; 7(**Pt** 5): 617-24.
11. Binder PS. Vision after RK surgery. *Rev Optom.* Oct 1987; 124(10):74-5.
12. McDonnell PJ, Nizam A, Lynn MJ, Waring GO III, PERK Study Group. Morning-to-evening change in refraction, corneal curvature, and visual acuity 11 years after radial keratotomy in the prospective evaluation of radial keratotomy study. *Ophthalmol.* Feb 1996; **103**(2):233-9.
13. Anonymous. Radial keratotomy for myopia. *Ophthalmol.* Jul 1993; **100**(7):1103-15.
14. Editor. FDA details required reading for PRK candidates. *AOA News.* Apr 8, 1996; **34**(19):9.
15. Braunstein RE, Jain S, McCally RL, Stark WJ, Connolly PJ, Azar DT. Objective measurement of corneal light scattering after excimer laser keratectomy. *Ophthalmol.* Mar 1996; **103**(3):439-43.
16. Department of Transportation/Federal Aviation Administration. Aeromedical certification statistical handbook. Washington, DC:1994-1996. FAA Civil Aeromedical Institute, Aeromedical Certification Division; Report No. AC 8500-1.
17. Department of Transportation/Federal Aviation Administration. Aeromedical certification systems manual. Washington, DC:1994-1996. FAA Civil Aeromedical Institute, Aeromedical Certification Division.
18. Moore RJ, Green RP Jr. A survey of U.S. air force flyers regarding their use of extended wear contact lenses. *Aviat Space Envir Med.* Nov 1994; **65**(11):1025-31.
19. Coon MW. Altitude and hypoxia. *Contact Lens Spectrum.* May 1993; **8**(5):9.
20. Dennis RJ, Miller RE II, Peterson RD, Jackson WG Jr. Contact lens wear with the USAF protective integrated hood/mask chemical defense ensemble. *Aviat Space Environ Med.* Jul 1992; **63**:(7):565-71.
21. Timberlake GT, Doane MG, Bertera JH. Short-term, low-contrast visual acuity reduction associated with in vivo contact lens drying. *Optom Vis Sci.* Oct 1992; **69**(10):755-60.
22. Butuner Z, Elliott DB, Gimbel HV, Slimmon S. Visual function one year after excimer laser photorefractive keratectomy. *J Refract Corneal Surg.* Nov-Dec 1994; 10(6):625-30.
23. Cartwright CS, Bourque, LB, Lynn M. Waring GO 3rd. Relationship of glare to uncorrected visual acuity and cycloplegis refractions 1 year after radial keratotomy in the prospective evaluation of radial keratotomy (PERK) study. *J Am Optom Assn.* Jan 1988; **59**(1):36-9.