AEROMEDICAL ASPECTS OF CONTACT LENSES (SOFT AND SEMISOFT)

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ABSTRACT

A comprehensive clinical study on the effects of various aviation stresses on soft and semisoft contact lenses was carried out to find out their compatibility in aviation environment. Twenty subjects (11 aircrew and 9 non air-crew) participated in the study. Twelve of them were given soft lenses of water contents of 38%, 50% and 78% and rest 8 were given semisoft lenses of daily wear and extended wear type. The environmental trial consisted of exposure to hypoxia, rapid decompression, acceleration, pressure breathing, vibration and high temperature. On successful completion of environmental trials on ground simulators, the inflight trials on high performance aircraft, transport aircraft, passenger aircraft and helicopters were conducted. The soft lenses with low, medium and high water contents and extended wear semisoft lenses (large diameter) were found compatible with all types of aircraft flying.

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KEY WORDS : Aviation stresses; Acceleration; Contact lenses; Hypoxia; Vibration.

Introduction

Vision is an important aspect of aerospace operations. Medical, environment or optical factors which affect vision, assume a special significance in the career of an aviator. The refractive errors in an aviator are presently corrected with corrective spectacles. However, spectacles are found to be incompatible with certain flying equipment, such as pressure helmet, night vision goggles and helmet mounted sights etc. [1,2]. They are also found to cause problems during flight such as field restriction, fogging under high temperatures, oscillations under conditions of vibrations and displacements during pressure breathing and acceleration. Contact lenses, as they are worn directly on the cornea are largely free from some of these problems.

A comprehensive clinical study was conducted at Institute of Aerospace Medicine to find out the behavior of contact lenses under

aviation stresses. In this study, the hard lenses were not studied as they are rarely prescribed now and have been found to be incompatible in the aviation environment in earlier studies [1,3-5]. In this study, soft lenses with low (38%), medium (50%) and high (78%) water content and semisoft lenses of daily wear and extended wear were studied.

Material and Methods

Twenty ametropic volunteer subjects from whom informed consent was obtained, participated in the study. Of these, 11 were aircrew and 9 were non-aircrew. Soft lenses were given to 12 and semisoft (RGP) lenses to 8 subjects. Details of the subjects and types of contact lenses are given in Table 1. One of the semisoft extended wear lens subjects required correction only in one eye. Two to four weeks of successful contact lens wear was made mandatory before the environmental trial.

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TABLE 1
Details of subject/contact lenses

Lens type	Subjects		Total
	Aircrew	Non-aircrew	
Soft 38% water content	4	1	5
Soft 50% water content	3	0	3
Soft 78% water content	2	2	4
Semisoft daily-wear	0	5	5
Semisoft extended-wear	2	1	3
Total	11	9	20

The environmental trial consisted of :

a. Hypoxia and rapid decompression : the effect of hypoxia and rapid decompression were tested in a hypobaric chamber on a total of 18 subjects (10 using soft lenses and 8 semisoft).

Protocol :

- i Two hours exposure to simulated altitude of 3048 m breathing atmospheric air.
- ii. One hour exposure to simulated altitude of 6096 m breathing 100% of oxygen.
- iii. Rapid decompression from 2438 m to 6706 m while breathing 100% oxygen.

Ascent and descent rate was 914 m/ minute. The eye test schedule consisted of visual acuity measurements, flare testing, keratometry and biomicroscopy.

b. Acceleration : The effect of positive acceleration (+GZ) was tested in a human centrifuge on a total of 18 subjects (10 using soft lenses and 8 semisoft).

Protocol :

- i. Determination of +GZ tolerance of each subject with anti-G suit with acceleration onset rate of 0.5 G/sec and deceleration rate of 0.1 G/sec.
- ii. A step-ladder profile was set up on the micro-processor controller upto the tolerance limit of the individual with a 10 sec plateau at 4 G and 5 G. During the plateau phase, the visual acuity was recorded on a self-illuminated, reduced Snellen's chart at 1m and lens displacement was

monitored on TV screen in each eye separately.

- iii. Displacement of the lens was graded as follows :

Mild - less than 2 mm

Moderate - 2 to 5 mm

Severe - 5 to 8 mm

- iv. Biomicroscopy before and after the acceleration run.

c. Pressure breathing : All the 20 subjects were given pressure breathing at 30 mm of Hg for 1 minute either through an oronasal mask or pressure helmet and were tested for visual acuity, lens displacement, effect of flare and misting.

d. Vibration : The effect of vibration was tested on vibrator at frequencies ranging from 2 to 18 Hz, on a total of 16 subjects (8 using soft lenses and 8 semisoft). Visual acuity monitoring was done on a Snellen's chart at 6m and reduced Snellen's chart at 1 m attached to the vibrator seat.

e. High Temperature : The effect of high temperature was tested in a hot cockpit on a total of 16 subjects (8 using soft lenses and 8 semisoft). They were exposed to temperature of 50°C with relative humidity of 20% and 50% for 30 minutes. The eye schedule consisted of visual acuity measurement, biomicroscopy and tests for effect of flare and misting.

Inflight Trials

This study was divided into two groups. In group I, the study was conducted aboard high performance aircraft (MIGs, Jaguar and Kiran) and in Group II, on transport (HS 748), passenger (Boeing 737) aircraft and helicopters (Chetak). Group I consisted of aircrew personnel who were qualified to fly fighter aircraft. In this group, a total of 6 aircrew (1 pilot and 5 flight test engineers) participated. Five of them wore soft lenses and 1 wore extended-wear semisoft lens. In group II, a total of 9 subjects (3 aircrew pilots and 6 non-aircrew) participated. The non-aircrew were taken aboard on a HS-748 transport aircraft to conduct the study. Out of the 3 pilots, 2 wore soft

TABLE 2
Inflight trial group I

Subject	Type	A/C	Hours	ACC (C)	Alt (m)	Temp (°C)	RH (%)
1.	Soft-38%	MIG-21 BIS	0 : 40	5.8	6096	26	40
2.	Soft-38%	Kiran	0 : 50	5.0	5180	25	40
3.	Soft-50%	Kiran	1 : 00	5.0	4267	26	50
4.	Soft-38%	Kiran	0 : 45	5.5	4420	30	45
5.	Soft-78%	Jaguar	0 : 45	6.0	4567	25	45
6.	RGP (EW)	Kiran	0 : 50	5.2	6705	26	50

A/C - Aircraft; ACC - Acceleration; Alt - Altitude; Temp - Temperature; RH - Relative humidity

(50% and 38%) lenses and 1 wore extended-wear semisoft lens. Out of 6 non-aircrew, 2 wore soft (78%) lenses and 4 wore semisoft (3 daily-wear and 1 extended-wear) lenses.

Protocol :

Inflight studies consisted of a subjective study using a questionnaire proforma and an objective study which involved monitoring the subjects at designated intervals during flight to look for any abnormal effects on the eye or contact lens. Details of inflight trials are given in Tables 2 and 3.

TABLE 3
Inflight trial group II

Sub-ject	AC/Non AC	Type	A/C	Hours
1.	AF F(P)	Semisoft (EW)	Chetak	25 : 00
2.	Navy F (P)	Soft 50%	Chetak	400 : 00
3.	Civil F (P)	Soft 38%	Boeing 737	400 : 00
4.	Non AC	Semisoft (EW)	HS - 748	2 : 00
5.	Non AC	Soft 78%	HS - 748	2 : 00
6.	Non AC	Semisoft (DW)	HS - 748	2 : 00
7.	Non AC	Semisoft (EW)	HS - 748	2 : 00
8.	Non AC	Semisoft (DW)	HS - 748	2 : 00
9.	Non AC	Soft 78%	HS - 748	2 : 00

F(P) - Flying pilot; Non AC - Non aircrew;
DW - Daily wear; EW - Extended wear

Results

Environmental Trials

a. Hypoxia and rapid decompression : At 3048 m, hypoxia, dryness and mild conjunctival injections were observed in 1 soft lens

(38% water content) user and 2 semisoft lens (daily-wear) subjects. No bubbles or visual decrements were observed. At 6096 m, hypoxia, dryness and mild conjunctival injections were observed in 2 soft lens (38% and 50%) subjects and 4 semisoft lens (3 daily-wear and 1 extended-wear) subjects, and subcontact-lens bubbles (peripheral in 2 soft lens subjects and both peripheral and central in 4 semisoft lens subjects) were observed. None of the subjects with bubble formation showed any visual decrement. However one user of semisoft lens, showed mild visual decrement of 6/9 in both eyes. No other abnormality was detected.

During rapid decompression, dryness and conjunctival injections were observed in 2 soft lens (38% and 50%) subjects and 2 semisoft lens (daily-wear) subjects. Subcontact-lens bubbles (peripheral in 2 soft lens subjects and both peripheral and central in 4 semisoft lens subjects) were observed. No visual decrement was seen in soft lens users. However, 2 of the semisoft lens subjects with bubbles showed visual decrement of 6/9. No other abnormality was noticed (Table 4).

b. Acceleration : Table 5 shows the visual acuity recording and contact lens displacements at +4 and +5GZ. At 4 GZ, among the soft lens group, in 4 (3 of 38% and 1 of 50%) out of 20 eyes visual decrement of 6/9 was recorded. Among the semisoft lens group, with daily wear lenses, all the 10 eyes showed visual decrement (6/9 in 9 and 6/12 in one) and with the extended-wear semisoft lenses, only 1 out of 5 eyes showed visual decrement

TABLE 4

Hypoxia and rapid decompression test evaluation (subject wise) n = 10 soft, 8 semisoft

Findings	At 3048 m		At 6096 m		Rapid decomp	
	Soft	Semi soft	Soft	Semi soft	Soft	Semi soft
Conjunctival injection	1	2	2	4	2	2
Bubbles	Nil	Nil	2	4	2	4
Visual acuity ↓	Nil	Nil	Nil	1	Nil	2

TABLE 5

Acceleration - Test evaluation (eyewise)
n = 20 soft, 10 semisoft DW, 5 semisoft EW

Findings	At 4G				At 5G	
	Soft	Semisoft		Soft	Semisoft	
		DW	EW		DW	EW
Visual acuity ↓	4	10	1	13	10	5
6/9	4	9	1	13	3	5
6/12	Nil	1	Nil	Nil	7	Nil
Displacement	1	8	2	8	10	5
Mild	1	8	2	8	4	5
Moderate	Nil	Nil	Nil	Nil	6	Nil
Non-appreciable	—	—	—	6	—	—

of 6/9. In the soft lens group, only 1 out of 20 eyes showed mild displacement. Among the semisoft lens group, with daily-wear lenses, 8 out of 10 eyes and with extended-wear lenses, 2 out of 5 eyes showed mild displacement. At +5GZ, among the soft lens group, in 13 (7 of 38%, 3 of 50% and 3 of 78%) out of 20 eyes, visual decrement of 6/9 was recorded. Among the semisoft lens group, with daily-wear lenses, all the 10 eyes showed visual decrement (6/9 in 3 and 6/12 in 7) and with the extended-wear lenses all 5 eyes showed effective visual decrement of 6/9 only. In the soft lens group, in 6 eyes (for 3 subjects) the displacement could not be appreciated due to the drooping of eyelid consequent to accelerative forces. In the rest of 14 eyes, 8 (6 of 38% and 2 of 50%) showed only mild displacement. In the semisoft lens group, all the lenses showed displacement of

lens. In the daily-wear group 6 showed moderate and 4 showed mild displacement and with the extended-wear lenses all the eyes showed only mild displacement.

c. Pressure Breathing : No abnormality was detected during pressure breathing with either type of lens.

d. Vibration : Mild visual decrement of 6/9 was noticed with both soft and semisoft lens group at 4, 6 and 8 Hz frequencies. The binocular visual acuity recorded at 1 m showed mild deterioration in 1 soft lens (38%) subject and 3 semisoft lens (1 daily-wear, 2 extended-wear) subjects at 4 Hz, 6 soft lens (2 each of 38%, 50% and 78%) subjects and 4 semisoft lens (3 daily-wear, 1 extended-wear) subjects at 8 Hz. The binocular visual acuity recorded at 6 m showed mild deterioration in 1 soft lens (78%) subject and 4 semisoft lens (2 each of daily-wear and extended wear) subjects at 4 Hz, 4 soft lens (2 of 38% and 1 each of 50% and 78%) subjects and 3 semisoft lens (2 daily-wear, 1 extended-wear) subjects at 6 Hz, 5 soft lens (2 each of 38% and 50% and 1 of 78%) subjects and 5 semisoft lens (2 daily-wear and 3 extended-wear) subjects at 8 Hz.

e. High Temperature : None of the subjects showed any misting of the lens or visual decrement.

Inflight Trials

In group I, none of the fighter aircrew reported any abnormal inflight response with the lenses on questionnaire proforma. In group II, out of 3 pilots, one pilot of helicopter stream who required correction only in right eye, was initially fitted with a daily wear semisoft lens of 9.2 mm diameter. He reported intense irritation, pain, discomfort and foreign body sensation in the eye with contact lens especially in windy dusty and smoky environment and that these complaints used to subside 15 minutes after removal of the lens. However, he was able to complete his flying mission with these complaints in one eye. He also observed ghost images while looking at bright objects at night. This pilot was subsequently fitted with extended wear semisoft lens (fluorosilicone) of larger

diameter (10.5 mm) with which he was comparatively comfortable during flying. The other two pilots showed no abnormal response while flying with the lenses. The 6 non-aircrew subjects also showed no abnormal response while flying in transport aircraft.

Discussion

During exposure to hypoxia and rapid decompression though the clinical findings of dryness and conjunctival injection were present with both types of lenses, the incidence was more with daily-wear semisoft than with soft and extended-wear semisoft lenses. At 6096 m altitude and during rapid decompression, though subcontact-lens bubbles were noticed with both types of lenses, the daily-wear semisoft lenses showed more incidence of bubbles both peripheral and central. However, soft lenses showed only peripheral bubbles and extended-wear semisoft lenses showed no bubbles. No significant visual decrements were associated with bubbles.

The minor visual decrement of 6/9 noticed with daily-wear semisoft lenses are considered insignificant in regard to the flying status of the individual. Flynn et al [6] reported peripheral subcontact-lens bubble formation in 100% (above 6096 m altitude) and central bubbles in 20% (above 7620 m) of eyes in users of semisoft lenses. Only peripheral bubbles were found in 24% of eyes of soft lens subjects even at 1828 m and above. However, no sequelae to vision or corneal epithelial integrity with either types of lenses was reported. These findings are similar to the results of the present study in that the semisoft lenses showed bubbles both at periphery and centre and soft lenses only at periphery. Brennan and Girvin [3], Eng et al [7] and Hapnes [8] did not report any bubble formation with soft lenses at high altitude. Flynn et al [9] in another study on soft lenses detected minimal signs of conjunctival injection, corneal vertical striae, epithelial staining and tear debris, at 3048 m for 4 hours and low relative humidity of 5%. However these effects were transient and had not resulted in visual deg-

radation. These effects were not observed in the present study probably due to higher quality of lenses. Eng et al [7] in his study on soft lenses at high altitude reported only increase in scleral injections similar to the findings in the present study. Dryness and conjunctival injections are indicative of physiologic stress on the cornea. The bubble formations are related to Henry's and Boyle's laws.

During exposure to positive acceleration of +4 and +5 GZ the minor visual decrements and mild displacement of lenses are considered insignificant. However the moderate visual loss of 6/12 and moderate lens displacement associated with daily-wear semisoft lenses of smaller diameter are considered significant and this finding goes against permitting these lenses for high performance aircraft. The variation in the behaviour of these lenses is self-explanatory. Pupillary dilatation is an associated factor following greyout and this phenomenon coupled with displacements of smaller diameter lenses compromised visual acuity significantly.

Polushuk and Raj of Israeli Air Force [10] and Nilsson and Rengstroff of Swedish Air Force [11] reported that pilots with soft lenses undergoing manoeuvres upto +6 GZ reported no problems. On the human centrifuge, Forgie and Meek [12] tested soft lenses upto +6 GZ and found small amounts of decentration not interfering with vision. Brennan and Girvin [3] tested soft lenses at +4GZ and +6GZ and found a maximum displacement of 1.75 mm only and related the visual decrements in few subjects to retinal ischaemia leading to greyout. Flynn et al [5] tested soft lenses including toric lenses upto +8 GZ in the centrifuge and found them to be remarkably stable on the cornea. Dennis et al [4] reported that the extended-wear semisoft lenses with larger diameter performed better than the smaller diameter lenses in centrifuge testing upto +8GZ acceleration. The findings of the above studies are similar to the results of the present study.

The response of the lenses with pressure breathing was normal. Both types of contact

lenses were found to be compatible with pressure helmets. Even Brennan and Girvin [3] reported no significant effect on soft contact lenses during pressure breathing. The minor visual decrements noticed during vibration at frequencies of 4,6 and 8 Hz are as expected since similar decrements were noticed with emmetropic controls and are related to mechanical effects of vibration on eyes. Brennan and Girvin [3] reported similar response to vibration stress on soft contact lens wear. The response of contact lenses during hot cockpit studies was normal. Even Brennan and Girvin [3] reported no adverse effect on soft lens wear in hot cockpit.

The United States Air Force recently conducted an inflight field test on soft contact lens use by Tactical Air command aviators and found them suitable [1,13]. The United States Army Aeromedical Research Laboratory conducted an inflight study on 44 Army ametropic aviators with extended-wear lenses of either soft or semisoft type and subjective flying performance assessment rated the contact lenses as being superior to spectacle wear in a majority of the aviators [1,14]. Even the result of inflight testing in the present study suggested that soft lenses of low, medium and high water content and extended-wear semisoft lenses with larger diameters fared well in all types of aircraft. However, the soft lenses are preferred to extended-wear semisoft lenses because the diameter of the soft lens is more (13 to 15 mm). The daily-wear semisoft lenses are contraindicated for high performance aircraft. However, they can be recommended for transport aircraft only in case of specific optical indication.

Pilots are exposed to adverse environmental conditions and prolonged missions during war, and extended-wear type of soft

lenses (with high water content) are preferred as they would be comfortable for prolonged wear.

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