Original Article

Effect of induced anisometropia on stereopsis and surgical tasks in a simulated environment

Pallavi Singh, Sitesh Kumar Bergaal, Pradeep Sharma, Tushar Agarwal, Rohit Saxena, Swati Phuljhele

Purpose: To quantitatively correlate the loss of stereopsis by induced anisometropia with its effect on tasks that require binocular vision and stereopsis, such as ophthalmic surgery in a simulated environment. **Methods:** Thirty-nine ophthalmic residents with best-corrected visual acuity of 20/20 or better OU, with normal binocular vision and stereopsis, were recruited for the study. Anisometropia was induced using spherical and cylindrical trial lenses from +1D to +5D in a trial frame. The residents performed an anterior chamber navigation exercise on the EYESi simulator and the surgical score at baseline and for each level of induced anisometropia was noted. Near stereopsis was assessed by the Randot test and TNO test at baseline and for each level of induced anisometropia. **Results:** Stereoacuity on the Randot test and TNO test were 30 (95% CI, 25.9–34.1) and 44.4 (95% CI, 28.5–60.3) arcseconds, respectively which reduced to 65.5 (95% CI, 48.7–82.3) and 75.9 (95% CI, 15.5–136.3) arcseconds at anisometropia of +1D Sph ($P < 0.001$) and 380 (95% CI, 309.9–450.1) and 1922.1 (95% CI, 1582.5–2261.7) arcseconds for +5D Sph, respectively for the two tests, ($P < 0.001$). The corresponding surgical score reduced from 93.8 (95% CI, 91.1–96.7) to 87.5 (95% CI, 79.2–95.8, $P < 0.001$) for 1 DSph and 55.97 (95% CI, 38.3–73.7, $P < 0.001$) for 5DSph. There was a strong negative correlation between stereopsis scores and surgical task scores (Spearman's rho -0.86, P value <0.001) Similar changes were seen for anisometropia induced with cylindrical powers. **Conclusion:** Induced anisometropia is associated with a significant diminution in surgical task scores in a simulated environment and this is correlated with the deterioration in stereoacuity. Assessment of stereopsis may be included as a regular part of the screening procedure for ophthalmic trainee residents.

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Binocular vision, especially stereopsis, has been at the center of visual physiology research for many years. It is the perception of depth, as perceived binocularly, due to disparity between the retinal images of each eye. However, its true significance for the visual function was questioned for a long time. Fielder and Moseley described stereopsis to be advantageous for tasks requiring an understanding of complex visual presentations and good hand-eye coordination,[1] thus making it an essential requirement for professions requiring heightened visual functions such as pilots and ophthalmic surgeons. Stereopsis is disrupted by blur, amblyopia, or strabismus. Most of the studies imply that binocular vision deteriorates with an increase in anisometropia due to the foveal suppression of the defocused eye.[2,3] Other factors like contrast and density of fusional details may also contribute. Yet, the effect of this reduced binocular vision and stereopsis on tasks requiring precise hand-eye coordination, such as ophthalmic surgery, has not been studied. The VRMagicEYESiOphthalmosurgical Simulator (VRmagic Holding AG, Mannheim, Germany) is a device used for intraocular microsurgical training. It contains a set of preinstalled courses that offer training in both cataract and vitreoretinal surgery at different levels of difficulty, combining training of basic skills with the training of actual surgical procedures. The device enables an objective assessment of surgical performance in a simulated environment. Our study has been designed to quantitatively correlate the anisometropia induced loss of stereopsis with its effect on tasks which require binocular vision and stereopsis, such as ophthalmic surgery in a simulated environment.

Methods

The study was a prospective interventional study conducted at a tertiary care ophthalmic center. After approval from the institutional review board, 39 ophthalmic residents with best-corrected visual acuity of 20/20 or better, in each eye with normal binocular vision and stereopsis were recruited for the study. All residents had completed at least 6 months of training in ophthalmology. Exclusion criteria included any manifest strabismus, evidence of amblyopia, any ocular pathology diminishing visual acuity, or anisometropia greater than 2.5 D.

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All participants underwent orthoptic assessment, including best-corrected visual acuity (recorded with an ETDRS chart at 6 m), ocular alignment, ocular motility, convergence, and assessment of sensory and motor fusion. The refraction of the subjects was done using 2% homatropine. Fogging technique was used for prescribing glasses if required, so that they may not develop excessive minus power. A trial frame was used to create the anisometropia with experimental lenses. Different types of anisometropia were induced by placing the lenses in random order over the left eye. All the cylindrical lenses were plus and placed at 90° axes in the trial frame.

All baseline tests and tasks were performed with appropriate refractive correction. Each resident was then assessed for near stereopsis by Randot test and TNO (The Netherlands Organisation for applied scientific research) test at baseline and after inducing anisometropia by adding trial lenses from +1D to +5D spherical and cylindrical lenses to his or her refractive correction in a trial frame over the left eye. Two different tests were used to assess stereopsis as both have different principles, i.e., anaglyph for TNO and vectograph for Randot test, respectively. Besides, these are the most commonly available tests for stereopsis in most ophthalmic setups. The residents performed an anterior chamber navigation exercise on the EYESi simulator for baseline score and each corresponding power of the inducing lens. The Eyesi Surgical system provides an objective assessment of surgical performance and detailed skill evaluation. Various parameters relating to the instrument and microscope handling, surgical efficiency, and tissue treatment are recorded by the system. At the end of each task, the trainee is presented with a performance summary based on these parameters. The surgical task score is made up of attained objectives and penalty points, e.g., for injuries caused or inefficient use of instruments. The exercise included spheres of different sizes at random distances and individually spaced at different levels of depth in the anterior chamber. The spheres were in the vicinity of important intraocular structures. The surgical task was to convert the red spheres into green, which happened when the depth was correctly judged [Video 1]. Statistical analysis was performed using statistical package for the social sciences (SPSS) Statistics Version 24 software.

Results

A total of 39 residents were included and evaluated for the study. The mean age of the residents was 26 (95% CI, 24.2–27.8) years. Out of all the subjects recruited 23 were male and 16 were female. The mean refractive error was -1.45 (95% CI, -0.2—2.65) diopters. Stereoacuity for near as measured on the Randot test was 30 s (95% CI, 25.9–34.1) of arc and 44.4 s (95% CI, 28.5–60.3) of arc on TNO test. The baseline surgical score on the EYESi simulator was 93.8 (95% CI, 91.1–96.7).

With an increase in plus spherical lenses, there was a worsening of stereoacuity on the TNO test from 44.4 s (95% CI, 28.5–60.3) of arc at emmetropia to 1922.05 s (95% CI, 1582.5–2261.7) of arc at +5D (Wilcoxon signed-rank test, $P < 0.001$, r = -0.62). The worsening of stereopsis was significant (Wilcoxon signed-rank test, $P < 0.001$, r = -0.43) even with one diopter of increase in anisometropia. A similar response was seen with cylindrical lenses [Table 1 and Fig. 1]. Similarly, for the Randot test, there was a worsening of stereoacuity from 30 s (95% CI, 25.9–34.1) of arc to 127.82 s (95% CI, 17.12–238.5) of arc even at +2D (Wilcoxon signed-rank test, $P < 0.001$, r = -0.3). The deterioration in stereoacuity was greater with higher dioptric power with stereoacuity measuring 380 (95% CI, 309.9–450.1) and 400 arcseconds, respectively (Wilcoxon signed-rank test, $P < 0.001$, r = -0.51) for +5D spherical and cylindrical lenses, compared to the baseline stereoacuity value [Tables 1,2 and Fig. 2]. A comparable trend was seen with cylindrical lenses, though the loss of stereopsis was more pronounced with these as compared to spherical lenses.

On the evaluation of the surgical task score, it showed statistically significant deterioration with increasing values of induced anisometropia for spherical lenses and cylindrical lenses when compared to baseline [Tables 1,2 and Fig. 3]. The surgical task score worsened from a baseline of 93.8 (95% CI, 91.1–96.7) to 55.97 (95% CI, 38.3–73.7, paired *t*-test, $P < 0.001$, r = 0.903) at +5D of spherical anisometropia and to 48 (95% CI, 32.3–63.7, paired *t*-test, $P < 0.001$, r = 0.891) at +5D of cylindrical anisometropia. Cylinder induced anisometropia was associated with a higher decline of the surgical task score than spherical induced anisometropia. On further analysis between subjects having less than and more than 0.5D of refractive error, without refractive correction at baseline, no significant difference was found between the baseline score and subsequent surgical scores at different values of induced anisometropia.

The Spearman's correlation coefficient was used to determine the strength of association between the stereoacuity and surgical task scores. There was a significant positive correlation seen between the level of stereopsis, as measured on TNO and Randot testing, and surgical task scores. The Spearman coefficient was -0.86 and -0.88 (*P*-value <0.001) when measured for correlation between TNO test values [Fig. 4a] and Randot test values [Fig. 4b], respectively with surgical task scores.

Discussion

Stereopsis is essential to see the world in three dimensions, and it plays a key role in visuomotor skills as well.[4] It is of particular importance in professions requiring fine hand-eye coordination such as microsurgery, piloting, etc., however, with the emergence of virtual classrooms and 3-D movies and games, stereoacuity is important even for individuals not involved in these professions. Particularly in the case of ophthalmic surgery,

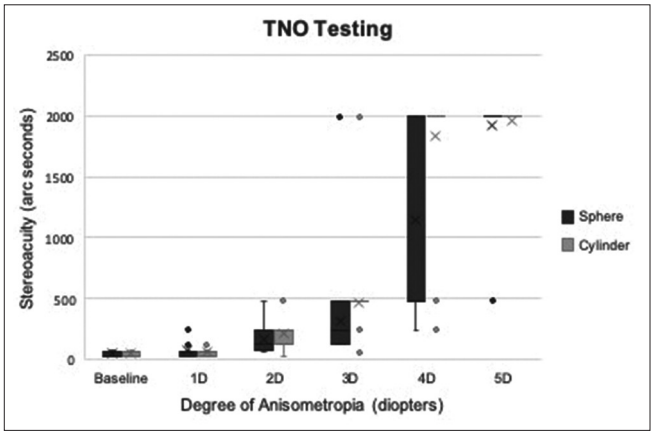

Figure 1: Graphical representation of progressive decrease in stereoacuity with increasing degree of induced anisometropia as measured by TNO testing

a high grade of visual function and coordination is required to process multiple visual inputs and translate them into precise manual actions. The Netherlands requires all students to achieve a minimum score on a standardized random-dot stereoscopy test as a part of the admission requirements for training in the specialty of ophthalmology.[5] However, most countries still do not have a visual standard for ophthalmologists and other surgeons operating under a microscope.[6] Refractive error is the most prevalent ocular pathology in the general population and uncorrected anisometropia is seen very frequently.[7] However, there are no studies that evaluate its impact on the stereopsis of these persons and consequently, their ability to perform fine tasks. Our study aims to bridge this gap by studying the effect of induced anisometropia on stereopsis and correlating it with its influence on performing microsurgical tasks in a simulated environment.

It is known that with increasing anisometropia there is a proportionate decrease in stereoacuity.[8] There have been several studies on the effect of experimental anisometropia and stereopsis which have shown stereopsis deteriorating with increased values of induced anisometropia.[2,9-13] It was observed that both spherical and cylindrical induced anisometropia had an impact and even 1D of anisometropia could lead to a significant diminution in stereopsis.

All of these studies demonstrated the relationship of stereopsis to anisometropia but none of them discussed the practical aspect of anisometropia affecting stereopsis in a real-time surgical task where stereopsis confers its utmost advantage. The importance of stereopsis for intraocular surgery is difficult to establish in a live theatre setting without compromising patient safety. Virtual reality simulators provide a safe alternative. As a profession, we owe it to the public to produce the highest quality ophthalmic surgeons in our training programs.

There are a few studies that have reviewed the impact of the loss of stereopsis on surgical skills in simulated environments. Grober *et al.* used hand motion analysis as a measure of microsurgical performance to determine the effect of reduced stereoacuity and found no significant correlation between the two.[14] However, unlike our study, which uses a graded scale to measure the increase in anisometropia and subsequent decrease in stereoacuity, they used an all or none stereoscopic response which might have affected the results. A study comparing the performance of "stereosufficent" and "stereodeficient" patients in simulated surgical tasks showed that the former group had a definite advantage over the latter.[15] Nibourg *et al.* demonstrated that even though stereoscopic vision does provide a definite advantage in performing surgical tasks in

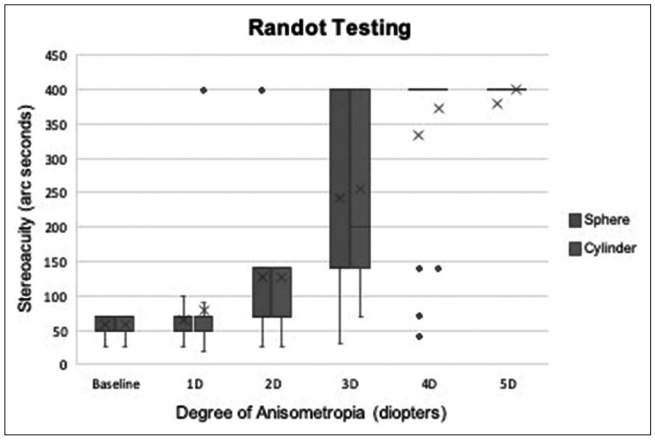

Figure 2: Graphical representation of gradual fall in stereoacuity with an increase in induced anisometropia as measured by Randot testing

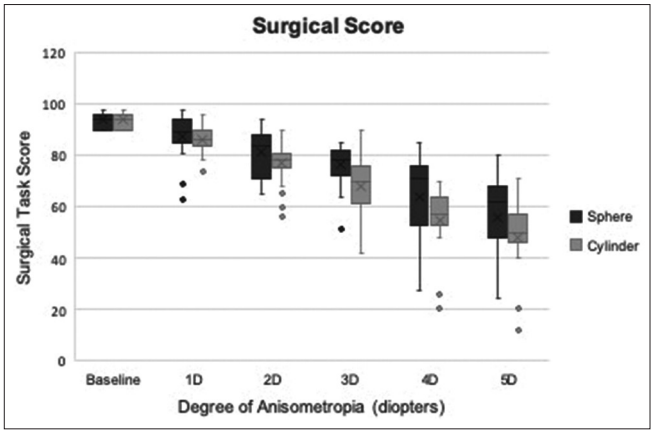

Figure 3: Graphical representation of the relationship between surgical task score and degree of induced anisometropia

Table 1: Representation of the quantitative degree of stereoacuity (as measured by TNO and Randot testing) and surgical task scores at various levels of induced spherical anisometropia

	Baseline value	1D (Sphere)	2D (Sphere)	3D (Sphere)	4D (Sphere)	5D (Sphere)
TNO Score (arc seconds)	44.35±15.8	75.89±60.4	161.02±124.8	312.82±312.5	1144.6±806.3	1922.051±339
Randot Score (arc seconds)	30±4.05	65.5±16.8	127.8±110.7	241.2±110.7	333.8±123.7	380±70.1
Surgical Task Score	93.8±2.8	87.5±8.3	81.12±8.8	76.3±7.3	63.8±16.8	55.97±17.7

Table 2: Representation of the quantitative degree of stereoacuity (as measured by TNO and Randot testing) and surgical task scores at various levels of induced cylindrical anisometropia

	Baseline value	1D (Cylinder)	2D (Cylinder)	3D (Cylinder)	4D (Cylinder)	5D (Cylinder)
TNO Score (arc seconds)	44.35±15.8	55.89±20.35	213.07±87.27	465.12±275.3	1837.9±486.7	1961.0±243.3
Randot Score (arc seconds)	30±4.05	78.85±77.3	126.7±99.4	256.4±137.6	373.3±79.91	400±0
Surgical Task Score	93.8±2.8	86.46±5.5	76.9±8.8	67.7±12.8	54.5±12.7	48±15.7

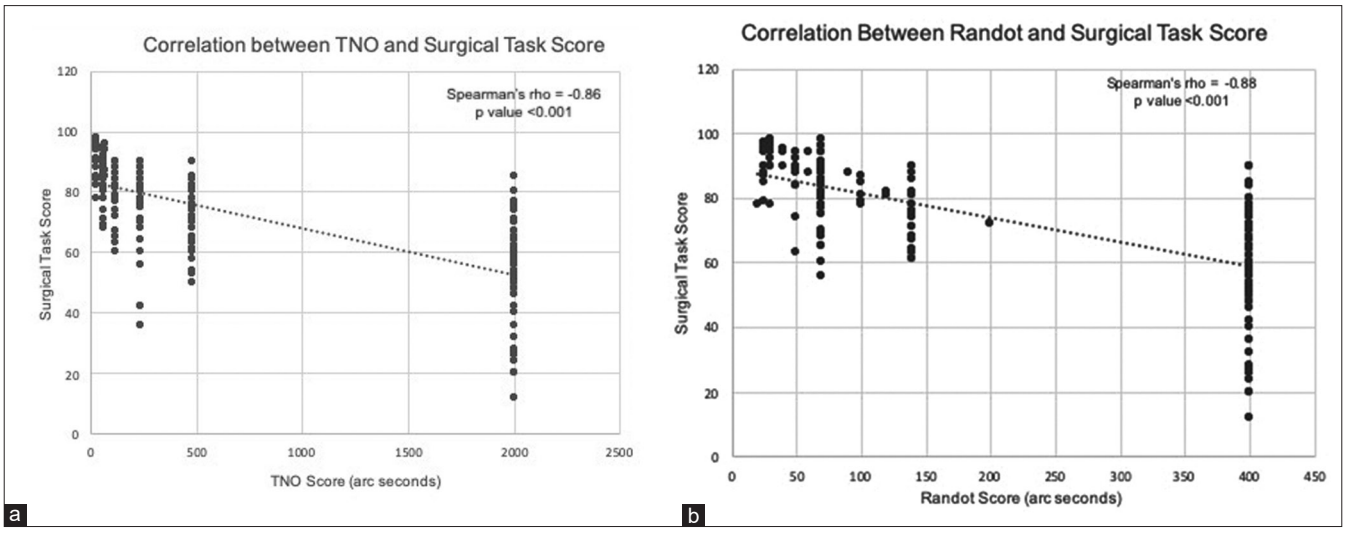

Figure 4: Graphs showing the correlation between stereopsis and surgical task score as measured by TNO testing (a) and Randot testing (b)

a simulated environment, there is still no evidence that the lack of it would lead to an inability to perform the same task. They found the learning curves for these surgical tasks to be similar for stereosufficient and stereodeficient subjects.[16] Other studies that observed the effects of acute and long-standing loss of stereopsis on simulated surgical tasks also found stereoscopic vision to be advantageous when performing fine motor tasks.[17,18]

To our knowledge, there are no studies that describe the effect of induced anisometropia on simulated surgical tasks requiring stereopsis. Our study showed statistically significant deterioration of the surgical task score compared to baseline on increasing anisometropia, and a negative correlation with an increase in mean seconds of arc using TNO and Randot test. Both spherical and cylindrical induced anisometropia led to a decrease in stereoacuity. The reduction in test scores was significant even at 1D of anisometropia implying that even a small degree of anisometropia could cause a substantial loss in surgical dexterity, as tested in a simulated environment. As all our test subjects were ophthalmic residents with at least 6 months of training, it goes to show that anisometropia induced stereodeficiency can cause diminished surgical score points even after a decent learning curve has been obtained. We aim to demonstrate a correlation, if not necessarily causative relation, between induced anisometropia, decreased stereoacuity, and surgical performance in a simulated environment.

Our study was limited by small sample size and only a single stereo-task being studied. Besides, we only studied the impact of acutely induced anisometropia and results may vary in cases with long-standing uncorrected anisometropia. Also, it needs to be considered that the measurement of surgical task scores in a simulated environment may predict but not exactly reproduce measuring surgical proficiency in a real-life situation.

Conclusion

Most studies done until now while showing that stereoscopic vision does provide an advantage in the performance of fine visuomotor tasks, caution that stereopsis may not be an absolute measure of such performance as many subjects may perform these tasks well despite stereodeficiency. However, as our study conclusively shows that even 1D of anisometropia leads to a drop in surgical scores in simulated situations, refractive correction is of paramount importance for ophthalmic surgeons. It would also be prudent to include stereopsis as a regular part of the screening procedure for candidates pursuing professions that require skilled and fine visuomotor tasks.

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Conflicts of interest

There are no conflicts of interest.

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