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Impact of Refractive Errors on Da Vinci SI Robotic System

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ABSTRACT

Objective: To investigate the impact of refractive errors on binocular visual acuity while using the Da Vinci SI robotic system console.

Methods: Eighty volunteers were examined on the Da Vinci SI robotic system console by using a near vision chart. Refractive errors, anisometropia status, and Fly Stereo Acuity Test scores were recorded. Spherical equivalent (SE) were calculated for all volunteers' right and left eyes. Visual acuity was assessed by the logarithm of the minimal angle of resolution (LogMAR) method. Binocular uncorrected and best corrected (with proper contact lens or glasses) LogMAR values of the subjects were recorded. The difference between these values (DiffLogMAR) are affected by different refractive errors.

Results: In the myopia and/or astigmatism group, uncorrected SE was found to have significant impact on the DiffLogMAR ($p < 0.001$) and myopia greater than 1.75 diopter had significantly higher DiffLogMAR values ($p < 0.05$). Subjects with presbyopia had significantly higher DiffLogMAR values ($p < 0.01$), and we observed positive correlation between presbyopia and DiffLogMAR values ($\rho = 0.33$, $p < 0.01$). The cut off value of presbyopia that correlated the most with DiffLogMAR differences was found to be 1.25 diopter ($p < 0.001$). In 13 hypermetropic volunteers, we found significant correlation between hypermetropia value and DiffLogMAR ($\rho > 0.7$, $p < 0.01$). The statistical analysis between Fly test and SE revealed a significant impact of presbyopia and hypermetropia to the stereotactic view of the subject ($\rho = -0.734$, $p < 0.05$).

Conclusion: Surgeons suffering from myopia greater than 1.75 diopter, presbyopia greater than 1.25 diopter (D), and hypermetropia regardless of grade must always perform robotic surgeries with the proper correction.

Key Words: Contact lenses, Glasses, Optics, Refractive errors, Robotic surgery

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INTRODUCTION

The main goal of robotic surgery is to improve the operative procedures by conferring upon the surgeon, enhanced view and control.[1] The three-dimensional (3D) high resolution camera view enables stereoscopic vision with depth perception to the surgeon and may lead to better surgical outcomes.[2] Nevertheless, many surgeons suffer from refractive eye disorders that may potentially alter their vision capability without the appropriate correction, which can lead to loss of this substantial advantage that robotic technology has to offer.

Refractive error is an eye disorder in which the eye is unable to focus light accurately on to the retina. The most common types of refractive errors are myopia, hypermetropia, astigmatism and presbyopia. The myopic eye cannot see clearly distant objects,[3] whereas the hypermetropic eye cannot see clearly near objects[4] Furthermore, the astigmatic eye sees blurry at any distance,[5] and the patient with presbyopia loses the elasticity of their eye due to aging.[6]

Stereopsis is a binocular sensation of relative depth caused by horizontal disparity of retinal images from both eyes. Stereopsis occurs when the two retinal images, which have small disparities due to the horizontal separation of the eyes, are cortically integrated.[7] Performance of motor skills tasks is related to stereoacuity, so presence of stereopsis provides quantifiable benefits to carrying out tasks that require fine motor skills.[8] There are no data to date concerning the possible influence of these eye disorders in the 3D vision provided by the robotic platform. In this study, we analyze the effects of refractive errors (myopia, hypermetropia, astigmatism, and presbyopia) on the binocular visual acuity (VA) while using Da Vinci SI Surgical System console. To our knowledge, this is the first and only study concerning this topic and may prove very important in clinical practice.

METHODS

Eighty volunteers with refractive eye disorders were included in the study. Individuals with organic eye disorders (intraocular bleeding, diabetic retinopathy, cataract, or amblyopia) were excluded. The study was approved by the Acibadem University ethics committee (decision number: 2019–9/11). Ophtalmologic examinations were performed by the same ophthalmologist. Refractive errors (myopia, hypermetropia, astigmatism, and presbyopia), anisometropia status and Fly Stereo Acuity Test scores were recorded. Anisometropia refers to a difference in refractive error between the eyes, in any meridian, of equal to or greater than 1.0 diopter. Prescriptions for glasses or contact lenses were provided for all volunteers.

Spherical equivalent (SE) values were calculated for all volunteers' right and left eyes. SE gives an estimate of the eye's refractive error. It combines the astigmatism with the sphere power (myopia or hypermetropia) and excludes the axis of astigmatism. SE is calculated by adding the sum of the sphere power with the half of the cylinder power (SE = Sphere Power + Cylinder Power/2). We performed analyses using the minimum and maximum SE from each eye.

Stereopsis was assessed using the Fly Stereo Acuity Test with LEA Symbols (Vision Assessment, Elk Grove Village, IL, USA). This test includes 10 grades, in descending order from 400 to 20 s of arc. The limited grade (LG) of the Fly Stereo Acuity Test with LEA Symbols was used as the index of participants' stereopsis function. Normal stereopsis was defined as LG ≥ 5 (arc ≥ 63 s). This test allows easy evaluation of both gross and fine stereo vision, and only works with the use of stereo glasses, thus subjects were not assessed through the DaVinci camera.

All 80 volunteers were examined on Da Vinci SI robotic system console by using a near vision chart placed 35 cm distance and through the 0-degree robotic camera. Examination was performed both before and after correction of eyesight with lens or glasses. Visual acuity was assessed by the logarithm of the minimal angle of resolution (LogMAR) method. Binocular uncorrected and best corrected (with proper contact lens or glasses) LogMAR values of the subjects were recorded. The difference between these values, which will be referred as DiffLogMAR, are affected by different refractive errors. We performed statistical analyses using the minimum and the maximum values of the refractive errors and SE from the two eyes of the volunteers.

Spearman's rank correlation coefficient method was used to evaluate correlation. In order to assesses whether DiffLogMAR differentiates between two groups (uncorrected and best corrected visual acuity groups), the Mann-Whitney U test was performed. In an effort to identify a threshold for refractive error that would best segregate low DiffLogMAR samples and high DiffLogMAR samples, we incremented the refractive error diopter step by step (0.25 D) and applied the Mann-Whitney U test to both groups (less than or equal to the threshold vs. greater than the threshold). P value < 0.05 was considered statistically significant. We calculated the sample size required for 0.8 power for the one-sided, two-sample t-test, and adjusted it for Mann-Whitney U test without any distribution assumption by dividing the determined sample size by 0.864 (since the Asymptotic Relative Efficiency for the Mann-Whitney U test is never less than 0.864). Our sample size satisfied these requirements.

RESULTS

Eighty volunteers were included in our cohort (**Table 1**). When SE and DiffLogMAR for all subjects were compared, we performed Spearman's rank correlation using both maximum and minimum SE from volunteers' right and left eyes. No statistically significant correlation was evident, ($p = 0.139$ and $p = 0.106$ for maximum and minimum SE respectively, Spearman's rank correlation). Nevertheless, the sub-group analysis revealed interesting results.

Myopia

In the group of myopia and/or astigmatism, uncorrected SE was found to have significant impact on the DiffLog-

Table 1.
Volunteers' Characteristics

Feature	Minimum	Maximum	Median
Age (years)	18	60	28.5
Hipermetropia (right eye)	0	+3.5 D	0
Hipermetropia (left eye)	0	+4 D	0
Hipermetropia (two eyes average)	0	+3.375 D	0
Myopia (right eye)	0	−5 D	−1.25 D
Myopia (left eye)	0	−5 D	−1.25 D
Myopia (two eyes average)	0	−4.875 D	−1.125 D
Astigmatism (right eye)	0	−5.25 D	0
Astigmatism (left eye)	0	−5 D	0
Astigmatism (two eyes average)	0	−5.125 D	0
Presbyopia	0	+2.5 D	0
Fly Stereo Acuity Test (score)	20	400	25
Uncorrected LogMAR	0.4	1	0.5
Corrected LogMAR	0.3	0.9	0.5
DiffLogMAR	0	0.6	0.1

3D, three-dimensional; 2D, two-dimensional; VA, binocular visual acuity; D, diopter; SE, spherical equivalent; LG, limited grade; LogMAR, logarithm of the minimal angle of resolution; DiffLogMAR, the difference between binocular uncorrected and best corrected (with proper contact lens or glasses) LogMAR values; EAES, European Association of Endoscopic Surgery; ESUT, European Section of UroTechnology.

MAR ($p < -0.6$, $p < 0.001$ for both cases of using minimum and maximum SE, Spearman's rank correlation) (**Figure 1**).

As we found a significant effect of anisometropia, isometropic myopic subjects were evaluated (n = 29).

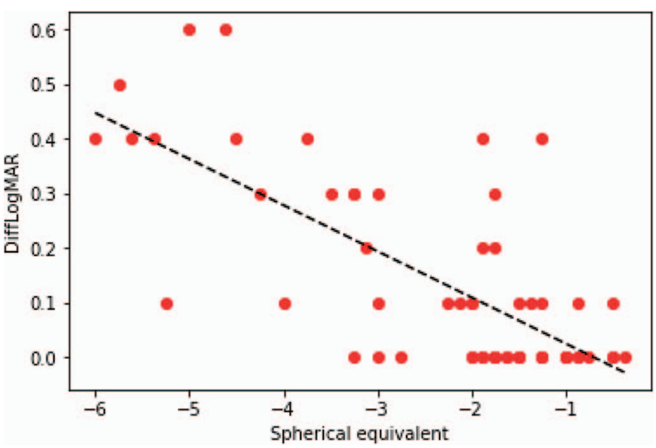

Figure 1. Spherical equivalent: DiffLogMAR plot and fitted line for patients with myopia and/or astigmatism (when minimum value of two eyes was used).

The outcome of this analysis proved that people with myopia greater than 1.75 diopter had significantly higher DiffLogMAR values ($p < 0.05$, Mann-Whitney U test) (**Figure 2**).

Presbyopia- Astigmatism

We observed that subjects with presbyopia had significantly higher DiffLogMAR values ($p < 0.01$, Mann-

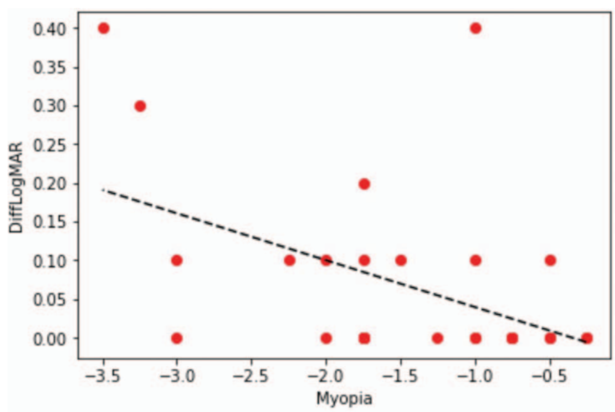

Figure 2. Myopia: DiffLogMAR plot and fitted line.

Whitney U test) and positive correlation between presbyopia and DiffLogMAR values (p = 0.33, $p < 0.01$, Spearman's rank correlation); whereas the correlation was more evident in subjects with pure presbyopia (p = 0.69, $p < 0.01$, Spearman's rank correlation) (**Figure 3**). The cut-off value of presbyopia that correlated the most with DiffLogMAR differences was found to be 1.25 diopter ($p <$ 0.001, Mann-Whitney U test). No correlation was observed between astigmatism and DiffLogMAR (p = 0.12, $p =$ 0.272, Spearman's rank correlation) in subjects with astigmatism and at least one other eye disorder. This was due to including only five pure astigmatism subjects, for which no statistical analysis could be performed.

Hypermetropia

In 13 hypermetropic subjects, we found significant correlation between hypermetropia value and DiffLogMAR (p > 0.7, $p < 0.01$ in both cases of using maximum and minimum hypermetropia value from the two eyes, Spearman's rank correlation) (**Figure 4**) (**Figure 5**).

Fly Stereo Acuity Test

Generally, a weak correlation was observed between Fly Stereo Acuity Test results and DiffLogMAR (p = 0.23, $p <$ 0.05, Spearman's rank correlation) and the same results were found between spherical equivalent and Fly Test correlation (p = 0.25, $p < 0.05$, Spearman's rank correlation). (**Figure 6**). Results for different eye disorders were revealing. As far as LogMar was assessed, there was no influence of myopia in the stereotactic view ($p = 0.712$) and the same for myopia combined with astigmatism ($p =$ 0.728). The combination of hypermetropia and presbyopia had no impact on the subjects' 3D vision ($p = 0.12$).

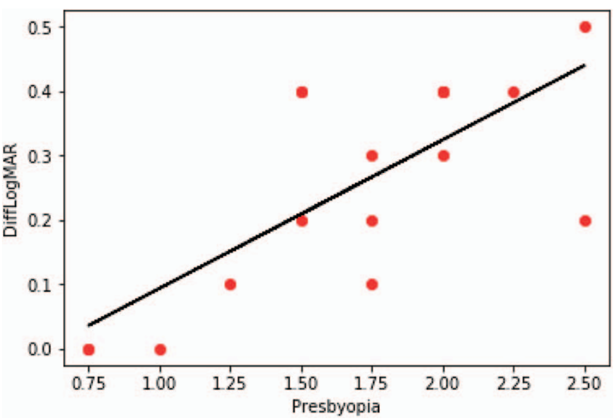

Figure 3. Presbyopia: DiffLogMAR plot and fitted line (subjects without presbyopia were excluded).

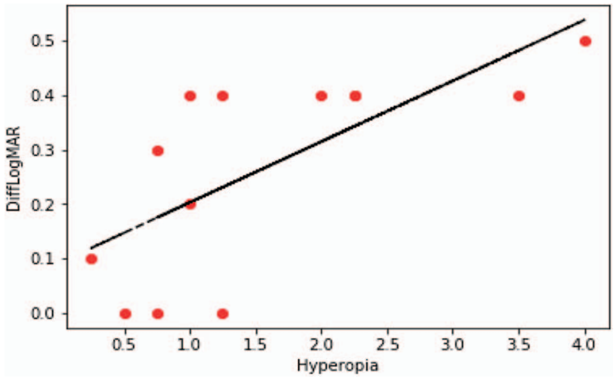

Figure 4. Hypermetropia: DiffLogMAR plot and fitted line (maximum value from two eyes was used).

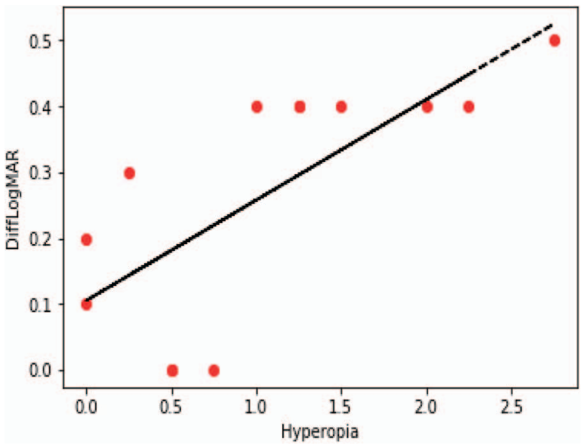

Figure 5. Hypermetropia: DiffLogMAR plot and fitted line (minimum value from two eyes was used).

Conversely, the statistical analysis between Fly test and SE revealed a significant impact of presbyopia and hypermetropia to the stereotactic view of the subject (p = −0.734, $p < 0.05$, Spearman's rank correlation). The other disorders (myopia and astigmatism) were not found to influence surgeons' 3D vision.

DISCUSSION

The lack of depth perception during a standard laparoscopic operation represents a major sensory loss for the surgeon. In order to increase laparoscopic skills and to overcome this loss, 3D laparoscopic systems have been developed which eventually progressed to the DaVinci robotic platform (Intuitive Surgical, Sunnyvale, CA). The potential pitfall of 3D laparoscopic systems is the feel of dizziness. The advantages of these technological marvels in different operation parameters have been the topic of extended debate, but it seems that they aid significantly in

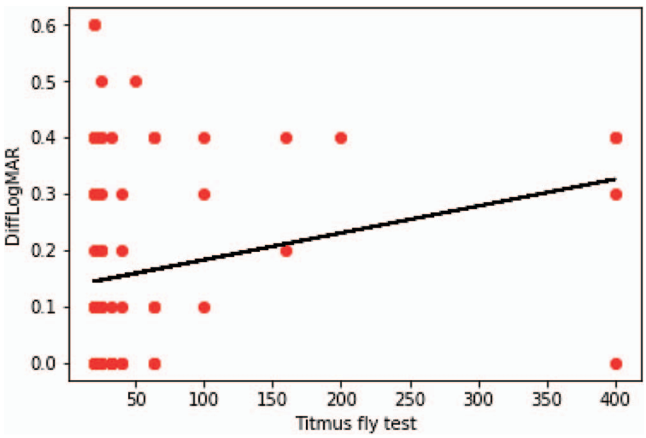

Figure 6. Fly Stereo Acuity Test: DiffLogMAR plot and fitted line.

overall surgery outcomes.[9–10] In this study, we test the possible impact of different eye refractive disorders in the clear vision and depth perception of the surgeon, which may influence the 3D vision of the surgeon (if uncorrected); possibly without the surgeon's awareness.

There are no data about the possible impact of different eye disorders in the vision of the console surgeon during operation, if these disorders remain uncorrected (using the robotic console without glasses or lens correction). In our study, a subject's vision was tested using the DaVinci camera without proper correction and the outcomes are quite revealing. Myopia greater than 1.75 diopter, presbyopia greater than 1.25 diopter, and hypermetropia irrespective of grade were significantly correlated with higher DiffLogMAR, whereas no correlation was observed for astigmatism and at least one more eye disorder (pure astigmatism couldn't be assessed in this cohort due to low number of volunteers). These findings suggest that surgeons with these factors must always perform robotic surgeries with the proper correction (glasses or contact lenses).

In the literature, many authors attributed the reduction of binocular perception to different eye refractive disorders. Patients with myopia seem to have reduced stereopsis with greater binocular imbalance compared to emmetropes,[11] whereas this effect has been shown to be more noticeable with myopic anisometropia compared to other disorders.[12] Other reports suggest hypermetropia as the sole significant eye disorder that can significantly affect stereoacuity,[13] whereas most of the papers seem to adhere to a marginal effect of other eye disorders (e.g., astigmatism).[12] In our study, presbyopia and hypermetropia are shown to be the two eye refractive disorders that significantly diminish stereo vision (if uncorrected) and may potentially influence vision and surgical outcomes of robotic procedures.

Studies regarding the potential benefits of 3D vision are continuously increasing. There are reports that 3D vision is associated with reduced operative time,[14] especially for the urological procedures that require intracorporeal suturing[15]and shorter hospitalization time.[16] There are even studies suggesting that 3D vision enhances the possibility of achieving better oncological and functional outcomes in radical prostatectomy compared to 2D vision systems.[17] Despite the low level of evidence, European Association of Endoscopic Surgery and European Section of UroTechnology, recommend 3D vision systems in order to facilitate better surgical outcomes.[18],[15] Since 3D vision is the cornerstone of robotic surgery, the potential loss of it may influence the surgical outcomes of the robotic procedures, particularly when the surgeon does not notice loss of depth perception loss.

There are several limitations to this study. First, the number of volunteers is relatively low to draw conclusions, and in particular, the number of volunteers with some pure eye disorders like astigmatism. Secondly, we utilized only the Fly Stereo Acuity Test (titmus fly test), it is possible that we missed some other significant differences that may rise with the other available tests for stereo vision. Finally, we did not include data about surgical outcomes (with or without lens correction) in order to prove any clinical significance of our findings (surgical outcomes, etc.) However, a potential strength of our study is its prospective nature.

CONCLUSION

Surgeons suffering from myopia greater than 1.75 diopter, presbyopia greater than 1.25 diopter, and hypermetropia irrespective of grade must always perform robotic surgeries with the proper correction (glasses or contact lenses). Presbyopia and hypermetropia have been found to have significant effect on the 3D vision of robotic surgeons (without their complete awareness).

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