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Reading performance in patients with severe vision impairment after providing near visual aids

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Abstract

This study aims to compare reading performance based on reading speed and print size in patients with severe visual impairment before and after providing near visual aids. The study included 100 patients with severe vision impairment. Examinations were performed for both distant and near vision. Training for reading with letter magnification was conducted over six months. Evaluation of letter magnification, visual acuity, and reading speed was performed at 2 weeks, 1 month, 3 months, and 6 months. Comparison between baseline letter magnification and periods with training showed that training had no improvement in letter magnification up to one month; however, improvements were observed by the 3rd and 6th months of training. The readable letter size became smaller with increased training duration. Visual acuity significantly improved during the first month of training ($p = 0.045$). The longer the treatment period, the greater the improvement in visual acuity ($p = 0.016$ and 0.014 at 3 and 6 months, respectively). Reading speed improved within 2 weeks of training, increasing from a baseline of 62.58 ± 9.95 words per minute (wpm) to 71.58 ± 9.84, 88.67 ± 8.95, 94.72 ± 9.05, and 98.49 ± 9.12 wpm at 2 weeks, 1 month, 3 months, and 6 months, respectively, with statistically significant differences ($p = 0.038$, 0.003, 0.001, and 0.001). These findings emphasize the importance of sustained low vision rehabilitation and training with magnifying aids to improve reading speed and performance in patients with severe visual impairment. The study demonstrated a significant improvement in reading speed and visual acuity through training in severely low vision patients who used optimal magnifying aids for an extended period. The effects remained stable after the completion of the training program, indicating that such interventions can enhance their quality of life.

Keywords: Reading performance, Severe vision impairment, Visual aids.

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1. Introduction

Low vision is defined as a permanent visual impairment that cannot be fully corrected by medical, surgical, or optical means and significantly affects an individual's ability to perform daily activities. According to the International Classification of Diseases (ICD), low vision encompasses moderate to severe visual impairment, characterized by presenting visual acuity less than 6/18 but greater than 3/60 in the better-seeing eye, even with the best possible correction [1].

Age-related macular degeneration (AMD), which primarily affects central vision, is a common reason people lose their ability to read. It is the most frequent cause of severe vision loss in the Western world [2] and can significantly diminish quality of life (QoL) [3].

Reading difficulties are among the most reported issues by individuals with low vision, making the improvement of reading speed a primary therapeutic goal. Vision rehabilitation has a long-established role and is extensively employed to aid patients in reading and managing daily tasks. Assessments such as near and distance visual acuity, contrast sensitivity, and visual field testing are typically conducted to identify the most appropriate assistive devices for each individual. However, accurately forecasting the extent of benefit a patient might derive from low vision rehabilitation remains a considerable challenge [4-6].

Depression may also contribute to a perceived decline in visual function among these patients, Rovner et al. [7] along with reduced cognitive performance [8]. This highlights the importance of vision rehabilitation, which has demonstrated an effective rate of 94% [9]. A previous pilot study showed that the use of magnifying aids not only enhanced reading speed (RS) but also improved emotional well-being, cognitive function, and quality of life (QoL) [10]**.**

A randomized controlled trial is currently evaluating whether incorporating additional reading training (RT), following the initial adaptation to visual aids, can further enhance the outcomes of vision rehabilitation in individuals with low vision [11].

So, the aim of this study is to compare the reading performance according to reading speed and print size in patients with severe visual impairment before and after providing near visual aids with training.

1.1. Patients and Methods

This is an experimental study involving 100 patients with low vision that cannot be corrected. They were collected from the visual rehabilitation clinic at Mansoura University Ophthalmic Center, Mansoura University, during the period from January 2020 to January 2023. The study protocol was designed to assess patients with visual impairment due to different pathologies, with and without the use of visual aids. It adhered to the tenets of the Declaration of Helsinki, and informed consent was obtained from the patients or their guardians according to the child's age.

The study was conducted on patients of both sexes older than 10 years (equivalent to sixth-grade reading material) with low visual acuities less than 6/60 (decimal: 0.1, LogMAR: 1.0), and near acuity less than N6 or M.08 in the better eye.

Patients who were illiterate, had unclear corneas, media opacities, or were mentally handicapped were excluded.

A counseling session was undertaken with the patients and their guardians to assess their visual needs, which included reading, writing, face recognition, household work, watching TV, and playing board games. The session aimed to explain the nature of their visual impairment and its effects, as well as to understand their expectations and identify any potential obstacles.

1.2. Ophthalmic Examination

BCVA was measured using the Lea translucent symbol distance visual acuity chart (Figure 1), 15 lines at 3 m, but if the top line appeared blurred, the chart was moved closer. The line recorded as threshold acuity was the one where more than 50% of the symbols were read. It was calculated (in decimals) as distance (in meters) divided by the last line read (letter size M).

Manifest and cycloplegic refraction were performed using the autorefractometer. Near visual acuity assessment was conducted at 40 cm using the Lea symbols near visual acuity chart (Figure 1, right). These charts used four symbols: the house, heart (or apple), circle, and square symbols. The results were converted to the decimal scale.

Slit-lamp biomicroscopy (Nidek, 22631, 2013, Nidek Japan) was performed to examine the anterior segment of the eye to exclude any corneal or lens abnormalities, such as corneal opacities, corneal dystrophy, corneal degeneration, and cataract.

Intraocular pressure measurement by applanation tonometer (Keeler, UK) was performed to exclude increased IOP that may affect corneal biomechanical properties.

Fundus examination: using a slit lamp aided with a 90D lens to exclude any treatable posterior segment disorder.

The central visual field was assessed by the Humphrey Field Analyzer. An Amsler grid was used to look for central scotoma with the Low Vision Central program of the Octopus Perimetry (HAAG-STREIT, Switzerland). Peripheral field assessment was done by the confrontation test.

Contrast sensitivity was assessed using the Pelli-Robson Contrast Sensitivity Chart. Color vision was tested with the Ichihara book. Relevant investigations such as fluorescein angiogram, optical coherence tomography, electroretinogram, and electrooculogram (FA, OCT, ERG, EOG) may be used in some cases to reach a diagnosis if the cases were not diagnosed.

1.3. Reading Performance

The reading test was conducted using the Come Closer reading size test Figure 2), developed by a senior project at Linnaeus University in Kalmar, Sweden, in 2008. The test was translated into Arabic and validated by the Vision Rehabilitation Department at the German Jordanian University. The Arabic texts were printed in various *Times New Roman* font sizes, including 10p, 16p, 20p, 24p, 30p, 60p, 80p, and 100p. During presbyopia testing, the patient was instructed to hold the reading chart at a distance of 25 cm while using a +4.00 D reading addition. The patient began reading from the largest font size, progressing to smaller sizes until a noticeable decrease in reading fluency was observed. The threshold reading acuity was defined as the smallest text size the patient could read without fluency. Reading acuity was assessed binocularly. To evaluate reading speed, the patient was asked to read aloud continuously for one minute.

The reading speed was measured by counting the words read per minute. To make the training accessible to everyone, including those with limited literacy skills and children, we began with very simple phrases. We did not repeat the sentences used for assessment. The word count varies from text to text, but it is measured in words per minute as the total number of words read in a minute (wpm).

1.4. Calculation of the Magnification Needed for Near

The threshold reading size at 25cm is measured. Then, estimate the size of print in the desired patient's book using a millimeter ruler. For a sustained task, halve the estimated size by dividing the threshold by the desired. If the device was needed for a spot task, do not divide the estimated size of the desired material by two.

For example, we measured the threshold reading size at 25cm as P24. Then we estimated the size of print in the desired patient's book to be P12. This is a sustained task, so half the estimated size, 12/2 = 6. Therefore, the target acuity to achieve is P6.

Magnification estimate (M) = (Threshold acuity)/(Target acuity) = 24/6 = 4x. Therefore, the patient needed a 4x magnifier for this sustained task, such as reading a book. If the device was needed for a spot task, such as reading a restaurant bill,

Magnification Estimate (M) = (Threshold Acuity)/(Target Acuity) = 24/12 = 2 x.

M = power of the lens /4.

The dominant eye was determined by keeping both eyes open and focused on a distant object, then extending the arm out and pointing with the index finger or thumb at the object. Alternately closing one eye at a time. The eye that kept the finger directly in front of the object while the other eye was closed was the dominant eye.

1.5. Types of Prescribed Aids

1. Dome magnifier 2x figure (Schweizer, Germany).
2. Hand and stand magnifiers (Eschenbach, Germany).
3. Max detail 2.1× that can be seen at an intermediate distance from 30 cm to 100 cm, figure [Galilean telescope (Eschenbach, Germany)].
4. Magnifying convex glasses, binocular and uniocular figure (made in India, China or Egypt)
5. Portable video magnifiers, such as those produced by Freedom Scientific (USA), include closed-circuit television (CCTV) functionality. These devices provide a broad magnification range from 2× to 45× and typically feature adjustable contrast settings as well as image freeze capability.

1.6. Follow-Up

UCVA and BCVA were measured pre- and post-visual aid usage, with calculations of reading distance, reading speed, and letter size for each participant. These measurements were repeated at 2 weeks, 1 month, 3 months, and 6 months after the use of visual aids.

Figure 1.
The Lea symbols far (left) and near (right) acuity chart.

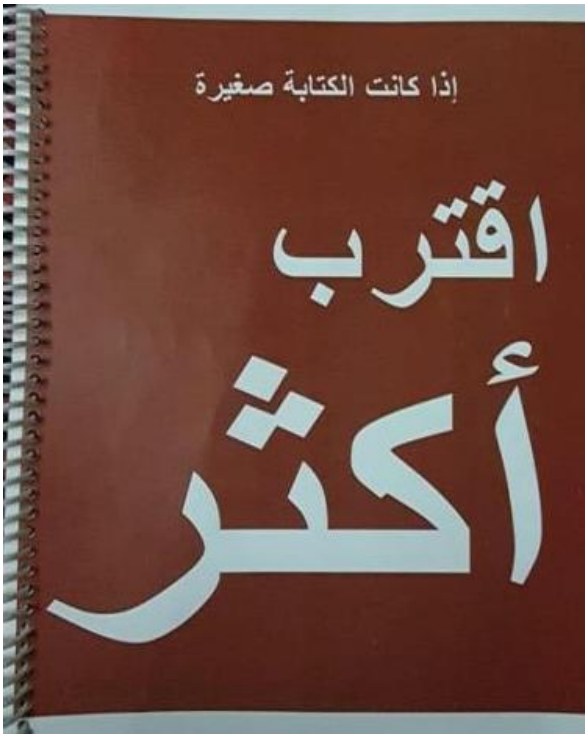

Figure 2.
Come Closer Test.

1.7. Statistical Analysis

Statistical analyses were performed using SPSS v23 statistical software (SPSS, Inc., Chicago, Illinois). Descriptive statistics (means, correlations, and standard deviations) were calculated for quantitative variables. Two-sided Chi-square, Student's t-test, and ANOVA were used as appropriate for parametric data, and Mann-Whitney U and Kruskal-Wallis tests were employed for non-parametric variables. The significance level was set at $P < 0.05$, which was considered statistically significant.

2. Results

This study involved 100 patients with low vision that cannot be corrected. There were 42 males (42%) and 58 females (58%), and the age ranged from 13 to 71 years old, with a mean ± SD of 50.76 ± 13.55 years. Positive family history was present in 15 patients (15%), and consanguinity was found in 25 patients (25%). The mean intraocular pressure (IOP) was 15.75 ± 1.91 mmHg. The mean spherical equivalent was 0.037 ± 1.4 diopters. The mean uncorrected decimal distant visual acuity in the best eye was 0.04 ± 0.012, and the mean corrected decimal distant visual acuity in the best eye was 0.049 ± 0.035. This is illustrated in Table 1.

Comparison between readable letter magnification at baseline and periods with training showed that training had no improvement in letter magnification up to one month, then showed improvement by the 3rd and 6th months of training. Letter magnification became smaller with a longer training period Table 2. Also, there is a significant negative correlation between visual acuity and letter magnification as shown in Figure 3.

The near visual acuity was significantly improved during the first month of training ($p = 0.045$). The more time spent on training, the greater the improvement in visual acuity ($p = 0.016$ and 0.014 at the 3rd and 6th months, respectively). Reading speed improved within 2 weeks of training, increasing from a baseline of 62.58 ± 9.95 wpm to 71.58 ± 9.84, 88.67 ± 8.95, 94.72 ± 9.05, and 98.49 ± 9.12 wpm at 2 weeks, 1 month, 3 months, and 6 months of training, respectively, with statistically significant differences ($p = 0.038$, 0.003, 0.001, and 0.001) Table 2.

The most commonly used visual aid was the illuminated stand, employed in 35 patients (35%), followed by high plus lenses used in 23 patients (23%), then the illuminated hand-held magnifier used in 17 patients (17%), clip-on magnifier lenses in 15 patients (15%), and telescopes in 10 patients (10%). The visual aid most associated with improvement was telescopes (100%), followed by illuminated hand-held magnifiers (88.2%), high plus lenses (86.9%), clip-on magnifier lenses (80%), and illuminated stands (71.4%). Patients reported the highest satisfaction with illuminated stands (100%), followed by clip-on magnifier lenses (93.3%), high plus lenses (60.9%), telescopes (50%), and the least satisfaction was with illuminated hand-held magnifiers (29.4%), shown in Figure 4.

Higher reading performance was achieved in albinism, with a mean reading speed of 116 ± 3 wpm, followed by cone dystrophy (109.7 wpm), and the lowest performance was observed in age-related macular degeneration (94.79 wpm). Also, advanced diabetic maculopathy, optic atrophy, advanced glaucoma, and retinitis pigmentosa had low performance (97, 97.2, 97.75, and 98.5 wpm) shown in Table 3.

We have 5 cases of syndromic visual disorder: 2 cases of Laurence-Moon-Biedl syndrome with moderate mental disorder and retinitis pigmentosa; 1 case of Wolfram syndrome with deafness, diabetes mellitus, and optic atrophy; 1 case of Down syndrome with mental illness and visual impairment due to high myopia; and 1 case of visual disorder in a cerebral palsy patient.

Table 1.
Patients' characteristics of the studied patients.

	Males		**Females**		**Significance**	
	No.	**%**	**No.**	**%**	χ^2	**P**
Gender	42	42.0	58	58.0	0.408	0.224
	Positive		Negative			
Family history	15	15.0	85	85.0	16.58	<0.001*
Consanguinity	25	25.0	75	75.0	9.374	<0.001*
Age (years)	Range		Mean ± SD			
Mean ± SD	13 – 71		50.76 ± 13.55			
Item			Range		Mean ±SD	
IOP (mmHg)			12.5 – 22		15.75 ± 1.91	
Spherical equivalent (D)			-4.0 – 3.25		0.0365 ± 1.405	
UCDVA (Decimal)			0.016 – 0.08		0.04 ± 0.012	
BCDVA (decimal)			0.016 – 0.50		0.049 ± 0.035	

Note: χ^2 = Chi square, t: paired t-test, SD: standard deviation, D: diopter, IOP: Intraocular pressure, SD: Standard deviation, UCDVA: uncorrected distance visual acuity, BCDVA: corrected distance visual acuity.

Table 2.
Comparison of magnification, BCNVA and reading speed between baseline and during the follow-up period using visual aids.

Period	Magnification (Diopter)	BCNVA (decimal)	Reading speed (wpm)
Baseline before training	8.425 ±3.37	0.22 ± 0.15	62.58 ± 9.95
2 weeks after training	8.425 ±3.37	0.26 ± 0.21	71.58 ± 9.84
P value	1.000	0.093	0.038*
1 month after training	8.25 ± 3.25	0.287 ± 0.28	88.67 ± 8.95
P value	0.962	0.045*	0.003*
3 months after training	6.25 ± 4.48	0.291 ± 0.19	94.72 ± 9.05
P value	0.042*	0.016*	0.001*
6 months after training	5.62 ± 4.17	0.299 ± 0.21	98.49 ± 9.12
P value	0.002*	0.014*	0.001*

Note: *P<0.05 = significant by unpaired t-test, BCNVA: best corrected near visual acuity.

Table 3.
The relation between the underlying disease and reading performance after 6 months of treatment.

Underlying Disease	**No. of patients**	**Reading speed (wpm)**	
		Range	**Mean ±SD**
Albinism	2	113 – 119	116.0 ± 3.0
Macular scar	3	84 – 120	106.7 ± 15.1
Diabetic maculopathy	3	96 – 98	97.0 ± 0.67
Advanced glaucoma	4	85 – 108	97.75 ± 6.38
Stargardt's disease	6	88 – 112	105.7 ± 6.78
Cone dystrophy	7	85 – 129	109.7 ± 14.3
Optic atrophy	9	88 – 114	97.2 ± 7.36
Myopic degeneration	11	83 – 115	99.5 ± 7.22
Retinitis pigmentosa	13	83 – 122	98.5 ± 6.96
ARMD	42	82 – 109	94.79 ± 5.31
Total	100		

Note: ARMD: age-related macular degeneration.

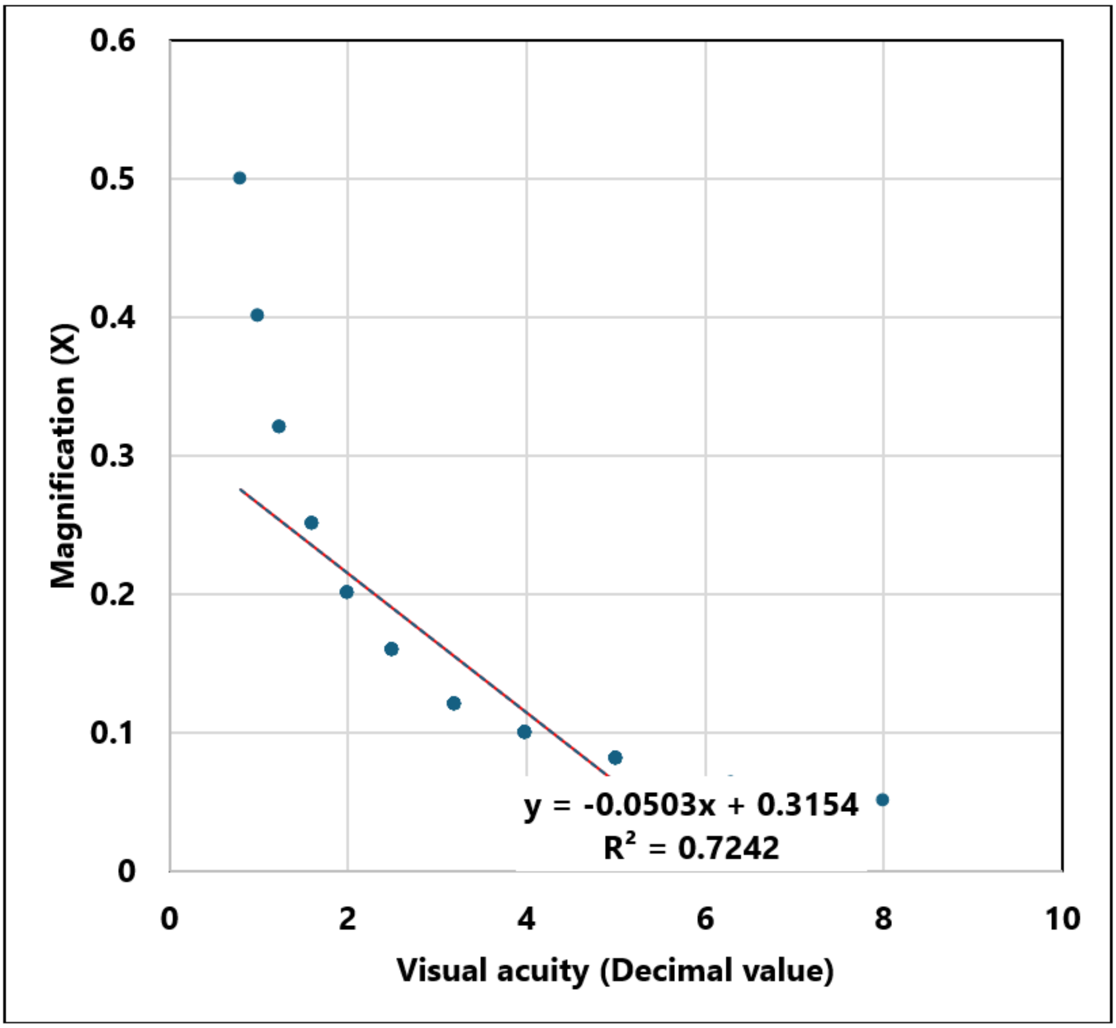

Figure 3.
Correlation coefficient (r) and regression curve between visual acuity and magnification. There is a statistically significant negative correlation between magnification and visual acuity (r = 0.851, p = 0.002). This indicates that the greater the magnification, the lower the visual acuity.

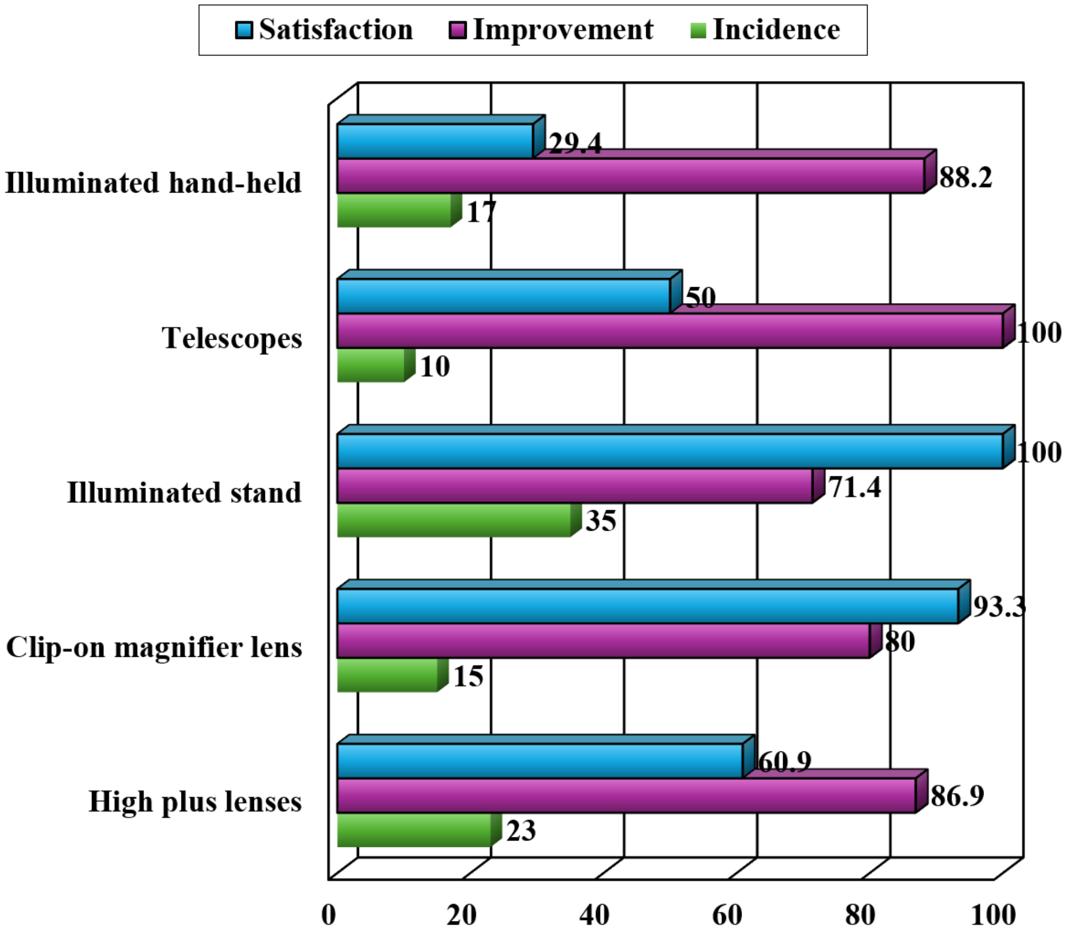

Figure 4.
Type of visual aids used in our study.

3. Discussion

Reading performance in patients with severe vision impairment (VI) can be significantly improved through the use of low-vision aids (LVAs) [12, 13]. Studies have shown that LVAs such as telescopes, video magnifiers, handheld magnifiers, and tinted lenses can lead to meaningful improvements in both distance and near visual acuities, as well as reading speed and critical print size [14]. The need for improving near vision in younger patients is of primary importance. Near vision in students and young adults directly impacts their education and learning. Despite poor distant vision, if there is considerable improvement in near vision, they can continue in mainstream education and employment [15].

The aim of the study is to compare reading performance based on reading speed and print size in patients with severe visual impairment before and after training for near visual aids. It involved 100 patients with low vision that cannot be corrected.

We used the Arabic translated version of the Come Closer Test. Previous studies commonly assessed reading speed using the Close-up test for English or the Radner test for Arabic. These assessments comprise simple, single sentences of equal character length, typically drawn from reading materials designed for second- and third-grade levels [16]. While they are effective for evaluating reading acuity and identifying the critical print size, the brevity of the texts limits their accuracy in measuring true reading speed.

To obtain more precise and consistent measurements over time, longer standardized text passages, uniform in length and linguistic complexity, are now used. These passages allow for a reliable assessment of reading speed during follow-up visits and are practical even in busy ophthalmic clinics. An additional benefit of these standardized texts is their availability in several European languages (English, Finnish, French, and German), with translations into other languages, such as Arabic, underway. This makes them especially useful for international research focused on low vision [9].

In agreement with our results, Nguyen et al. [9] showed that without suitable vision aids, reading speed in almost all patients was < 30 wpm, constituting no reading ability. Using adapted vision aids, patients could read newspaper print with a mean reading speed of 72 ± 35 wpm. As shown in a previous study, fluent reading corresponded to > 70 wpm [17]. The effectiveness of low vision aids has been demonstrated in previous studies using vision-related questionnaires [18] or according to reading speed in a small group of patients following macula translocation [19].

Subjects read more words/letters per minute after providing aids than during the baseline phase [20]. Consistent with our findings, Kaltenegger et al. [11] reported that training was beneficial for individuals with severe visual impairment, focusing exclusively on patients with AMD. They defined a clinically relevant improvement as an increase of ≥10 words per minute (wpm) and observed that 14 out of 37 participants experienced meaningful gains. However, they were unable to identify any predictive factors for future improvement.

Christen and Abegg [1] found that although reading speed for small text sizes did not significantly differ across the three visual conditions: central scotoma, blurred vision, and oscillopsia the same degree of magnification produced a more pronounced improvement in reading performance for individuals with blur-related vision loss compared to those with central scotoma or nystagmus. The authors suggest that the limiting factors for reading differ across various visual impairments and may respond uniquely to magnification. For instance, in cases of blur, the main limitation may be reduced two-point discrimination, making it difficult to distinguish between similar letters such as “U” and “O.” A slight increase in size may resolve this issue and improve readability. Conversely, in central scotoma, the key challenge may be the number of letters obscured, requiring greater magnification to identify more letters within a word. A similar rationale may apply to conditions like oscillopsia or nystagmus, where reading performance may be affected by different underlying mechanisms.

In our study involving five children with multiple disabilities, similar findings to those of Ramani et al. [20] were observed. Two male children with cerebral palsy and optic atrophy experienced a temporary decline in reading speed after the intervention, lasting about two weeks, followed by a steady improvement. A third male child with cerebral palsy, along with speech and visual impairments, did not show any initial decline; instead, he demonstrated continuous progress throughout the intervention period, mirroring our own results. This variation may be explained by the type of low vision aids used: the first two children used dome and stand magnifiers, which require fine motor coordination, whereas the third child used a closed-circuit television (CCTV) device that demands less manual control. These outcomes suggest that low vision rehabilitation can enhance reading speed in children with multiple disabilities and visual impairment (MDVI). Although the degree of improvement varied, all participants showed increased ability to read more words or letters during and after the intervention [21].

Similarly, baseline data from Ramani et al. [20] revealed that children with low vision and additional disabilities tend to have lower reading accuracy. This may be due to two overlapping reasons. First, limited visual input can make it harder for these children to clearly see text, leading them to guess words that fit the context. Second, they may misread words that have similar visual or spelling patterns. There were a few cases of children with syndromic conditions, so we couldn’t obtain results from these cases.

We achieved an increase in RS to 9 WPM within the first two weeks, 26 WPM after one month, 32.14 WPM after three months, and 35.9 WPM after six months of treatment. Kaltenegger et al. [11] found an increase in reading speed by a median of 14.7 wpm, which was much less than ours. This may be due to the short training period of 6 weeks and also the type of disease, as they studied only AMD patients. Another study in juvenile macular dystrophy (35 patients with Stargardt disease) showed a higher increase in reading speed, which increased to 20 wpm after 4 weeks of training [22]. However, Nguyen et al. [9] studied patients with AMD and found an improvement of up to 40 wpm after training. All these studies had shorter training periods and involved patients of much higher ages than ours (age of AMD < 80 years). It should be considered that magnification aids are the main factor in increasing reading speed in AMD.

Tarita-Nistor et al. [23] in a feasibility study, patients with central vision loss were trained at their acuity threshold using a perceptual learning approach, which led to improvements in both reading acuity and maximum reading speed (RS).

In the present study, the required magnification decreased gradually over the course of 6 months of training. There was an improvement in visual acuity after 6 months of training. Additionally, there was a marked improvement in reading speed during this period.

Christen and Abegg [1] demonstrated that artificially induced low vision reduces reading speed, which can be improved through enhancements in both contrast and magnification. Their research observed that near-normal reading speeds were achieved with maximum magnification, but not with optimal contrast, across all simulated low vision conditions. Notably, the benefit of magnification varied depending on the type of visual impairment: it was most effective for blurred vision, followed by vision affected by text motion, whereas individuals simulating a central scotoma experienced the least improvement. Conversely, contrast enhancement proved beneficial across all types of visual impairments.

Nguyen et al. [9] Appropriately customized low vision aids have demonstrated a significantly positive impact on preserving and enhancing reading capabilities in the majority of patients with age-related macular degeneration (AMD). Following the use of these aids, 94% of patients were able to read, compared to only 16% prior to intervention. Notably, the patients who were initially able to read had a visual acuity ranging from 0.4 to 0.6 in their better eyes. Despite this, they reported difficulties reading newspapers, which was the primary reason they sought professional assessment and reading aid support.

Correlation coefficient (r) and regression curve between visual acuity and magnification showed a statistically significant negative correlation ($r = -0.851$, $p < 0.01$). This indicates that increased magnification is associated with decreased visual acuity and reading speed in our study.

In agreement with the current study, Nguyen et al. [9] found a highly significant correlation between BCVA and reading speed with low magnification after the provision of visual aids ($r = 0.6$, $p < 0.0001$), which shows an increase in reading speed with increasing visual acuity.

Where available, our data aligns with previous research showing that magnification can improve reading speed in low vision patients. For instance, Christen and Abegg [1] reported near-normal reading speeds at the highest magnification levels across various types of visual impairment. In contrast, Legge et al. [16] observed that such reading speeds were only achievable in individuals with preserved central vision. Patients with central vision loss, by comparison, reached a median maximum of just 25 words per minute. In their study, font sizes ranged between 12° and 24°, whereas smaller font sizes around 2° were used in other contexts [16]. These findings suggest that the results are most applicable to patients with intact central vision, as font sizes exceeding 2° are generally linked to a decrease in maximum reading speed [24].

This also helps explain why the present study observed the least reading improvement among patients with age-related macular degeneration.

4. Conclusion

The study demonstrated a significant improvement in both reading speed and visual acuity through training in patients with severe low vision who had been using optimal magnifying aids for an extended period. Notably, the improvements were sustained after the training concluded, suggesting a lasting positive impact on their quality of life.

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