

Validation of DDIVAT a Smart TV–Based Digital Visual Acuity Test Among Bulgarian-speaking Population

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Abstract

Background:

Significant geographic disparities in Bulgaria isolate rural populations from ophthalmic centers, creating an urgent need for accessible, remote eye care solutions. The present study aimed to validate the DDiVAT digital visual acuity test application for distance visual acuity (VA) assessment in a Bulgarian-speaking population, enabling reliable VA assessment.

Methods:

This prospective observational study included 150 adult Bulgarian-speaking participants (294 eyes). We included normal- and low-vision participants for validation. Distance VA was assessed monocularly using both the DDiVAT application and the gold-standard European-wide ETDRS Chart under standardized conditions. Statistical equivalence was evaluated using an intraclass correlation coefficient (ICC) analysis, and a non-inferiority margin, established at 2.5 letters with Bland–Altman plots. We assessed DDiVAT's test-retest reliability within a 15-day window.

Results:

A total of 150 participants completed the assessments for 294 eyes. The mean difference in letters between the modified ETDRS and the DDiVAT testing was 0.9 letters, which fell comfortably below the predefined 2.5-letter non-inferiority margin. Intraclass correlation coefficients (ICCs) indicated excellent agreement (0.95), while Bland–Altman analysis confirmed a high degree of method consistency. The system demonstrated strong stability with a 15-day test-retest reliability ICC of 0.998.

Conclusions:

The DDiVAT provides accurate visual acuity measurements for both normal and low-vision patients, offering results comparable to traditional ETDRS tests. By enabling reliable VA assessment, this digital tool is considered valid for Bulgarian-speaking population and helps overcome geographical barriers and addresses the shortage of eye care access in remote and rural regions.

BACKGROUND

Visual acuity (VA) testing is a fundamental part of systematic visual examination and the most frequently used test in clinical and outpatient ophthalmology. Deteriorated vision hurts the quality of life of patients, their families, national health systems, and society, and is a measure of visual impairment (VI). According to WHO data, 2.2 billion people worldwide suffer from VI, and almost half of these cases are preventable and/or reversible if addressed promptly and appropriately [1]. Uncorrected refractive

errors [2], cataract [3], diabetic retinopathy (DR) [4], age-related macular degeneration (AMD) [5], and glaucoma [6] are leading and growing causes of VI. Many patients lack access to quality eye care services, especially those living in rural areas or with limited mobility. The COVID-19 pandemic has posed new challenges to humanity, particularly in quality medical care, including ophthalmological care, by limiting in-person meetings between doctors and patients. This, in turn, has greatly reduced the use of prophylaxis and preventive medicine, especially during the lockdown and even after.

Global technological progress and the availability of accessible internet and smart hardware have revealed telemedicine's potential in conditions of limited human (staff), financial, and equipment resources. Ophthalmology is a highly favourable speciality for telemedical services. Telemonitoring technologies screen for retinopathy of prematurity (ROP) [7], amblyopia [8], diabetic retinopathy (DR) [9], age-related macular degeneration (AMD) [10], and glaucoma [11].

VA evaluation, though subjective, is the cornerstone of diagnosis and follow-up in various ocular diseases and a primary outcome endpoint in clinical trials. Many vision charts exist; one of the most widely used in everyday practice is the Snellen VA chart. Designed by Dutch ophthalmologist Herman Snellen in 1861, initially with abstract shapes and later with alphanumeric capitals in a 5×5 grid, it is widely accepted, user-friendly, and a national standard in many countries [12]. Its main disadvantages are the varying number of optotypes within each row, the non-geometric progression in optotype size from the upper to the lower rows, and its use in patients with low vision.

In 1976, Australian ophthalmologists Bailey and Lovie introduced a new chart format with proportional font size, an equal number of letters per row-5, with decreasing sizes in a geometric progression, providing greater precision and reproducibility in the results and allowing the examination of patients with low VA, which subsequently became known as LogMAR (MAR - Minimum Angle of Resolution) [13]. In 1982, as part of the Early Treatment Diabetic Retinopathy Study (ETDRS), logarithmic charts were refined and are now recognised as the international gold standard for VA testing, especially for scientific research [14].

A VA test with these charts requires the physical presence of an eye-care professional and a patient, a set of trial lenses and frames, and specific distance and lighting conditions. In modern life, this is not always possible for various reasons. Shortage of medical personnel, overloaded healthcare systems, mobility difficulties of disabled patients, remoteness from professional ophthalmological care, etc. The COVID-19 pandemic and subsequent lockdown further complicated the promotion and prevention of ophthalmological health, leading to negative consequences for many patients' quality of life.

A promising, easily applicable, and feasible approach to assessing and self-assessing VA is using various smart devices, such as smartphones, iPads, and tablets. Many applications have been developed for this purpose, some of which are validated or compared with the ETDRS VA chart [15, 16, 17]. Potential disadvantages of working with smartphones and tablets include difficulties, especially for older and disabled patients, in using and managing these devices, which require clear, appropriate instructions from an eye care professional. Another disadvantage is that VA testing again requires a certain distance,

adequate illumination, and correct screen position in front of the patient, which is difficult to standardise when using a phone, for example. A correct examination requires presenting 5 LogMAR 1-size symbols on the screen at an appropriate resolution, which is challenging on the relatively small screens of most handheld smart devices.

This, in turn, shows the potential of smart TV applications for correct and reliable assessment of VA at a standardised distance, with a standardised contrast, at the same screen position in front of the patient's face, and with the presentation of all 5 LogMAR symbols from a given row. One such application is the Democritus Digital Visual Acuity Test (DDiVAT), designed, developed and validated for the Greek population by a team from Democritus University of Thrace, Alexandroupolis, Greece (18). Therefore, this study aims to compare distance VA in Bulgarian-speaking patients aged 18 years or older using two methods: the ETDRS chart and the DDiVAT digital online optotypes and to validate the latter for the Bulgarian population.

METHODS

Setting

This prospective, observational, non-interventional, blinded cohort study examined the distance VA of adult Bulgarian-speaking patients at the University Eye Clinic (UEC) of “St. George” University Hospital, Plovdiv, Bulgaria, between October 2025 and December 2025. The study protocol fully complies with the tenets of the Declaration of Helsinki, the principles of Good Clinical Practice, and Bulgarian laws and regulations governing clinical and scientific research involving human subjects. The Medical University of Plovdiv ethics committee, Bulgaria, approved it. All participants provided written informed consent after receiving a thorough explanation of the study's goals and aims. The study's official registration number is NCT07208838 {09/04/2025}.

Participants

Bulgarian-speaking inpatient and outpatient visitors of the UEC, as well as healthy volunteers, with and without previously prescribed optical correction, were enrolled in the study on a consecutive, if eligible, basis. Inclusion criteria were as follows: a) age ≥ 18 years, b) Bulgarian-speaking patients, and c) VA $\leq$ Log MAR 1. We excluded participants unable to understand the study objectives or diagnosed with neurologic, mental, and/or psychiatric diseases.

Visual acuity testing protocol

All patients were examined one by one in the same room, under constant lighting conditions and at a constant testing distance, by one of three ophthalmologists (V. M., K. B., and Y. I.) using the DDiVAT smart TV application and a modified European-wide-use retroilluminated ETDRS chart [19]. Both the

application and the chosen ETDRS chart contain letters that are the same in the Cyrillic and Latin alphabets. Participants were asked to wear their distance visual correction (spectacles or contact lenses), if they had any. We did not measure prior refraction or administer mydriatic or cycloplegic drops. The examination began with the right eye, with the fellow eye occluded without pressure, followed by the left eye with the right eye occluded. One examiner initially tested each patient with the DDiVAT application, then another examiner tested the same patient with the ETDRS chart, blinded to the previous results. All 3 investigators strictly followed the test protocol, as described later.

The DDiVAT test was performed first, using a 32-inch smart TV at a distance of 3 meters, as described in detail by the application's designers [18]. The device required a stable internet connection, and the test began with 5 optotypes per row, starting at logMAR size 1 and decreasing in size. The patient was asked to pronounce each optotype in the row clearly and distinctly, from left to right, and was encouraged to do so when hesitating. The examination was terminated when the patient failed to identify 2 optotypes in a given row correctly, and the application software automatically calculated the VA of the tested eye.

Then, the modified European-wide use retroilluminated ETDRS chart, at a distance of 4 meters, was used by another of the aforementioned 3 investigators, who was unaware of the DDiVAT test results, to assess monocular distance VA in the study participants. The patients were again encouraged to pronounce the optotypes in each row loudly and clearly until two errors occurred in a row, and the examiner calculated the LogMAR VA for each eye. The examiners carefully measured the testing distance and closely monitored the patient's position.

DDiVAT's test-retest reliability was assessed within 15 days for each patient by one of the three ophthalmologists, none of whom had previously examined that patient with the application. The results of the two tests were cautiously recorded in a personal file for each participant.

Statistical analysis

An a priori power calculation indicated that, assuming an effect size of 0.274 for dBCVA, we would need 145 participants to achieve 95% power at a significance level of 0.05. We used the Shapiro–Wilk test to assess whether VA data were normally distributed. Data that were normally distributed were summarized as mean $\pm$ standard deviation, while non-normally distributed data were presented as the median and interquartile range (IQR) (25th and 75th percentiles).

We compared the two VA measurement charts using the paired-samples t-test for normally distributed variables and the Wilcoxon signed-rank test for non-normally distributed variables.

We assessed agreement among the different tests using Intraclass Correlation Coefficients (ICCs), calculated with a two-way mixed-effects model focused on absolute agreement and based on single measurements. We also examined agreement between test pairs using Bland–Altman plots, including the corresponding 95% limits of agreement. We conducted a noninferiority analysis to compare each of the four DDiVAT tests with its respective conventional dBCVA test, using a predefined margin of 2.5

symbols, as reported previously (20). We also evaluated test–retest reliability (TRT) of the DDiVAT for dBCVA measurement using ICCs. We performed all analyses using MedCalc version 20.1.4 (MedCalc Software, Mariakerke, Belgium).

RESULTS

We included 150 Bulgarian-speaking participants aged 18 years and older (N = 294 eyes) in the present study. Table 1 presents the gender distribution and other baseline demographic and clinical characteristics.

Table 1
Demographic data of the enrolled patients

Parameter	Total Sample (N = 294)	Shapiro–Wilk (p-value)
Age (years)	45.9±16.4	p = 0.12
Gender (Male/Female)	75 males/75 females	NA
ETDRS dBCVA	85 (77,90)	p < 0.0001
DDiVAT dBCVA	87 (78,92)	p < 0.0001

Distance VA measurements obtained using the DDiVAT and the ETDRS chart demonstrated a high level of agreement. The mean VA values between the two methods were comparable (Mean difference: 0.90 letters [95% CI: 0.5286, 1.2810]; Median difference: 2 letters), with no clinically significant differences observed. Mean difference in distance BCVA (in letters) between DDiVAT and ETDRS, as well as the corresponding 95% CIs, is below the noninferiority margin, which was set at 2.5 letters (equivalent to 0.05 logMAR). This fact is considered sufficient for both clinical and research settings. The confidence interval for the difference between DDiVAT and ETDRS was nearly symmetrical around 0.

ICCs between the two tests indicated excellent agreement, with a value of 0.952 [95% CI: 0.94, 0.96]. Bland–Altman analysis further supported this finding, showing a narrow mean difference between the two methods, with most measurements falling within the 95% limits of agreement. The Bland–Altman plots for all participants depict differences between DDiVAT and ETDRS (Fig. 1). This indicates strong agreement and no systematic bias between the digital and conventional methods. The dispersion of data points in the Bland–Altman plots suggests consistent agreement across the entire range of VA values, with no evidence of proportional bias.

Moreover, TRT reliability showed that the mean differences were below 1 letter, with an ICC of 0.998 [95% CI: 0.9975, 0.9984] for the DDiVAT test variants. The mean difference in distance BCVA was 0.2 ± 0.66 letters [95% CI: 0.053, 0.1]. Overall, these findings indicate that DDiVAT provides reliable and reproducible measurements of distance VA, which are highly comparable to the gold-standard ETDRS chart.

DISCUSSION

The healthcare landscape in Bulgaria exhibits significant geographic disparities, leaving large rural and isolated populations with limited physical access to specialized ophthalmic centers located in major urban hubs. This logistical barrier creates an urgent, unmet need for dependable, remote visual acuity (VA) testing systems that can reach underserved communities. Accessible telemedicine solutions are particularly critical for continuous monitoring of patients with chronic ocular conditions, such as diabetic retinopathy, age-related macular degeneration, and glaucoma, where early detection of vision changes is vital to prevent irreversible vision loss. By leveraging ubiquitous household technologies such as smart TVs, remote screening platforms can bridge this accessibility gap, enabling high-risk individuals to undergo regular visual assessments without the burden of long-distance travel. To address this, the study evaluates the Democritus Digital Visual Acuity Test (DDiVAT), a smart TV-based tool for remote screening in underserved areas [18].

The present study aimed to validate the DDiVAT digital visual acuity test for distance VA assessment in a Bulgarian-speaking population by comparing it with the gold-standard ETDRS chart. Our findings demonstrated that DDiVAT measurements are highly comparable to ETDRS, with no statistically significant differences between the two methods, supporting the validity of the application.

These results are consistent with previous validation studies of digital VA tools. Labiris et al. demonstrated that the Democritus Digital Acuity and Reading Test (DDART) produced nonsignificant differences compared to conventional charts, with excellent agreement (ICC up to 0.985) and minimal mean differences within clinically acceptable limits. Crucially, our findings closely align with the original DDiVAT validation study in a Greek-speaking cohort, which established its fundamental non-inferiority relative to standard clinical tests. The consistency of these findings across diverse linguistic populations underscores the robustness of the underlying software platform [20].

Other digital and web-based VA assessment tools have reported comparable outcomes. Smartphone- and web-based applications typically demonstrate small mean biases (often < 0.02 logMAR in normal-vision populations) and acceptable limits of agreement, although variability may increase in low-vision groups. Applications such as DigiVis and Peek Acuity have also shown good agreement with conventional testing methods, further supporting the feasibility of remote VA assessment [17, 21, 22].

However, a key limitation of standard digital testing in diverse populations is the linguistic barrier of optotypes. By using the modified "European-wide" ETDRS chart configuration, this study addressed the lack of a native Cyrillic ETDRS chart. The seven cross-alphabet Roman characters employed (A, B, E, M, P, T, X) are fully recognizable to Bulgarian speakers. This design choice ensured that differences in literacy or cognitive friction did not skew the comparison between the analogue chart and the digital application [19].

Furthermore, a significant structural advantage of DDiVAT lies in its implementation on a smart TV platform rather than a mobile device. This architecture allows for strict standardization of testing conditions, including fixed examination distance, stable screen size and position, and controlled

optotype presentation. This setup reduces variability compared to handheld devices, in which variable screen sizes, hand tremors, and fluctuating viewing distances often introduce clinical inconsistencies.

In addition to standardized testing conditions, a primary systemic advantage of the DDiVAT framework is its fully automated, cloud-based data architecture. Rather than relying on patients to manually record or report their scores, the application securely synchronizes test metrics directly to a centralized cloud database. This network capability grants the patient's primary ophthalmologist instantaneous, remote access to longitudinal visual acuity data. By eliminating manual transcription errors and automating clinical data transfers, the platform transitions from a simple isolated screening tool into a fully integrated teleophthalmology network, enabling seamless clinical surveillance of high-risk or remote patients.

Ultimately, DDiVAT's systemic architecture underscores its utility not merely as an isolated clinical test, but as a population-wide public health screening tool. Standard visual screenings have historically been plagued by a high loss-to-follow-up rate, primarily because patients in remote areas struggle to travel from community screening sites to tertiary care centers for definitive diagnosis. DDiVAT effectively bypasses this bottleneck; its automated, cloud-synchronizing database creates an immediate digital referral pathway, meaning a positive screening result at home or in a rural clinic is instantly flaggable by a central ophthalmic specialist [23].

From a clinical perspective, the lack of statistically significant differences between DDiVAT and ETDRS suggests the application can be used reliably in both clinical and telemedical settings. This utility is particularly critical in Bulgaria, where geographic disparities in ophthalmic care remain significant. Currently in Bulgaria, preventive healthcare and prophylaxis are assigned to General Practitioners (GPs), who are overloaded with pediatric and maternal healthcare, vaccinations, and care for chronically ill and mobility-impaired patients. Rural and isolated populations often endure limited physical access to urban eye care centers. By enabling dependable, automated remote screening on a ubiquitous household appliance such as a smart TV, DDiVAT offers a viable telemedicine solution to bridge this healthcare gap, potentially lowering the threshold for early detection of blinding pathologies.

However, certain limitations remain. While our study population of 150 participants (294 eyes) provided sufficient statistical power, expanding the sample size to include a broader spectrum of specific ocular pathologies would better map its performance across various visual impairments. Additionally, despite controlled laboratory testing conditions, the real-world deployment of nonhospital-based digital tools is inherently vulnerable to environmental factors, such as suboptimal room illumination, screen glare, and variable patient compliance during unmonitored testing by an eyecare professional. The current study included patients and healthy volunteers aged 18 years or older. It would be interesting to see how the application works with Bulgarian-speaking school- and pre-school-aged children, as promising reports come from a kindergarten cohort in Greece [23]. Thus, DDiVAT can serve as a screening tool for a nationwide preventive medicine program for early amblyopia detection.

CONCLUSIONS

The DDiVAT digital visual acuity test provides reliable distance VA measurements, with no statistically significant differences compared to the ETDRS chart. The application represents a valid alternative for clinical and telemedical use, supporting its implementation in screening programs and remote ophthalmological assessment. To our knowledge and current review of literature, this is the first comparative study among Bulgarian-speaking (adult) population checking distance visual acuity by using a digital VA test (DDiVAT) and the gold-standard European-wide ETDRS Chart. Our results show high agreement with no clinically significant differences between the two methods; the application's user-friendly design and ease of use make DDiVAT a valuable tool for the increasingly scarce VA screening-trained personnel.

Abbreviations

VA – Visual acuity

VI – Visual impairment

DR – Diabetic retinopathy

AMD – Age-related macular degeneration

ROP – Retinopathy of prematurity

ETDRS - Early Treatment Diabetic Retinopathy Study

DDiVAT - Democritus Digital Visual Acuity Test

UEC – University eye clinic

dBCVA – distance best corrected visual acuity

ICC – Intraclass correlation coefficient

TRT – Test-retest

Declarations

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Author's contributions:

V.M. and M.A - conceptualization and methodology of study; V.M.; K.B. and Y. I.- recruitment and testing of patients; A.A. - statistical analysis, figures and tables; V.M.; M.A. and A.A. - writing the manuscript;

K.B.; Y. I.; V.M. and A.A - literature review. All authors critically reviewed the manuscript and unanimously approved the submitted version, confirming their collective responsibility for the content.

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Data availability statement:

The data from this study are not publicly available because they contain protected personal information, but can be provided by the corresponding author upon reasonable request.

Ethical approval:

The study protocol is in full compliance with the tenets of the Declaration of Helsinki, the principles of Good Clinical Practice, and Bulgarian laws and regulations governing clinical and scientific research involving human subjects, and has been approved by the ethics committee of the Medical University of Plovdiv, Bulgaria (approval code: № 15, approval date: June 15-th 2025).

Informed consent:

All participants provided written informed consent after receiving a thorough explanation of the study's goals and aims.

Consent for publication:

Not applicable

Competing interests:

The authors declare no competing interests regarding the research, authorship and/or publication of this manuscript.

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Figures

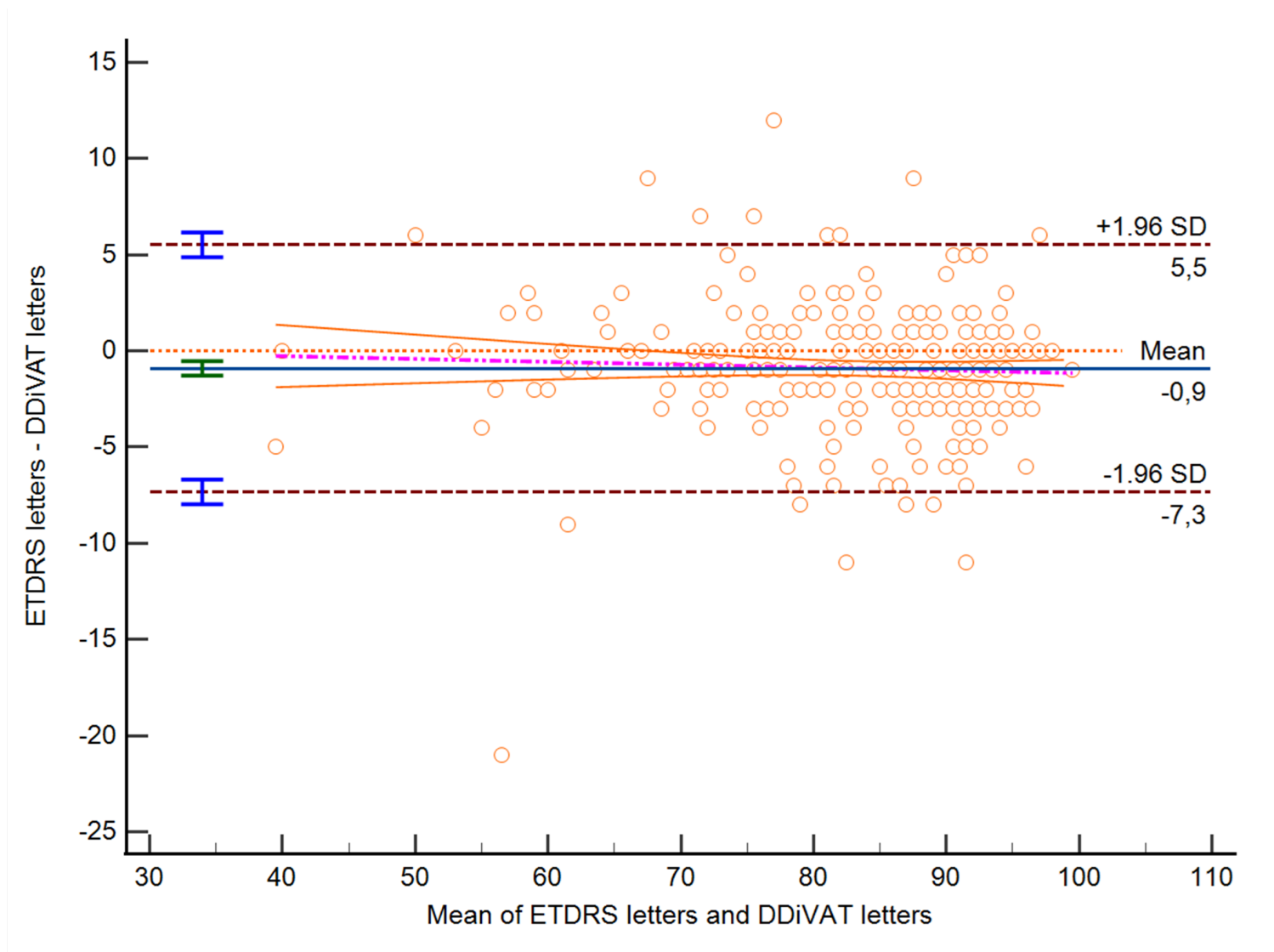


Figure 1

Bland-Altman plots comparing dBCVA (in letters) between ETDRS and DDIVAT.