HAS SNELLEN CHART LOST THE BATTLE TO ETDRS IN CATARACT SURGERY VISUAL ACUITY EVALUATION?

Sanja Petrović Pajić[1], Tiana Petrović[2], Milenko Stojković[1,2] and Slađana Anđelić[3,4]

[1]Eye Hospital, Clinical Center of Serbia, Belgrade, Serbia;
[2]Faculty of Medicine, University of Belgrade, Belgrade, Serbia;
[3]Emergency Medical Care, Belgrade, Serbia;
[4]Faculty of Health and Business, Singidunum University, Valjevo, Serbia

SUMMARY – This study was designed to explore practical differences between visual acuity (VA) scores measured on Snellen chart *versus* ETDRS chart, to grade cataracts using LOCS III system, and to compare VA on both charts depending on cataract grade and type. Prospective evaluation of uncorrected and best-corrected visual acuity was carried out on the eye scheduled for cataract surgery preoperatively and postoperatively on the Snellen and ETDRS charts. The study was carried out at Department of Eye Diseases, Clinical Center of Serbia, during a two-year period. Inclusion criteria were met by 540 patients who underwent testing, surgery, data collection and analysis. The mean VA score was better on ETDRS than on Snellen chart. The mean difference was 6.05 letters or 1.21 lines. VA results correlated with all types of cataract regardless of the chart used, with the highest statistical significance (p<0.0001) for subcapsular cataract. The ETDRS chart was found to be more discriminative and precise than Snellen chart, especially for poor VA.

Key words: *Visual acuity; ETDRS chart; Snellen chart; LOCS III; Age-related cataract*

Introduction

Numerous testing charts are used for evaluation of visual acuity (VA), but Snellen and Early Treatment Diabetic Retinopathy Study (ETDRS) charts are most frequently applied[1,2]. Snellen chart has some advantages as it is readily available, relatively affordable, small, does not take up much space, and testing is fast and does not require examiner training[3]. However, disadvantages of Snellen chart are more numerous. There is an unequal number of symbols in rows and changes in symbol size is linear from row to row[4], crowding phenomenon is therefore amplified in rows with more letters, some chart letters (e.g., C, D, E, O) are easier to read than others (e.g., A, J, L)[5]. Visual acuity testing on Snellen chart relies on the line assignment method

Correspondence to: *Prof. Slađana Anđelić, MD, PhD*, Emergency Medical Care, Franše d'Eperea 5, 11000 Belgrade, Serbia
E-mail: novizivot94@gmail.com

and the term Snellen chart is not standardized, i.e. the Snellen chart definition criteria are not precisely defined[6]. Snellen chart has high test-retest variability (TRV) values, e.g., more than 2 rows for healthy eyes[7,8] and up to 3.3 rows for eyes with some ocular disease[9,10].

The ETDRS chart has an identical number of letters *per* row, and equal spacing between the letters and between the rows, expressed in logarithmic values[3]. Instead of Snellen letters, quadratic or so-called Sloan letters are used, which are balanced based on the 'reading difficulty' in each row. ETDRS chart is graded in LogMAR (Logarithm of the Minimum Angle of Resolution) units, corresponding to the logarithmic perception of the visual system[11].

Each letter read is assigned a value of 0.02 LogMAR marking based on the number of read letters, not rows. The TRV values were significantly better than for Snellen charts, and were in the range of 3.5 to 10 letters depending on whether the patient had normal VA and function[12-15]. Disadvantages of the ET-

DRS chart are its size, insufficient knowledge of testing protocols, longer testing time, need for personnel training, and high price[16,17].

Senile cataract is a progressive cloudiness or opacity of the lens in people older than 45 without a known source of origin such as trauma, inflammation, hypocalcemia, medicaments, or congenital factors[18,19]. The Lens Opacities Classification System III (LOCS III) is used to grade and compare the type and progression of the cataract[20,21].

The present study investigated the degree of compliance of the measurement results of the best corrected visual acuity (BCVA) and uncorrected visual acuity (UCVA) in patients suffering from senile cataract preoperatively (poor VA) and postoperatively (good VA) using Snellen and ETDRS charts.

Patients and Methods

The study involved adult patients suffering from senile cataract and operated on at Department of Eye Diseases, Clinical Centre of Serbia, during a two-year period. Exclusion criteria were failure to show up for control check-up; VA <6/60 according to Snellen chart; diagnosed or suspected accompanying eye diseases or diseases of the central nervous system which might affect VA along with the cataract; complications during cataract surgery; oligophrenia, presenile or senile dementia, psycho-organic syndrome, poor cooperation with the patient; and patient failing to provide written consent to participate in the study.

A total of 540 patients satisfied the set criteria and were included in statistical analysis. Grading of the cataract was performed 7 days prior to the operation based on slit lamp examination through medically dilated pupils. All patients were successfully tested for VA with both test charts selected. VA testing was done by the same examiner and in the same room with a standardized ambient lighting, i.e. dark room (approximately 10 cd/m^2 measured by digital lux meter MS-1500 (Voltcraft, No. 12 88 02) and standardized test chart lighting (inside lighting of the test box). Prior to VA testing, refraction was determined on both eyes, followed by possible optical correction (where necessary). Subsequently, VA was tested on the eye scheduled for operation, first on Snellen chart and then on ETDRS chart. During testing, the patient's pupil size

was adequate for the ambient lighting, i.e. the pupils were not medically dilated.

Snellen chart testing was carried out using Snellen chart with a standard back-lighting of 85 cd/m^2 (Instrumentaria, Zagreb, Croatia; TIP PV/02, V 220/24, W 14.25, attest number 3024) from a 6-m distance. Snellen chart was printed in high-contrast letters on a translucent back-lit white panel and was represented in a standard light box. Only letter symbols were used during testing. VA testing was initiated from the top of the scale and progressed top-to-bottom to the final row which the patient could read clearly with all the pictured symbols (numbers). Patients were allowed only one attempt at reading the chart. The recorded results were confirmed using Tumbling E test eye chart in order to avoid the possibility of false reading (false positive result).

ETDRS Chart Testing (ETDRS chart Precision Vision, Catalog No. 2110) was carried out at a 4-meter distance from the patient, with a chart box mounted on a stand. The chart box had a standard backlighting of 300 cd/m^2 (Chart Illuminator, Precision Vision, Catalog No. 2425, 230 V, 50 Hz). ETDRS chart was printed in high-contrast letters on a translucent polystyrene back-lit panel, and was shown in a standard light box. The chart had 5 letters *per* line, spaced in steps of 0.1 LogMAR, as *per* ETDRS protocol. VA testing was initiated with the first letter in the upper row of the chart and progressed top-to-bottom until the patient would erroneously read all the letters in one of the lines, or until the patient read all the letters in all the lines (on the chart). The examinees were allowed to read off the chart only once.

In order to achieve partial concordance between different methodologies of determining VA using ETDRS and Snellen charts, we partially modified testing on the ETDRS chart. We tested patients on the ETDRS chart by using line assign method (similar to Snellen chart). In other words, we did not take into account the letters from the subsequent row, instead we only counted those rows that were read in full. This principle will henceforth be labeled as the 'modified ETDRS chart'.

Cataract grading was done 7 days prior to the operation. The examination was performed on a slit lamp through dilated pupil (tropicamide 1% and phenylephrine 2.5%). The slit lamp setup (slit height, width, slit beam angle and focus) was made according to the

Harvard Medical School recommendations (LOCS III) in grading human age-related cataract[21]. Classification was performed by a single ophthalmologist, based on the subjective perception of the clinical shape of the cataract and comparison with a set of standardized photographs.

Visual acuity testing was carried out under the same testing conditions and standards one month after the operation, both on Snellen and ETDRS charts.

Statistical analysis

Study results were expressed as mean ± standard deviation (SD). The normality of data distribution was assessed with Kolmogorov-Smirnov test. Statistical analysis included descriptive statistics and paired *t*-test used for comparison of the Snellen and ETDRS chart results. The level of statistical significance was set at $p < 0.05$. Difference between group medians was tested by Mann-Whitney U-test.

Non-parametric data were expressed as numbers and percentages, and tested by the χ^2-test. Correlation coefficient was used to test the relationship between two properties. Bland-Altman analyses were used to compare variability between the two scales.

Results

A total of 540 patients were operated on. There was no significant difference according to sex, operated eye, age, and cataract type distribution (Table 1). The mean age of patients in the posterior subcapsular cataract group was lowest and statistically significantly different.

The lowest preoperative VA value on all charts was measured on Snellen chart (0.797±0.235 LogMAR) and the best VA was recorded on ETDRS chart (0.605±0.235 LogMAR) (Fig. 1).

Visual acuity measurements recorded postoperatively were very good, i.e. lower than 0.1 LogMAR. The lowest postoperative VA of 0.098±0.097 LogMAR was measured with UCVA on Snellen chart. When measurements were repeated on a modified ETDRS chart, the lowest recorded VA value was 0.095 LogMAR. Thus, postoperative VA measurements on
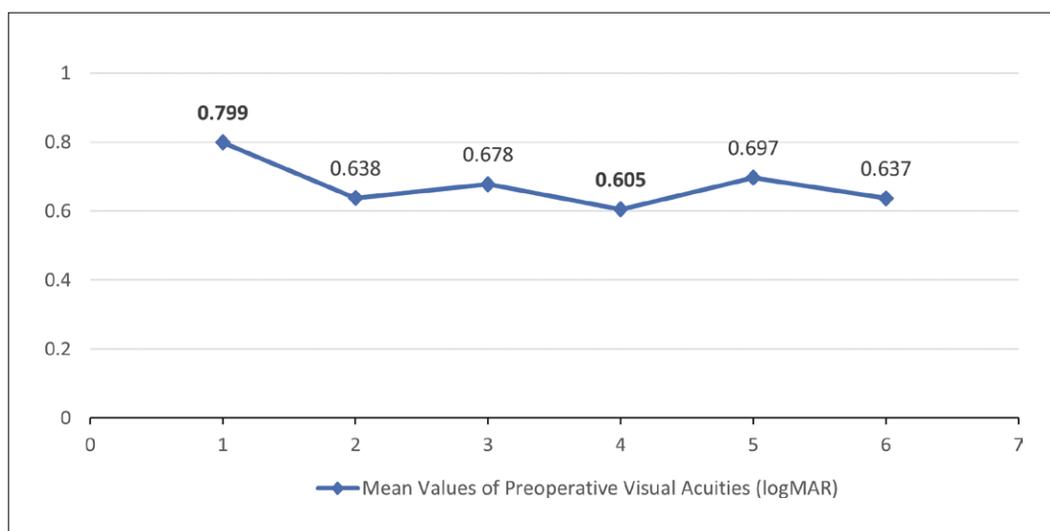
Table 1. Patient distribution by sex, operated eye, age, and cataract type

Sex	Male	244
	Female	296
Operated eye, n	Right	300
	Left	240
Age (years)	Posterior subcapsular group	62.75±6.03
	Cortical group	65.85±6.54
	Nuclear group	65.92±6.92
Cataract type, n (%)	Posterior subcapsular group	184 (34.07)
	Cortical group	160 (29.63)
	Nuclear group	196 (36.29)

Fig. 1. Mean preoperative visual acuity, uncorrected (UCVA) and best corrected (BCVA), on both charts.

Table 2. Preoperative visual acuity values measured on Snellen chart vs. ETDRS chart

Preoperative visual acuity	Snellen chart, AM ± SD	ETDRS chart, AM ± SD	Statistical significance	95% confidence interval
UCVA	0.799±0.235	0.678±0.147	p<0.0001	-0.145-0.093
BCVA	0.639±0.225	0.605±0.155	p=0.007	-0.056-0.009

ETDRS = Early Treatment Diabetic Retinopathy Study chart; AM = arithmetic mean; SD = standard deviation; UCVA = uncorrected visual acuity; BCVA = best corrected visual acuity; p = probability value
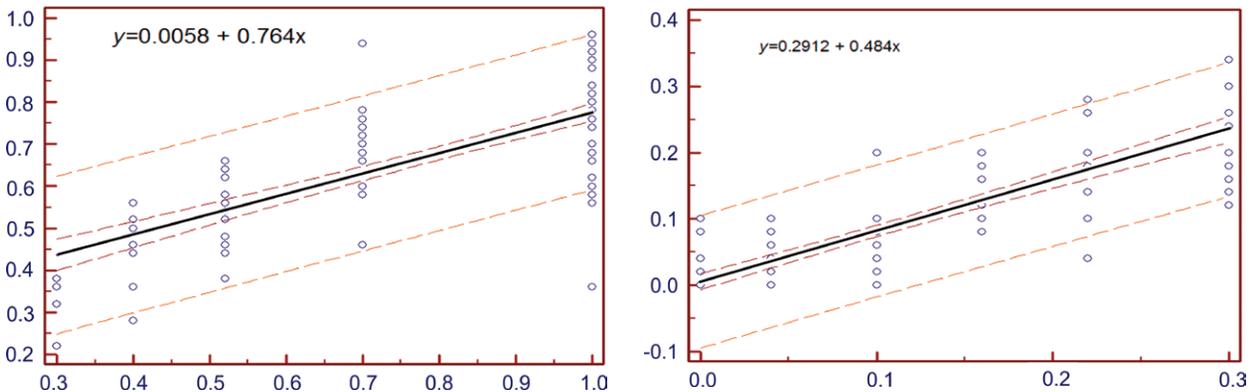

Fig. 2. Correlation of preoperatively (left) and postoperatively (right) measured uncorrected visual acuities (UCVA) on ETDRS and Snellen charts; X and Y axes represent visual acuity values expressed in LogMAR; X-axis represents Snellen chart values and Y-axis ETDRS chart values; solid black line is the line of regression; dashed lines represent 95% confidence interval of the regression line.
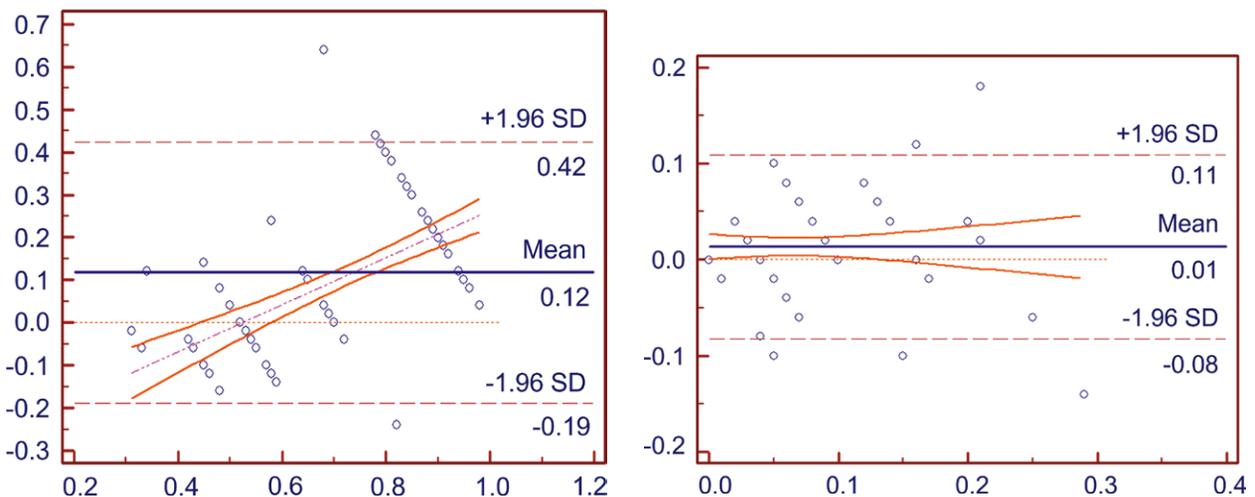

Fig. 3. Bland–Altman graph showing differences in the values of preoperatively (left) and postoperatively (right) measured visual acuities on Snellen and ETDRS charts, expressed in LogMAR; Y- axis represents difference between measurements on the two charts, whereas X-axis represents the mean visual acuity on the two charts; solid blue line represents the mean visual acuity expressed in LogMAR (0.12 preoperatively, poor visual acuity vs. 0.01 postoperatively, good visual acuity); the area between dashed lines equals the limit of 95% overlap between the two charts; all the points below the solid line represent Snellen chart results as poorer compared to ETDRS chart results on the same eye.
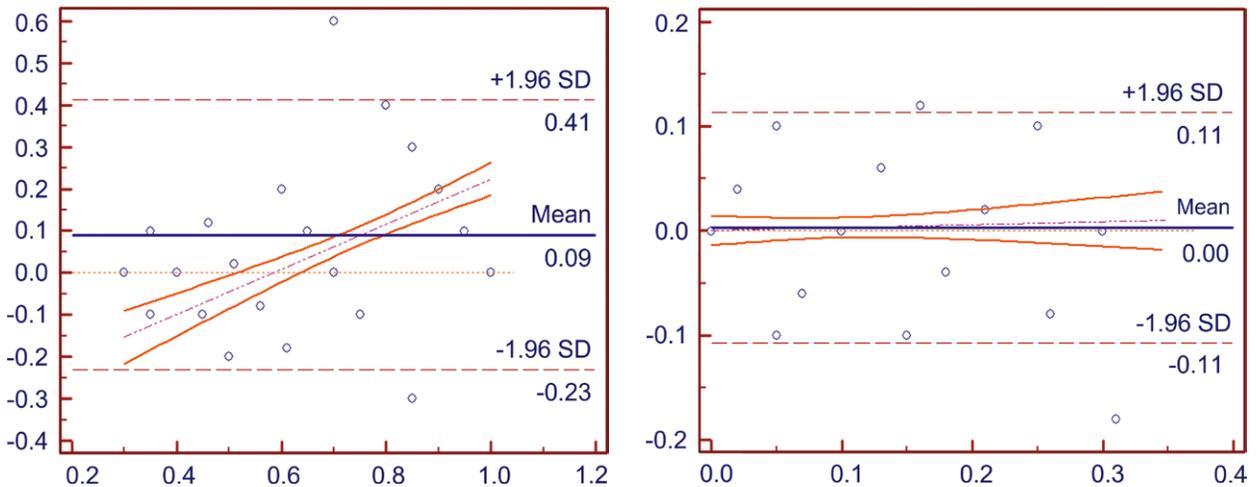
Fig. 4. Bland–Altman graph showing differences in the values of preoperatively (left) and postoperatively (right) measured visual acuities on Snellen and modified ETDRS charts, expressed in LogMAR; Y–axis represents difference between measurements on the two charts, whereas X–axis represents the mean visual acuity value on the two charts; solid blue line represents the mean visual acuity expressed in LogMAR (0.09 preoperatively, poor visual acuity); the area between dashed lines equals the limit of 95% overlap between the two charts; all the points below the solid line represent Snellen chart results as poorer compared to ETDRS chart results on the same eye.

Table 3. Correlation between cataract progression and preoperative UCVA and BCVA for all three cataract types measured on Snellen, ETDRS and modified ETDRS charts

Preoperative visual acuity	Posterior subcapsular cataract		Cortical cataract		Nuclear cataract	
	r	p	r	p	r	p
Snellen chart, UCVA	0.466	0.0346	0.324	0.042	0.309	0.048
Snellen chart, BCVA	0.519	0.0007	0.430	0.0041	0.410	0.0049
ETDRS chart, UCVA	0.467	0.0021	0.487	0.00039	0.483	0.0015
ETDRS chart, BCVA	0.685	<0.0001	0.494	0.0003	0.677	<0.0001
Modified ETDRS chart, UCVA	0.386	0.0081	0.498	0.0003	0.306	0.0387
Modified ETDRS chart, UCVA	0.567	<0.0001	0.461	0.0009	0.496	0.0005

ETDRS = Early Treatment Diabetic Retinopathy Study chart; UCVA = uncorrected visual acuity; BCVA = best corrected visual acuity; p = probability value; r = correlation coefficient

the two scales were almost completely equalized. Preoperatively measured VA were statistically significantly different. The greatest difference was observed with UCVA. Its value was 6.05 letters or 1.21 sequence rows on Snellen chart compared to ETDRS chart (Table 2). However, with regard to BCVA, the values recorded on Snellen and ETDRS charts were approximately the same, i.e. 0.639 LogMAR on Snellen chart and 0.636 on modified ETDRS chart.

Considering postoperative VA, statistical significance was only found with UCVA, which was lower on Snellen chart by 1 letter. Regression analysis of the

Table 4. Comparison of UCVA and BCVA preoperative visual acuity measured on Snellen and ETDRS charts according to cataract type

Cataract type	UCVA			BCVA		
	Snellen chart AM ± SD, 95% CI	ETDRS chart AM ± SD, 95% CI	Statistical significance	Snellen chart AM ± SD, 95% CI	ETDRS chart AM ± SD, 95% CI	Statistical significance
Posterior subcapsular	0.879±0.197 CI=0.822-0.936	0.742±0.122 CI=0.706-0.777	p<0.0001	0.729±0.211 CI=0.668-0.789	0.681±0.132 CI=0.643-0.719	p=0.0336
Nuclear	0.798±0.243 CI=0.720-0.876	0.654±0.167 CI=0.600–0.708	p<0.0001	0.601 ± 0.232 CI=0.527–0.675	0.567±0.169 CI=0.513-0.622	p=0.1442
Cortical	0.710±0.237 CI=0.639-0.780	0.631±0.129 CI=0.593-0.670	p=0.0009	0.573±0.206 CI=0.512-0.634	0.556±0.135 CI=0.516-0.597	p=0.3596

ETDRS = Early Treatment Diabetic Retinopathy Study chart; AM = arithmetic mean; SD = standard deviation; UCVA = uncorrected visual acuity; BCVA = best corrected visual acuity; 95% CI = 95% confidence interval

preoperatively measured UCVA indicated a statistically highly significant connection (p<0.001) between the two scales with determination coefficient R^2=0.6029 (Fig. 2a). These values correspond to poor VA. Similar result was also obtained on postoperative measurements, i.e. for good VA (Fig. 2b). There was a statistically highly significant connection (p<0.001) between the two scales with determination coefficient R^2=0.6863. The relationship between the two charts is clearly defined, and the values obtained using one chart can be used to calculate the values on the other chart using the regression line equation.

The Bland-Altman analysis of difference between the results of the preoperatively measured, native (UCVA) VA (low values, poor VA) on Snellen and ETDRS charts compared to their mean values showed that VA deterioration increased the variability between the two charts (Fig. 3a). On postoperatively measured VA (good eye sight) on Snellen and ETDRS charts, the observed difference was not so significant (Fig. 3b).

We also analyzed the relation between the values of native VA measured on Snellen and modified ETDRS chart. Once again, it was observed that the variability increased with VA reduction (Fig. 4a). Analysis of postoperatively measured VA on Snellen and modified ETDRS charts showed that there was virtually no between-chart variability at better VA (Fig. 4b).

The mean cataract grade was 3.96±0.686. Our results showed a statistically significant relationship between the degree of cataract progression and measured VA in all three cataract groups. The highest correlation was observed in posterior subcapsular cataract with a correlation coefficient of r=0.683 for the modified ETDRS chart (Table 3).

As illustrated in Table 4, preoperatively measured UCVA in all three cataract types was statistically significant lower on Snellen chart than on the other two charts. The situation was different with BCVA, whereby the difference was statistically significant only in posterior subcapsular cataract.

Discussion

To our understanding, based on MEDLINE database search (February 2016), our research is the only one that directly estimated VA measurement differences between Snellen and ETDRS charts based on the grade of cataract progression. Furthermore, to our knowledge, this research is the only one carried out on a significant group of patients with age-related cataract, whereby both the preoperative and postoperative VA measurements were compared on both aforementioned charts. The only known previous research of this kind included a group of cataract patients comprised of only three subjects[22]. Our research showed significantly higher VA values on ETDRS than on Snellen chart with a high statistical significance (p= 0.000000001). The mean difference was 6.05 letters or 1.21 lines. This could be of significance during the patient selection process for operation. Similar results have been reported by Falkenstein *et al.*[23], who observed a mean difference in the measured VA values on the two charts of 2.5 lines, as well as by Kaiser[22], who recorded a difference between the two charts of 6.5 letters or 1.3 lines. When we introduced the method of assigning rows to VA measurements on ETDRS chart, i.e. when the so-called modified ETDRS chart was used, with an appropriate optical correction we ob-

served almost no difference in the mean VA values between the two charts. This questions the importance of the precision difference between the two charts from the aspect of daily clinical practice.

The mean postoperative VA showed a statistically significant difference between the two charts only when it was measured without appropriate optical correction, and it was about one letter (non-modified, standard ETDRS compared to Snellen chart). Given the lack of appropriate study to compare data, we can only compare the obtained results with those reported by Kaiser[22] and Falkenstein *et al.*[23], who examined VA in different patient groups suffering from a number of ophthalmologic diseases, as well as those included in the healthy group as a whole, whereby one of the ways of group sorting was based on the measured VA. Kaiser's results[22] indicated the group of patients with good VA (VA better than 20/50) to show difference between Snellen and ETDRS charts smaller than one line. This is similar to the previous findings that patients with VA better than 20/30 exhibited difference in the two charts of 3.5 letters[23]. Based on our results, as well as the results of previous research, for clinical trials/tests requiring patients with good VA, it is justified to assume that the measurements recorded on ETDRS chart largely correspond to Snellen chart measurements with a deviation of up to 1 line.

Similar results measured on the two aforementioned charts in patients with good VA, as well as a significant difference in poor VA patients can be explained by the very nature of the vision sense. Humans perceive the linear increase of a stimulus by a logarithmic increase in perception[24]. Weber-Fechner law stipulates that the perception intensity is proportional to the logarithm of the stimulus intensity. At the very beginning, i.e. at lower stimulus intensities above the necessary threshold, the perception intensity increases proportionally. However, as we increase the amount of stimulus, the intensity of perception does not change at the same rate, instead it increases more slowly. Perception intensity does not increase with the absolute value of the stimulus intensity. Rather, it increases with its logarithm. For lower stimulus intensities, i.e. at lower VA as applied in our research, this logarithmic scale varies significantly from the linear scale and has a greater bandwidth. In contrast, for greater values, it contracts and achieves maximum value which tends to infinity and invariance, and thus approximates the linear scale[25].

Our research showed that there was a highly statistically significant correlation among cataract grade, cataract type and VA. The greatest level of correlation was observed in posterior subcapsular cataracts, which is in line with the existing research[26]. This is somewhat in contrast to the adopted belief that the estimate of the posterior subcapsular cataract VA is somewhat less precise than for nuclear cataracts, as it is much more reliant upon ambient illumination. However, our research excluded the factor of different ambient illumination (minimal degree, darkened room, approximately 10 cd/m^2), thus enabling greater light penetration for subcapsular cataracts than it is the case (at least for the majority) for nuclear and nuclear brunescent cataracts. It is possible that the reason why the best correlation of VA with cataract grade is present in posterior subcapsular cataracts is the relative structure and optical homogeneity of subcapsular cataracts compared to the relative structure and optical homogeneity of cortical and nuclear cataracts[27]. In this special case, there is a possible justification for the preferential utilization of ETDRS over Snellen chart.

The results we obtained in our research clearly indicated that in poorer VA, the ETDRS chart (modified or non-modified) was more discriminative and precise than Snellen chart. The ETDRS chart should find its place in prospective clinical trials. In everyday clinical practice, it is possible to predict results on ETRDS chart using regression analysis of the results obtained with Snellen chart. Furthermore, in accordance with the theory and analysis of the existing literature on the subject, it is also recommended to utilize ETDRS chart for medico-legal purpose, as well as for establishing decision-making standards on the appropriateness of certain medical procedures.

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Sažetak

JE LI TABLICA ETDRS BOLJA OD SNELLENOVE TABLICE U PROCJENI VIDNE OŠTRINE KOD OPERACIJE KATARAKTE?

S. Petrović Pajić, T. Petrović, M. Stojković i *S. Anđelić*

Cilj studije bio je procijeniti razlike vidne oštrine mjerene Snellenovom tablicom nasuprot tablici ETDRS, odrediti stupanj katarakte primjenom sustava LOCS III i usporediti vidnu oštrinu dobivenu pomoću oba optotipa ovisno o tipu i stupnju katarakte. Provedena je prospektivna procjena nekorigirane i najbolje korigirane vidne oštrine primjenom tablica Snellen i ETDRS prije i nakon operacije katarakte. Ova dvogodišnja studija izvedena je na Klinici za očne bolesti Kliničkog centra Srbije. Kriterije za uključivanje u studiju ispunilo je 540 bolesnika koji su podvrgnuti testiranju, operaciji, prikupljanju i analizi podataka. Srednja vrijednost zbroja vidne oštrine procijenjena tablicom ETDRS bila je bolja u usporedbi sa Snellenovom tablicom. Srednja vrijednost bila je 6,05 slova ili 1,21 linija. Rezultati vidne oštrine korelirali su sa svim tipovima katarakte bez obzira na tablicu koja se primijenila, s najvećom statističkom značajnošću (p<0,0001) za subkapsularnu kataraktu. Grafikon ETDRS pokazao se više diskriminativnim i preciznijim nego Snellenov, osobito za slabu vidnu oštrinu.

Ključne riječi: *Vidna oštrina; Tablica ETDRS; Snellenova tablica; LOCS III; Katarakta povezana s dobi*