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Refractions and reflections

Methods for the study of near, intermediate vision, and accommodation: an overview of subjective and objective approaches

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ARTICLE INFO

Article history:
Received 1 March 2018
Received in revised form 2 August 2018
Accepted 6 August 2018
Available online 3 September 2018
Joseph M. Miller,
Editor

Keywords
accommodation
near vision measurement

ABSTRACT

Purpose: To present an overview of contemporary methods and metrics used to measure near vision, intermediate vision, and accommodation.
Methods: A search in PubMed was performed with the following key phrases: near vision, intermediate vision, objective and subjective methods for the measurement of accommodation. For subjective methods, we included only those that are most widely used, had a scientific evidence of its outcomes, and have an easy availability at the doctor's office. For objective methods, we included those aberrometers or autorefractometers that have been proven to give good repeatability and reproducibility in the study of changes in optical power of the eye along the accommodative process.
Results: Near vision should be tested at 40 cm and intermediate vision at 63 or 80 cm. Accommodation should be measured with objective methods such as autorefractometers or aberrometers.

Financial support: This publication has been carried out in the framework of the Red Temática de Investigación Cooperativa en Salud (RETICS OFTARED), reference number RD16/0008/0012, financed by the Instituto Carlos III - General Subdirection of Networks and Cooperative Investigation Centers (R+D+I National Plan 2008-2011) and the European Regional Development Fund (Fondo europeo de desarrollo regional FEDER).
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0039-6257/$ – see front matter
https://doi.org/10.1016/j.survophthal.2018.08.003

intermediate vision measurement
reading charts
depth of field
objective methods
subjective methods

Conclusions: The standardization for the measurement of near and intermediate vision, as well as the reading charts, will facilitate the comparison of visual outcomes between studies. Measurement of accommodation should be performed with objective methods as subjective methods tend to overestimate the accommodative power.

1. Introduction

Reading is a daily activity that is affected by the development of presbyopia, an age-related condition characterized by loss of accommodation. This begins early in life and usually clinically manifests around the age of 40 years, with little effective accommodative functions remaining after the age of 55 years.[71]

Accommodation is a reflex increase in the dioptric power of the lens that allows focus from far to near. Objective measurements of accommodation are important to evaluate treatments such as accommodative intraocular lenses (IOLs) and scleral expansion techniques that claim to restore accommodation[7,46,72] and to determine the extent to which near-vision performance may be increased by mechanisms other than a real accommodative gain (pseudoaccommodation). Subjective tests of near- and intermediate-vision performance are more relevant to patient satisfaction, but there is no current agreed standard for methods used or test distances. Lack of standardization and confusion over the roles of objective tests of accommodation and subjective tests of visual function complicates study design and makes comparison between studies difficult.

We present a critical overview of contemporary methods and metrics used to measure near vision, intermediate vision, and accommodation, aiming to provide clinical practitioners and investigators studying accommodation, presbyopia, and presbyopia surgery with uniform, updated standard test protocols and guidance on the role of discretionary additional test methods.

2. Methods

The authors are a group created in June 2016 by the American-European Congress of Ophthalmic Surgery to standardize the metrics and evaluation methods for measuring near vision, intermediate vision, and accommodation. This work aimed to build an update 1988 International Council of Ophthalmology (ICO) standards.[18]

Test methods were categorized into subjective tests of near vision (20-40 cm) and intermediate vision (50-80 cm), depth of field (the range of viewing distances or dioptric powers over which visual acuity performance is maintained), and objective tests designed to measure accommodation function.

Commonly used test methods in these categories are described in the results section of our survey of the current literature, summarizing recommended applications and methodology for each test, together with a brief commentary in each section on the rationale for recommendations made.

3. Results

3.1. *Near vision*

Near visual function is tested in the range 20-40 cm. The simplest test of near vision is near visual acuity. This can be tested with single optotypes—standardized letters, numbers, or symbols—using charts identical in format to those used for distance vision testing but with optotype size reduced in direct proportion to the test distance. For tests of reading acuity, the ICO[18] recommends that near-vision charts are calibrated for testing at 40 cm. The test distance can then be decreased or increased as needed by the study design. In this case, corresponding distance corrections of the logMAR/RAD have to be incorporated. To facilitate the distance correction for logMAR/RAD, we recommend using a geometric (logarithmic) sequence of test distances.

Because reading difficulty is the most common complaint of patients with poor near vision,[60] and reading words and sentences correctly is a more complex task than reading single optotypes, a number of specialized reading charts have been developed presenting patients with words or sentences. More recent reading charts standardize elements such as word length, character count, sentence length, syntactic structure, and lexical complexity. These reading charts aim to standardize the visual task so that print size is the only significant variable from one level to the next. Reading charts can be used to measure near visual acuity and for functional measures such as mean reading speed, maximum reading speed (the maximum number of words per minute read at any print size) and critical print size (the smallest print size at which the maximum reading speed is maintained).

Functional tests of reading are influenced by cognition, neurological function, and retinal function; so, they are less relevant to the refractive surgery population and comparisons between presbyopia treatments than simple tests of near visual acuity.

3.2. *Recommendations for near visual acuity testing*

- Unit of measurement
  Reading acuity: Log_{10} of reading acuity determination (logRAD) is the reading equivalent of logMAR.
  Single optotype near acuity: Log_{10} of the minimum angle of resolution (logMAR)
- Equipment
  RADNER reading charts (Fig. 1) or optional single optotype near-vision charts produced in the format of the ETDRS distance acuity charts.
- Test Protocol
  Where near vision is being studied to compare depth of field between presbyopia treatments, patients should be tested

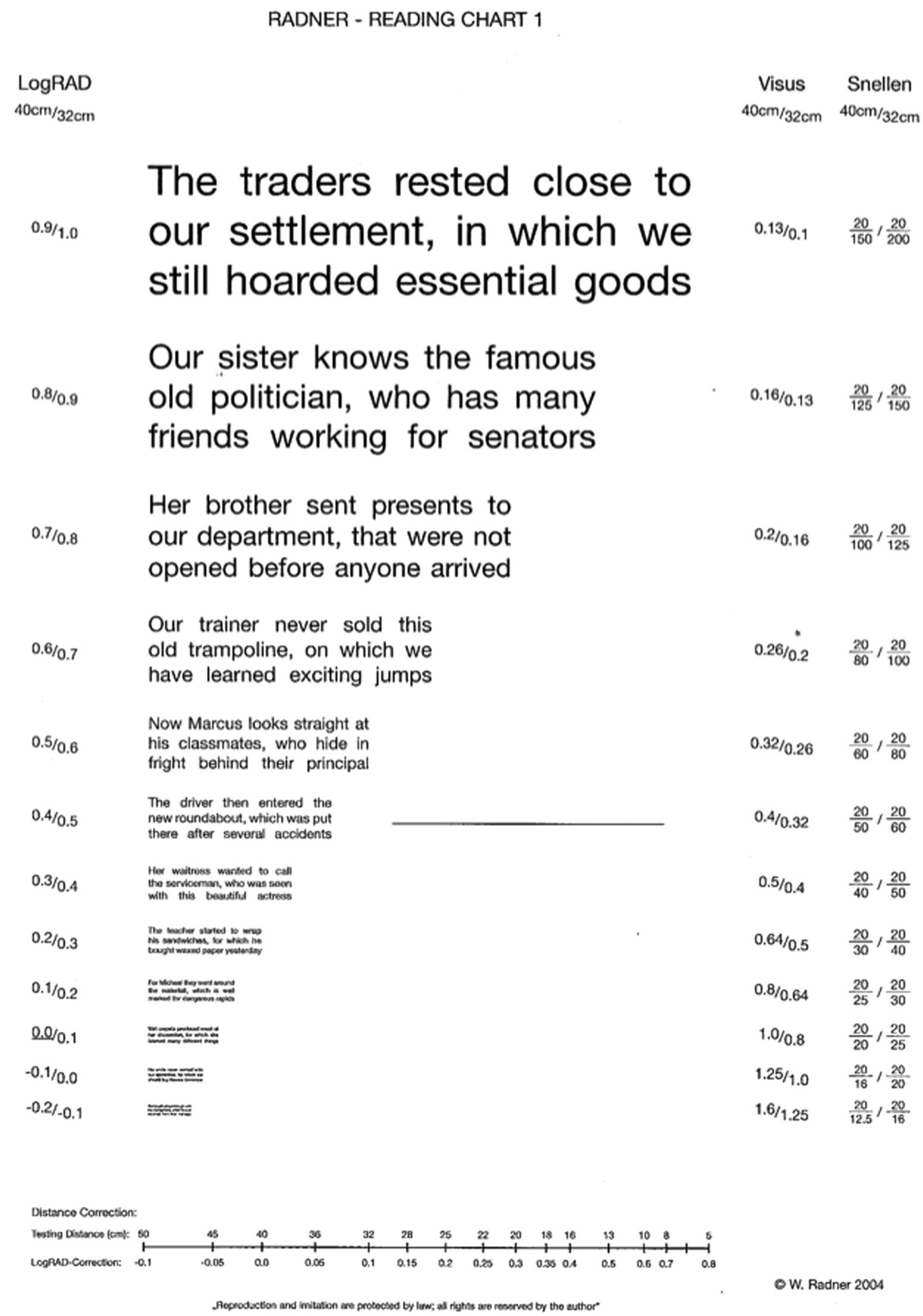

Fig. 1 – RADNER Reading Chart - English version.

wearing their full-distance spectacle correction. For studies of real-world function, particularly where the presbyopia treatment may influence accuracy of the subjective refraction end point, unaided near visual acuity testing may be more appropriate.

Reading acuity or near visual acuity should be tested binocularly unless specific features of the clinical trial design, for example, a contralateral eye study, suggest that monocular testing is relevant.

In standard office illumination (>500 lux), the test chart should be held at 40 cm from the eye (other distances such as e20 cm, 25 cm, and 32 cm are possible according to a specific study design).

3.2.1. Reading acuity tested with the RADNER reading charts

Reading parameters can be determined as given in the instructions in the reading charts. The luminance should be within 90 and 110 cd/m^2. The reading distance can be determined with a ruler or a 40-cm cord and should be verified during the test procedure. The participants are asked to read each sentence aloud as quickly and accurately as possible. They are further instructed to read to the end before correcting any reading errors. The reading acuity (logRAD) is given by the last paragraph read in $\leq$20 seconds (stop criterion).[54,56] For measuring reading speed, the reading time is measured with a stopwatch. Reading speed in words per minute (wpm) is calculated on the basis of the number of words and the time a patient needed to read a text to the end. Reading errors are noted. Errors are counted even when immediately corrected. The reading acuity score including reading errors can be calculated as given in the instructions. A stop criterion can be freely chosen with regard to the requirements of a particular study design. For the RADNER Reading Charts, a stop criterion of 20 seconds is suggested,[52,54,56] corresponding to a reading speed of about 40 wpm, which represents the higher limit of spot-reading.[70] The limit for fluent, sense-capturing reading was found to be at about 80 wpm[70]; however, to determine the threshold using 80 wpm would be too short for a stop criterion because 80 wpm represents a reading time of about 10 seconds per sentence for the RADNER Reading Charts (7 seconds for the MNread Charts) and rather represents the reading acuity close to the critical print size.[52]

Using a single optotype near-vision chart printed in the design of the ETDRS distance acuity charts, patients should be asked to start reading aloud at a level they can easily see. Then, the patients read until they read less than 3 letters correctly in a 5-letter line when at least 4 letters were read correctly in the previous line. When the patients stop, they should be asked once to also try the next line.

Scoring is then carried out either using a single-letter protocol, in which the total number of letters read correctly is converted to a LogMAR score, or a line-scoring protocol, in which the lowest line in which $\geq$3 letters are read correctly gives the logMAR score.[10]

Note that logRAD ($\log_{10}$ of the reading acuity determination) given on RADNER reading charts is the reading equivalent of logMAR and is mathematically calculated identically. Because reading acuity is a different visual task than single optotypes acuity, the LogRAD notation was introduced to distinguish reading acuity from single optotype tests.

Testing at a standardized distance simplifies comparison between studies and test scoring. Although complex conversion to logMAR/RAD scores is possible using standard 40-cm distance test charts to enable testing at the preferred reading distance for each patient, most presbyopia interventions aim for good reading vision at approximately 40 cm, and a preferred reading distance that departs significantly from this target may lead to greater spectacle dependence in the real world. For trials comparing presbyopia treatments, we therefore recommend the simplest approach, using the standard test distance of 40 cm.[18]

In 1988, the Visual Function Committee of the ICO[18] published the following standards for reading measurements:

- The print sizes of reading charts should progress exponentially in a geometric (logarithmic) sequence.
- Test conditions, optotypes, and chart design should be standardized.
- The test distance should be specified (40 cm recommended).
- Continuous text materials for reading charts should be used.
- The typeset material should be based on the distance at which the height of lowercase letters such as “o”, “m”, and “x” subtends five minutes of arc.

Building on these recommendations, the RADNER reading charts incorporate highly standardized sentence optotypes and paragraph structures to minimize the influence of factors such as comprehension and reading ability, which confound the evaluation of presbyopia interventions on test performance. Sentence optotypes equal in reading length and difficulty have the advantage that when reading slows down, it is caused by the print size rather than by the difficulty of the text.

The 1980 Bailey-Lovie Word Reading Chart uses unrelated words arranged in a geometric (logarithmic) progression of print sizes.[9] The MNread Near Acuity Chart incorporates sentences of 60 characters including spaces. Advantages of the RADNER charts are the higher accuracy of print sizes[50] and the availability in 12 different languages, including German,[54] Italian,[13] Spanish,[6] Dutch,[34] Portuguese,[58] Danish,[41] English,[53] Hungarian,[66] Swedish, Turkish, French, and Romanian.[52]

The history and development of reading test charts have been extensively described elsewhere.[52] Obsolete reading charts such as Parinaud, Nieden, Keeler, and Jaeger based on nonstandard letter sizes (N and J notation) are still widely used but do not progress geometrically (logarithmically) and do not yield useful comparative data because letter size may differ significantly between different editions of these charts at the same scoring level.[19,49,51,60]

3.2.2. *Other reading charts*

A comprehensive review article about reading charts in ophthalmology has been recently published [52] and gives a detailed overview about the backgrounds of modern, geometrically (logarithmically) progressing reading charts. In this publication, all developers of reading charts coauthored the chapter of their chart. In short, it can be explained as follows:

1. Bailey-Lovie Word Reading Chart
   This chart was created in 1980 by Bailey and Lovie, it uses unrelated words arranged in geometric (logarithmic) progression of size.[52] The notations given for a distance of 25 cm are the N-notation, logMAR, and M-units.[52]
2. MNread Acuity Chart (Precision Vision, Woostock, IL, USA)
   This chart was created for the evaluation of low-vision patients but can also be used for the evaluation of normal-sighted persons.[33] The sentences of the MNREAD tests are characterized by the number of characters (60 characters including spaces, with an implied period at the end of a sentence).[36] Based on a suggestion by Carver to define the difficulty level of a text,[42] these 60 characters are considered to represent 10 standard-length words of 6 letters, independent of the real word count. This assumption is used to calculate a reading-speed estimate.[36] The print sizes range from 1.3 logMAR (20/400) to −0.5 logMAR (20/6) in 0.1 logMAR intervals standardized to a 40-cm (16 inch) reading distance[62]; however, there is

evidence that the accuracy of print sizes is not as good as that of the Radner charts at relevant print sizes. They are available in several languages. The notations given on the charts for 40 cm are logMAR, Snellen, and M-units.[49]

3. Colenbrander Continuous Text Near Vision Cards (Precision Vision, Woodstock, IL, USA)
This chart covers decimal acuities for a test distance of 40 cm from 0.063 to 1.25 (1.2 to −0.1 logMAR). They also give the Snellen notation and M-units, but a logMAR notation is not given.[52] From decimal acuities ranging from 0.063 to 0.1, one sentence is presented per print size, and from a decimal acuity of 0.12 to higher acuities (decimal 1.25), two sentences are presented. The sentences have 44 characters and 9 to 11 words. No statistical data are available, and these cards have not been developed for reading-speed analyses. In addition, near acuity can just be measured down to a decimal acuity of 1.25 (logMAR −0.1) what will be not enough for research purposes and can cause ceiling effects. There is evidence that the print quality should be improved, and the accuracy of print sizes is considerably lower than that of the Radner charts.[51] These reading cards are available in high and low contrast and in 11 different languages.[49]

We recommend the use of the RADNER Reading Charts because there is evidence for a higher accuracy of print sizes.[51] In addition, the RADNER charts are available in 12 languages and have the best standardized test items (sentence optotypes).

3.3. *Intermediate vision*

Intermediate vision is tested in the range 50 to 100 cm, covering the zone of extended near activities including computer work, cooking, shopping, engaging in conversation, eating, controlling the car dashboard, or organizing a desk.

Recently developed IOLs, such as trifocal IOLs, accommodative IOLs, and extended depth of focus IOLs, have increasingly been designed to cover intermediate distances,[4,5,11,14,17,25,39,45,47,59,61] as well as the near visual range; but, comparison between studies is complicated by lack of standardization, with commonly used test distances for intermediate vision varying between 60 cm and 80 cm.[11,14,16,17,25,32,35,37,39,45,47,59,61,65]

Intermediate visual acuity can be investigated with standard (40 cm) reading charts with a scoring adjustment based on the modified viewing distance. This is achieved easily for test distances of 50 cm, 63 cm, and 80 cm by subtracting 0.1, 0.2, and 0.3 Log units, respectively, from the observed LogMAR or LogRAD.

3.4. *Overview for intermediate visual acuity testing*

- Unit of measurement
  Reading acuity: Log_{10} of reading acuity determination (logRAD)
  Single optotype chart: Log_{10} of the minimum angle of resolution (logMAR)
- Equipment
  RADNER reading charts or ETDRS optional single optotype near-vision charts produced in the format according to the ETDRS distance acuity charts.
- Test Protocol
  When intermediate and near visual acuity are being tested, the intermediate vision should be tested first. The test protocol is identical to that for near visual acuity testing but with a viewing distance of 63 cm.

The central debate in intermediate-vision testing revolves around the viewing distance used.[11,14,16,17,25,32,35,37,39,59,61,65] The choice may be based on the following conditions:

(a) the geometric (logarithmic) sequence that would be represented by 63 cm or 80 cm and would also be in accordance with the Weber-Fechner law[22,23,67] and visual acuity and reading charts[8,18,21,24,27,52];
(b) optical determinants, that is, the focal distance of diopters (1,5 dpt = 66.6666 cm periodic; 1,25 dpt = 80 cm)[35,65]; or
(c) other more empirical considerations (60 cm, 70 cm, 80 cm)[11,14,16,17,25,32,37,39,59,61]

In accordance with the Weber-Fechner law,[16,32,37] the ISO #3 standard R′10 preferred numbers,[45] and the standards for visual acuity measurements,[18,42] we suggest making use of the geometric (logarithmic) sequence for the test distances. Embracing the full spectrum of near- and intermediate-vision testing, the distance is 25 cm, 32 cm, 40 cm (standard reading distance), 50 cm, 63 cm (standard intermediate distance), 80 cm, and 100 cm—each test distance corresponding to 0.1 log unit score modifications. Of the choices within this range, standardizing the basic intermediate test distance at 63 cm helps make testing practical because 63 cm is within the reach of most patients to hold the test chart. Sixty-three centimeter also closely approximates the mean preferred screen-viewing distance for laptops and tablet devices[2] and the target intermediate focal distance for contemporary trifocal IOLs.[25,43]

Additional testing at 80 cm may be useful in some studies to compare performance in the central (63 cm) and far (80 cm) intermediate range. As with near-vision testing, contrast sensitivity tests,[48] visual acuity tests under varying light conditions,[16,32,55] and further psychophysical tests may also be used to explore intermediate visual function in greater depth.

Using a logarithmic sequence for test distance allows direct comparison of the logMAR/logRAD values obtained at various distances, such as reading acuity (40 cm), intermediate acuity (63 cm), and distance acuity (400 cm). For test distances outside the geometric (logarithmic) progression outlined previously, corrections are also possible, but they are more complex to perform.

3.4.1. *Examples*

3.4.1.1. *For geometrically (logarithmically) sequenced test distances.* Test distance, 63 cm: A patient achieves 0.4 logMAR/RAD on the logMAR/RAD scale for 40 cm. In this case, the logMAR/RAD for 40 cm has to be corrected for 63 cm by adding −0.2 (Table 1).

Calculation: 0.4 logMAR/RAD (for 40 cm) − 0.2 (adjustment for distance) = 0.2 logMAR/RAD (for 63 cm).

Table 1 – LogMAR/logRAD distance corrections

Test distance (logarithmic sequence)	logMAR/logRAD correction
25 cm	+0.2
32 cm	+0.1
40 cm	**0.0**
50 cm	−0.1
63 cm	−0.2
80 cm	−0.3
100 cm	−0.4

LogMAR, Log of the minimum angle of resolution; logRAD, Log of the reading acuity determination.
Bold values indicate standard reading distance.

3.4.1.2. *For test distances deviating from the geometric (logarithmic) sequence*. Test distance, 66 cm: The patient achieves 0.4 logMAR/RAD on the logMAR/RAD scale for 40 cm. In this case, the logMAR/RAD for 40 cm has to be corrected by −0.2 for two log-steps (63 cm) and additionally by −0.0202 for the deviation of 66 cm from the geometric (logarithmic) sequence (i.e., 63 cm). Calculation: 0.4 logMAR/RAD (for 40 cm) − 0.2 − 0.0202 = 0.1798 logMAR/RAD (for 66 cm).

For all intermediate test distances, we recommend that corrections for logMAR/RAD from 40-cm test charts should be clearly documented in the method section of publications for the test distance used.

3.5. *Depth of field*

Depth of field is a measure of the range of viewing distances or dioptric powers over which a clear focus is maintained. In comparisons between presbyopia treatments, functionally important basic information on depth of field can be obtained from comparisons of distance, intermediate and near visual acuities, where patients are wearing their full-distance spectacle correction. The range and sampling frequency over which depth of focus is examined can be extended using two commonly used tests: 1) Defocus curves, and 2) the push-up test.

3.6. *Recommendations for defocus curve testing*

- Units of measurement
  Defocus curves plot (D) power of dioptric additions/subtractions on the x-axis versus (LogMAR units) LogMAR distance visual acuity on the y-axis.
- Equipment
  Electronic screen–based EDTRS distance vision testing chart and standard equipment for subjective refraction.
- Test protocol[1,15,29,31]:
  Measurement of the defocus curve can be performed under monocular or binocular conditions by first providing the corrected distance visual acuity for the examined eye.[15,29,31] Additional lenses are then superimposed on the distance visual correction in 0.50D steps between +1.50D and +0.50D, then 0.25D steps between +0.50D and −0.50D, and 0.50D steps between −0.50D and −2.50D. For each dioptric addition, distance visual acuity is retested, randomizing letter presentation between steps to avoid memorization.[31]

3.7. *Recommendations for performing the push-up test*

- Units of measurement
  The push-up test measures the limit of the near focus range (cm) or 'near point'.
- Equipment
  EDTRS single optotype near-vision charts or RADNER reading charts.
- Test protocol
  The test is carried out monocularly, with the distance spectacle correction in place.[40,63] The patient is asked to look at an optotype in the range 0.00–0.20 logMAR at a distance of 40 cm. The chart is brought closer to the eye gradually (about 2-3 cm per second) until the patient sees the reading chart blurry.[20,38,44] The distance between the chart and the spectacle plane at this end point defines the subjective near point. The inverse of this distance is the depth of field in diopters (D).[28,38,40,44]

Although not essential in comparisons of presbyopia treatments, both these tests add supplementary information on the depth of field by testing the range proximal to 40 cm (the push-up test) and sampling points outside standard distances for near (40 cm), intermediate (63 cm) and distance (4 m) visual acuity testing (defocus curves).

The push-up test has the advantage of being relatively quick to perform but is generally more relevant to testing changes in accommodation function in relation to age than to clinical comparisons of presbyopia interventions. This is because patients with good uncorrected acuity at 40 cm are generally spectacle free for near-vision tasks regardless of their performance at closer viewing distances. Tables developed by Duane and Donders describe population mean near-point distances across age groups. Depth of field (accommodation amplitude for untreated eyes) in relation to age can also be estimated using Hofstetter's formulae:

- Average accommodation amplitude (AA mean) = 18.5 − 1/3 years.
- Minimum amplitude (AA minimum) = 15 − 1/4 years.[30,63]

The push-up test is vulnerable to error if the end point is not accurately recorded because even small errors in measurement can lead to large differences in results.

Defocus curves provide reliable and detailed information on the strong and weak points of focus for presbyopia interventions such as multifocal intraocular lens implantation, and dioptric powers on the x-axis can easily be expressed as viewing distances. Viewing a distant object through a −1.00 D add-on lens, positioned in the spectacle plane, is optically equivalent to viewing an object at 1 m. Similarly, viewing a distant object through a −4.00 D add-on lens is optically equivalent to viewing an object at 25 cm[15] (Fig. 2).

Test fatigue is an important consideration in pragmatic clinical trial design. An important drawback for examinations of the defocus curve is that they are time-consuming and can be a tedious test for both the examiner and the patient. We believe that the measurement of distance, intermediate, and near visual acuity, as described previously, is essential in trials of presbyopia interventions; additional tests of depth of field

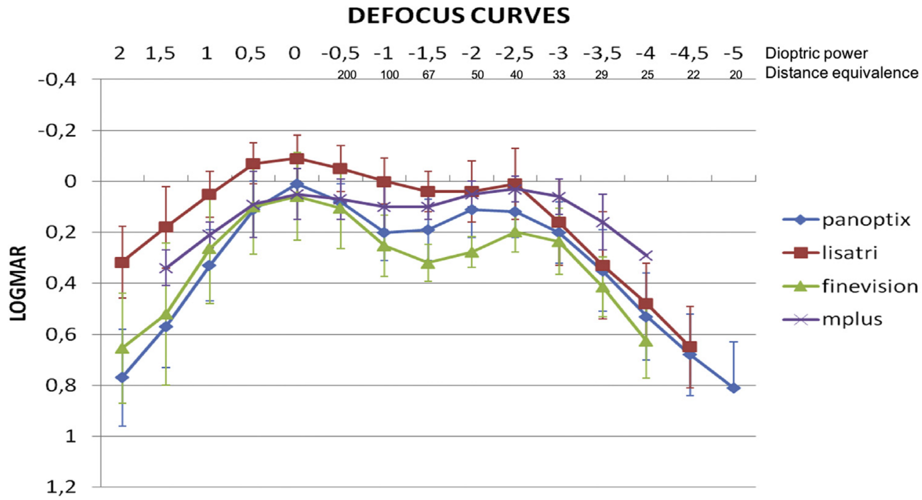

Fig. 2 – Defocus curve comparing four different types of multifocal intraocular lenses. The "x" axis shows the dioptric power with its distance equivalence in centimeters, and the "y" axis shows visual acuity achieved at each distance in LogMAR.

such as defocus curves and the push-up test are discretionary. Alternatives for providing supplementary information on depth of field that may have more real-world relevance include patient-reported outcome measures (PROMs). Most PROMs in refractive surgery include near-vision questions[60] and items relevant to intermediate vision. A dedicated, Rasch-weighted PROM for the evaluation of presbyopia interventions is now also available.[12]

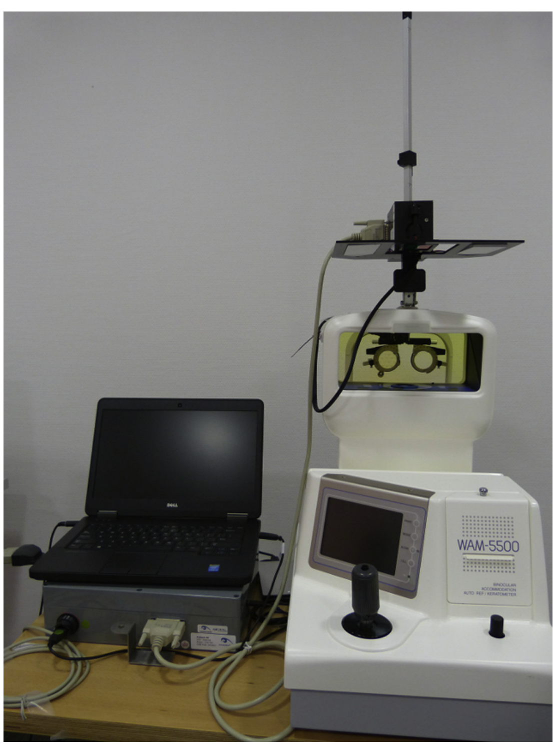

Fig. 3 – The WAM 5500 (Grand Seiko, Japan) autorefractometer.

3.8. *Accommodation*

None of the tests listed previously distinguish between true accommodation and other mechanisms for increasing the depth of field such as astigmatism, higher order aberrations, and pupil constriction or pin-hole optics (grouped together as pseudoaccommodation), multifocal refractive addition, diffraction, and binocular blur suppression (monovision variants). Monocular estimation method retinoscopy is the

Fig. 4 – The iTRACE (Tracey Technologies) aberrometer.

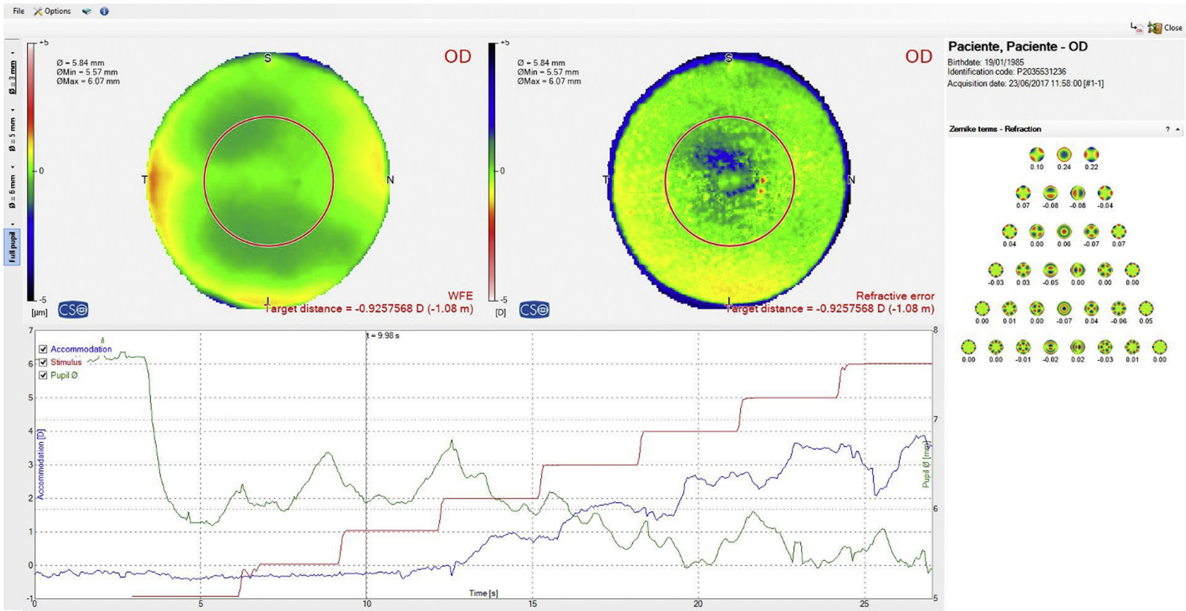

Fig. 5 – Data obtained with a pyramidal aberrometer (OSIRIS, Costruzione Strumenti Oftalmici, Italy) during accommodation. On the bottom of the image, the red line is the accommodative stimulus of the aberrometer, the blue line is the accommodative effort of the patient, and the green line is the pupil diameter. The changes on ocular aberrometry at each stimulus are displayed in Zernike polynomials. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

most widely used method for estimating the accommodative response at near working distances in clinical practice, but some contemporary autorefractors, aberrometers, and dynamic optical coherence tomography imaging devices may be more useful in quantifying the extent to which presbyopia interventions, such as accommodating IOLs and scleral expansion, actually use the mechanism claimed.

3.8.1. *Instruments for the measurement of accommodation*

For the objective measurement of accommodation, we can rely on optical and biometric test studies. Optical methods to measure accommodation include autorefractometers and aberrometers. Dynamic and static accommodation can be measured with validated autorefractometers such as the WAM 5500[64] (Grand Seiko, Japan) (Fig. 3) and the Power-Ref-II

Table 2 – Subjective and objective tests used for the measurement of accommodation

Test	Method	Pros	Cons	Validation
Defocus curve	Subjective	Nonexpensive; noninvasive; gives relative information about accommodation at different distances without using several tests.	Requires a good collaboration from the patient. Time-consuming test	Yes[27]
Push-up amplitude	Subjective	Nonexpensive; noninvasive fast and simple method to determine the amplitude of accommodation	Very dependent on the patients collaboration	Yes[32]
Monocular Estimation Method Retinoscopy	Objective	Nonexpensive; noninvasive; simple method for determining the accommodative response; it is used as an aid in the diagnosis of nonstrabismic disorders of binocular vision	Dependent on the examiner and on the patients' collaboration	Yes[38]
WAM 5500	Objective	Noninvasivel; binocular static and dynamic measurement; pupil measurement	Does not give the measurement with small pupils (<2.3 mm); distance refractive error has to be corrected with contact lenses.	Yes[69]
Power Ref-II	Objective	Static and dynamic measurement; binocular measurements; pupil measurements	Does not provide the possibility for individual calibrations	Yes[70]
iTrace	Objective	Noninvasive; good repeatability	Pupil detection may be a problem.	Yes[71]
Osiris	Objective	Dynamic pupil measurement; noninvasive; fast procedure	Lack of studies proving its repeatability	No

(Plusoptix AG, Nurnberg, Germany). Aberrometers such as the iTrace (Tracey Technologies) (Fig. 4), which has a ray-tracing technology, and the OSIRISs (Costruzione Strumenti Oftalmici, Italy) (Fig. 5), that is, a pyramidal wavefront sensor, provide the dioptric and aberrometric change during accommodation. All of them also measure changes in pupil diameter.

In static measurements 3, independent repeated measurements should be performed to calculate the mean and standard deviation due to the variation of accommodation at high-amplitude stimulus.[26]

The autorefractometers and aberrometers yield comparable results,[3,68,69] except for the Osiris which is a new optical system and has not undergone clinical trials (see Table 2 for a summary of the subjective and objective tests for accommodation).

Biometric changes during accommodation include change in anterior chamber depth, IOL thickness, or position (in accommodative IOLs), which can be measured with anterior segment optical coherence tomography, Scheimpflug photography, magnetic resonance imaging, ultrasound biomicroscopy, and partial coherence interferometry.[26,57]

Although the biometric changes and the objectively measured accommodative optical response are linearly correlated,[57] biometric methods should be used if we do not count on optical methods.[26]

3.9. *Summary*

In the preceding subsections, we have described a preferred protocol for near (40 cm) and intermediate (63 cm) visual acuity testing based on a comprehensive literature review and consensus discussion. Key elements are the use of standard near-vision testing charts based on logarithmic progression of both optotype size and test distances to allow easy gathering and interpretation of test data. We recommend that information on manifest refraction outcomes plus LogMAR/LogRAD unaided binocular distance, intermediate, and near vision should be included in all clinical trials of presbyopia interventions. Distance-corrected near and intermediate visual acuity can be used to provide additional information on depth of field for interventions independent of refractive outcome. Other discretionary tests that can add useful supplementary information on depth of field include defocus curves and the push-up test. Dedicated tests of accommodation function are required to discriminate between accommodation and pseudoaccommodation for interventions that claim to enhance depth of focus by true restoration of accommodative function. We suggest the use of optical tests rather than biometric tests for the objective measure of accommodation.

3.9.1. *Methods of literature search*

A search in PubMed was performed with no limitation in language with the following key phrases: 1) reading distance, 2) near distance, 3) intermediate distance, 4) reading chart, and 5) measurement of accommodation. Test methods identified were filtered by the level of evidence supporting their use, practicality, and availability in routine clinical practice. For subjective methods, we included only those that are most widely used, had a scientific evidence of its outcomes, and have an easy availability at the doctor's office. For objective methods, we included those aberrometers or autorefractometers that have been proven to give good repeatability and reproducibility in the study of changes in optical power of the eye along the accommodative process.

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