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Comparing methods of determining addition in presbyopes

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Background: The use of plus lenses to compensate for the reduction in the range of accommodation associated with presbyopia, brings the near point of accommodation to a comfortable distance for near visual tasks. Our aim was to compare the tentative near addition determined using the most common procedures with the final addition prescribed in presbyopic patients.
Methods: Sixty-nine healthy subjects with a mean age of 51.0 years (range 40 to 60 years) were studied. Tentative near additions were determined using seven different techniques: dynamic retinoscopy, amplitude of accommodation (AA), age-expected addition, binocular fused cross-cylinder with and without myopisation, near duochrome, and balance of negative and positive relative accommodation. The power of the addition was then refined to arrive at the final addition.
Results: The mean tentative near additions were higher than the final addition for every procedure except for the fused cross-cylinder without initial myopisation and age-expected addition methods. These biases were small in clinical terms (less than 0.25 D) with the exception of the AA procedure (0.34 D). The intervals between the 95% limits of agreement differed substantially and were always higher than ±0.50 D.
Conclusions: All the techniques used displayed similar behaviour and provided a tentative addition close to the final addition. Due to the wide agreement intervals observed, the likelihood of error is high and supports the idea that any tentative addition has to be adjusted according to the particular needs of each patient. Among the methods examined here, we would recommend the age-expected procedure, as this technique produced results that correlated best with the final addition.

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In healthy persons, the amplitude of accommodation (AA) diminishes gradually and consistently from the first years of life until an age of approximately 55 years. At this age, the AA is essentially considered to be zero and what is measured in clinical practice is the depth of focus.[1] When a patient's AA is insufficient for comfortable, clear vision at his/her normal working distance, the subject suffers from presbyopia.[2]

Presbyopia tends to manifest around the age of 40 to 45 years. The time of appearance and its expected progression will depend, among other factors, on the subject's habitual working distance, the distance refractive state, the visual needs of the individual and some other factors, such as, race, gender, illumination conditions, ambient temperature or geographic factors.[3–6] Plus lenses counteract the reduced range of accommodation associated with presbyopia by placing the near point of accommodation at a comfortable distance for near visual tasks. The advance of presbyopia is faster at the time of appearance, such that between the ages

of 40 and 50 years a mean increase of approximately 0.25 D occurs every two years, while the increase is much slower after the age of 50 years, around 0.25 D every eight years.[7]

The literature contains little information on the prevalence of presbyopia,[8] although it seems clear that in many countries, it is the leading visual defect and its incidence is increasing owing to a higher life expectancy, improved social/health conditions and to the consequent ageing of the population. Moreover, we should consider that the onset of presbyopia occurs at an extremely productive stage in life and that its inadequate correction will compromise a person's work performance with the economic losses this entails.[9] According to Hanlon, Nawakayashi and Shigezawa[10] an error in reading addition is one of the most common causes of patients' unhappiness with their new spectacles. For example, when the range of clear vision is not well determined, patients may complain that the new spectacles are fine for reading but that they are now unable to see a computer screen.

Determining the addition required by a presbyope in optometric terms is a simple procedure. Normally, a tentative addition is established first and this is then adjusted to obtain the final addition.[11] In the final adjustment, the physical characteristics and needs of the patient are taken into account. It is also important to consider the previous near addition and patient symptoms when working with someone who has previously worn a near addition. Several techniques have been described to establish a tentative addition,[2] some of which are based on the different procedures designed to measure the amplitude of accommodation.[12] Most clinicians select one or two of these procedures for routine use depending on their personal preferences. We feel it would be more reasonable to use the method that provides the tentative addition closest to the final addition. Indeed, this would accelerate the entire evaluation process.

We found no general consensus in the literature concerning the most appropriate methods to determine the tentative addition in a presbyopic patient.

This study was designed to compare final addition values with the tentative additions obtained using dynamic retinoscopy, amplitude of accommodation, age expected addition, fused cross cylinder without initial myopisation, fused cross cylinder with initial myopisation, near duochrome and the negative relative accommodation/positive relative accommodation (NRA/PRA) balance.

METHODS

Study population

The study population comprised the first 69 consecutive patients (40 women, 29 men) attending our clinic who satisfied the inclusion criteria and gave their consent to participate after the nature of the study had been fully explained to them. The study protocol fulfilled the tenets of the Declaration of Helsinki. The age range of the subjects was 40 to 60 years (mean: 51.0 ± 5.3 years). The spherical refractive error ranged from -6.50 to +8.00 D with up to -2.25 D of astigmatism.

The inclusion criteria were:

1. aged 40 to 60 years and required addition
2. corrected monocular visual acuity (VA) greater than or equal to 6/7.5 at distance and near
3. anisometropy less than 2.00 D
4. no binocular problems
5. no history of refractive surgery, strabismus or amblyopia
6. no manifest or latent nystagmus
7. no ocular pathology
8. no systemic disease that could affect accommodation, fusional vergences and/or ocular motility
9. no medication likely to have side-effects on accommodation and/or on fusional vergences.

Data collection

Age, gender and the visual history were documented for each subject. The optometric characteristics of each subject were determined by examination including habitual correction, refraction and tests of binocular vision. Subjective refraction was established using monocular refraction followed by binocular balancing, with Snellen optotypes presented at six metres. The subjective refractions were conducted to maximise the amount of positive sphere without compromising distance visual acuity. Astigmatism was adjusted using the Jackson cross-cylinder.[11] The binocular vision tests performed were horizontal phoria using the modified Thorington technique, near point of convergence and stereopsis with the TNO test.

TENTATIVE ADDITION

All the procedures used to determine tentative addition were performed in random order, except the dynamic retinoscopy, which was always undertaken first to avoid the results of the subjective tests influencing this objective procedure. In cases in which the tentative addition was found to be less or equal to zero, the test result was recorded as 0.00 D.

The final addition for a 40 cm working distance was established for each patient by adjusting the tentative addition obtained using one of the seven methods selected at random.

DYNAMIC RETINOSCOPY

In this procedure, the best distance correction was placed on the phoropter and the patient was instructed to try to keep clear a line of optotypes of VA 0.8 presented at 40 cm. The retinoscopy was conducted at this distance, adding plus lenses in front of the patient's eye until the neutral point was seen. The mean of the added plus lenses to the RE and LE was taken as the tentative addition.

AMPLITUDE OF ACCOMMODATION

This procedure assumes that the prescription of addition should not use more than one-half to two-thirds of the total amplitude.[2,11,13] In our study, the working distance was 40 cm, so the tentative addition value was calculated as 2.50 D -2/3(AA), where AA is the mean amplitude of accommodation between both eyes. To measure the AA, we used a modification of the minus lens to blur method.[12] The subject was instructed to look at a line of optotypes (VA of 0.8), placed at six metres, while the accommodative demand was

Age	Addition power
40–42	+0.75
43–45	+1.00
46–47	+1.25
48–50	+1.50
51–52	+1.75
53–55	+2.00
56–57	+2.25
58–60	+2.50

Table 1. Age expected addition

increased using minus lenses in 0.25 D steps, until it was impossible to clearly view the optotype by making a conscious accommodative effort.

AGE-EXPECTED ADDITION

Several authors have prepared tables indicating the correlation between age and reading addition. We used a modified version of the table proposed by Pointer[4] (Table 1) because Pointer's table is more recent than other consulted tables[2,3,14,15] and the recommended additions are closer to our own clinical experience.

FUSED CROSS CYLINDER

This method was used to establish the point of accommodation for a 40 cm working distance, adding plus lenses until the horizontal and vertical lines on the cross cylinder grid subjectively appeared equally clear. Two variations of this technique were explored.

With myopisation

A +3.00 D lens was added binocularly to the distance correction of the patient such that the individual could see the vertical lines more sharply. This addition was then decreased binocularly in 0.25 D steps until both the vertical and horizontal lines appeared equally clear.

Without myopisation

With the distance correction placed in the phoropter, the subject was instructed to identify which lines appeared most sharp. If the horizontal lines were considered to be clearer, which is usually the case in presbyopes, plus lenses were added binocularly in 0.25 D steps until equality was reached between the two. The power of the plus lenses added was taken as the tentative addition. In subjects who initially appreciated the vertical lines or both more clearly, the addition was recorded as zero.

NEAR DUOCHROME SUBJECTIVE PREFERENCE

A card with Landolt's C (VA of 0.8 optotypes) on a red and green background was presented at 40 cm. The duochrome test is based on the natural chromatic aberration of the eye and it can be used for determining the spherical components for distance and near. When an ametropic eye is out of focus for distance, a red monochromatic target is seen clearer in myopia and a green target in hyperopia. For presbyopic patients, both red and green will focus behind the retina. Because the red light will focus further behind the retina than the green light, the presbyopic patient will see the letters on the green background as clearer. Then, plus lenses are added until the letters on the red background become as clear as on the green.[2] The tentative addition is the plus lens that, binocularly added to the patient's distance refraction, provided a similarly sharp image on both coloured backgrounds.

NRA/PRA

The tentative addition was determined as the lens that placed the accommodative demand in the middle of the range of relative accommodation (NRA-PRA/2). Total relative accommodation was determined by finding the range between the least plus (PRA) and most plus (NRA).

Data analysis

Once the data had been collected for the entire study population, they were analysed using the Analyse-it program for Microsoft Excel (Leeds, UK. See http://www.analyse-it.com) statistics program.

The level of agreement between the different tentative addition tests and the prescribed addition, or reference addition, was estimated using the Bland-Altman method.[16,17] From a clinical perspective, the advantage of this method is that the agreement of the tests is expressed in the same units of measurement as the test itself and allows clinicians to establish their own criteria for whether a difference is significant.

The factors determined were the mean difference (bias), the standard deviation (SD), the coefficient of agreement (COA = 1.96 x SD) and the limits of agreement at the 95% level (bias ± COA). The t-test for paired samples was also used to establish the significance of the differences. The level of significance was set at $p < 0.05$.

RESULTS

Table 2 provides data on the level of agreement between each of the tests used to determine tentative addition in presbyopes and the final addition. The mean differences between tentative and final additions were generally low (less than 0.13 D), with the exception of the tentative values rendered by the dynamic retinoscopy (bias = 0.19 D) and the amplitude of accommodation procedure (bias = 0.34 D). Notwithstanding, the coefficients of agreement are moderately high in clinical terms, as they always exceeded ±0.50 D. The extreme case was the tentative addition obtained by measuring the AA with minus lenses at distance, for which the COA was ±1.02 D.

Figure 1 shows plots for each subject of the difference between the tentative addition (AdT) and the final addition (AdF), namely, [AdF - AdT] versus the mean of the two additions. The lines at U and L, respectively, show the upper and the lower 95% limits of agreement. The same scales are used in all figures to aid the visual comparison of biases and agreement intervals.

DISCUSSION

Determining the addition in the presbyope is an essential clinical test for evaluating patients over the age of 35 to 40 years. The results of these tests are usually refined according to the subject's prefer-

	BIAS (D)	p (test-t)	COA (D)
AA L vs. AdF	-0.34 (AA L > AdF)	0.0001	±1.02
AGE vs. AdF	+0.007 (AdF > AGE)	0.8	±0.52
RA vs. AdF	-0.07 (RA > AdF)	0.04	±0.53
RET vs. AdF	-0.19 (RET > AdF)	0.0007	±0.86
BICHR vs. AdF	-0.13 (BICHR > AdF)	0.0004	±0.55
FCC WITHOUT vs. AdF	+0.13 (AdF > FCC WITHOUT)	0.003	±0.66
FCC WITH vs. AdF	-0.02 (FCC WITH > AdF)	0.6	±0.57

AdF = final addition
COA = Coefficient of agreement (1.96 x standard deviation)
Tentative add: AA L = one-half amplitude accommodation with minus lenses
AGE = based on patient age
AR = balance of negative and positive relative accommodation
RET = dynamic retinoscopy
BICHR = near duochrome
FCC WITH/WITHOUT = binocular fused cross-cylinder with or without initial myopisation

Table 2. Agreement between tentative and final addition

ence in terms of image clarity and a comfortable near task distance. This procedure is the reference or gold standard for establishing additions in presbyopes. The refinement stage will be shorter and easier if the tentative addition is determined as precisely as possible. In this study, our aim was to establish the level of agreement between tentative additions determined by several methods and the final addition.

Our results indicate that the mean differences between tentative and final additions were low for all the tests examined (less than 0.25 D), with the exception of the tentative values rendered by the amplitude of accommodation procedure (bias = 0.34 D). Despite these differences being significant in many cases, they are clinically of little consequence, indicating that any of the methods used could provide an appropriate result on which to base the final adjustment. The agreement intervals ranged from ±0.50 D to ±0.75 D in five of the tests and were as high as ±0.86 D for the dynamic retinoscopy method and ±1.02 D for the AA method using minus lenses at distance. This means that the tentative addition provided by the AA method could be up to 1.02 D higher or lower than the final addition prescribed to the patient.

Several possible factors could explain the wide agreement intervals observed here for the tests examined. The different methods used to determine tentative addition based on objective or subjective tests show low reliability. Indeed, this characteristic is true of many optometric tests.[18–24] In particular, one would expect an especially low reliability when calculating addition power via the AA, due to the low AA range of the presbyope. This could explain why the COA for this method was the highest (±1.02 D). In addition, the absence of accommodative convergence when performing monocular tests to measure AA could underestimate the accommodative effectiveness of the visual system in binocular conditions when comparing with another binocular method to obtain a tentative addition. We chose the distance minus lens to blur method[12] versus the near or the push-up technique because to measure AA in near vision, many presbyopic patients need a plus addition to see the target. This addition has to be considered when calculating the amount of AA and it could provide a less accurate value.

The dynamic retinoscopy method is partly subjective, in that it depends on both the examiner and the co-operation of the patient, who needs to make a conscious effort to keep the test image clear. It yields highly variable results among subjects and thus reduces the reliability of the tentative addition.

Several other factors, which relate to the conditions of each test and the particular characteristics of each subject (visual needs, work habits, previous prescription et cetera), could contribute to the low agreement detected. In particular, the additions established by the age-based method reveal that subjects of similar age may require different additions depending on their degree of ametropia, although these differences diminish after the age of 44 years.[25]

It is difficult to compare our results with those of other authors, as there are few investigations in which tentative and final additions are compared. Hanlon, Nawakayashi and Shigezawa[10] compared four procedures for establishing addition in terms of the percentage of errors. These authors reported that tentative additions based on binocular cross cylinder, NRA/PRA and AA measured by the push-up procedure tended to overestimate the final addition, while the age-expected addition was closer to the definitive addition. Similarly, our findings indicate that the tentative addition determined from age-expected table was closest to the definitive addition and the AA method with minus lenses overestimated the final addition ($p = 0.0001$).

Likewise, the NRA/PRA based addition is higher than the final addition ($p = 0.04$), the cross cylinder without myopisation method underestimated the addition ($p = 0.003$). There are several methodological differences between our study and that of Hanlon, Nawakayashi and Shigezawa[10] that could explain the discrepancies observed. We opted for measuring the AA at distance with minus lenses.[12] We consider that this variation to the generally accepted method is more appropriate for the presbyopic patient, as it avoids the need to add plus lenses to achieve a clear starting image. Moreover, in our study the tentative addition with this method was calculated as two-thirds of the total AA, whereas Hanlon, Nawakayashi and Shigezawa[10] considered one half of AA.

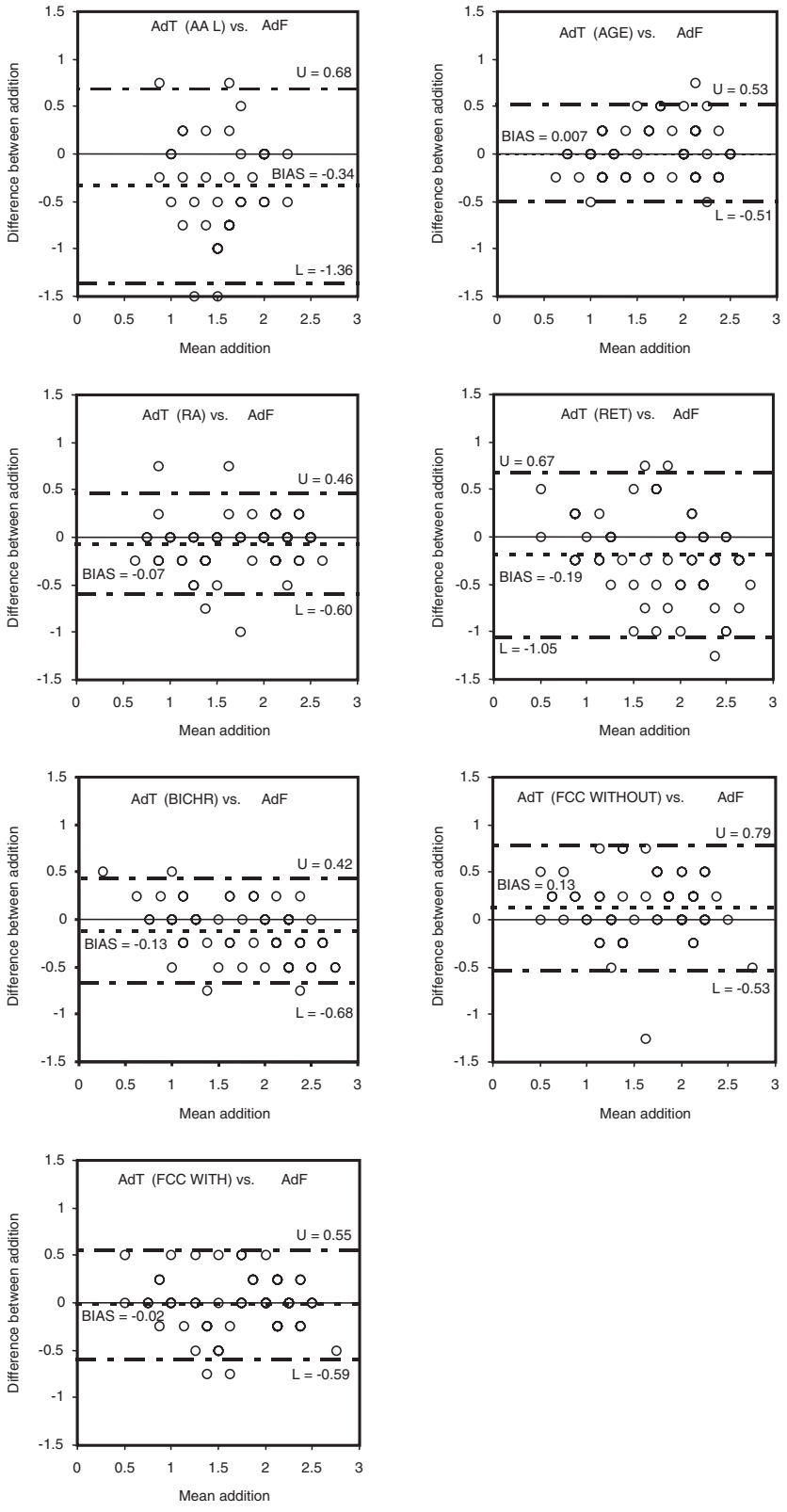

Figure 1. Plots for each subject of the difference between the tentative addition and the final addition (AdF - AdT) against the mean of both. The lines at U and L, respectively, indicate the upper and lower 95% limits of agreement.

Whitefoot and Charlan[26] compared the addition required at 33 cm determined by dynamic retinoscopy with the additions established from AA measurements, the duochrome test and subjective preference. These authors concluded that dynamic retinoscopy has limited value for indicating the appropriate near addition, as it significantly overestimates this value, which is confirmed by our results. They also concluded that using the age-expected addition as the tentative power is as effective as conducting a dynamic retinoscopy to obtain the estimate. These authors did not compare the level of agreement of these tests with the final addition yet they did demonstrate that the typical differences between dynamic retinoscopy-determined additions and the final additions are high, suggesting low agreement between the two values, as we also established here.

Over the years, numerous methods have been used to determine the power of the reading addition, often yielding different results. Our findings suggest that all the studied techniques displayed similar behaviour and provided a tentative addition close to the final addition. The method that provided the result closest to the final addition power was the age-expected AA procedure. This test showed the narrowest agreement interval and the least bias. Because all tests were similar in accuracy for the tentative addition, other aspects, such as ease of application and time taken, will affect the choice of method. The age-expected addition method for assessing the tentative addition is an easy and effective test and it takes no time.

Finally, the wide agreements detected here suggest that every tentative addition should be adjusted according to the particular needs of the patient.

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