Comparison of PD measuring devices

Part 1

Dr Wolfgang Wesemann investigates the accuracy of measurement and usage characteristics of four video centration devices and four pupillometers in a comparative study

Eye care practitioners' main activities include eye refraction and subsequent selection, mounting and dispensing of spectacles. For a pair of spectacles, the lens power and centration need to be correct. Centration errors may cause asthenopic problems, degrade the quality of stereoscopic vision and reduce the usable zones of progressive addition lenses.

Due to the increasing success of so-called 'personalised progressive addition lenses', accurate lens centration continues to gain in importance. Pupillary distance measurement alone is no longer sufficient. Additional fitting parameters such as back vertex distance, frame wrap angle and pantoscopic angle, need to be determined and specified for the lens order. Without precise knowledge of these parameters, it is not possible to compute personalised progressive lenses.

In a paper published in 1997, Wesemann *et al* presented information on the accuracy of measurement obtainable with a PD-ruler, pupillometer and the only video centration device which was commercially available at that time. Recently, however, several other companies have introduced video-based centration systems capable of measuring pupillary distance and all other relevant centration parameters.

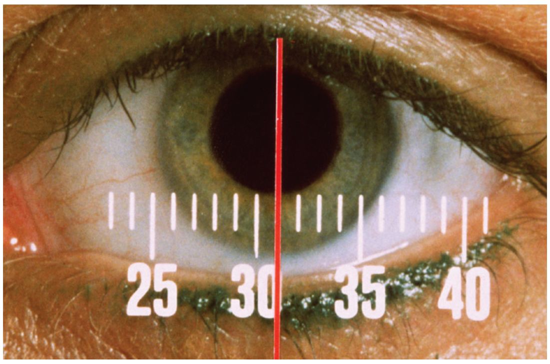
How user-friendly and how accurate are these new devices? This article study tries to answer these questions.

Devices

Four video centration systems were tested in this study:

- Essilor: 'Visioffice'
- Rodenstock: 'ImpressionIST'
- Ollendorf: 'Visureal'
- Zeiss: 'Remote Vision Terminal (RVT)'.

These four instruments provide a representative sample of all devices currently available on the market. It is important to note, however, that several other video centration devices are technically less advanced, as they are pure PD measurement devices and incapable of measuring additional centration parameters.



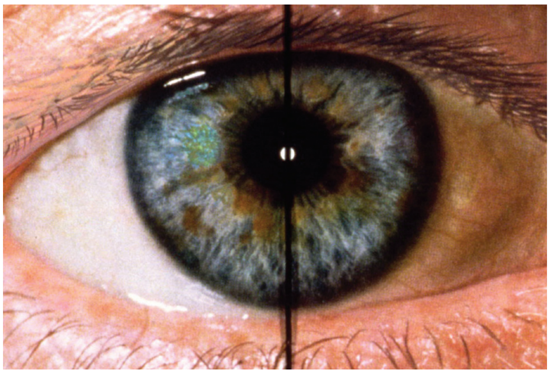


Figure 1 Centration according to the pupil centre (left) and corneal reflex method (right)

The video centration devices were compared to four state-of-the-art digital pupillometers that were purchased for the study.

- BON: PD-2
- Essilor: Digital CRP
- Rodenstock: Pm-100
- Topcon: PD-5.

All manufacturers were aware that their devices would be used within a comparative study.

Differences in measurement philosophies

Use of one or two cameras

The first technically 'mature' video centration system, ie Video Infral from Zeiss, used sophisticated technology including two cameras. One camera directly 'looked' at the subject's face, whereas the other simultaneously captured a side-on image using a mirror. Today, this 'two camera principle' including subsequent 3D analysis is only used by Rodenstock's ImpressionIST. All the other video centration systems use only one camera and capture two images one after the other.

Horizontal centration based on pupil centre or corneal reflex

There is no consensus among manufacturers on the best measurement technique. Some manufacturers demand that the device's hairline must coincide with the 'corneal reflex', whereas others require the hairline to be aligned with the pupil centre.

This causes an undesired problem, since the PD measured according to the corneal reflex method is on average 0.5mm smaller than the PD value measured according to the pupil centre method (Wesemann *et al*, 1997). With most people the corneal reflex is slightly shifted towards the nasal side relative to the pupil centre. The shift of the pupillary reflex relative to the pupil centre, however, is not a 'constant', but shows interpersonal variances. Today, it is still under discussion which centration method works better. If one looks at the image formation inside the human eye on a purely geometric-optical basis, the pupil centre method seems more appropriate. It must be noted, however, that the position of the pupil centre is not constant. This was investigated by Yang *et al* (2002). They found that the pupil centre normally undergoes temporal shifts, as the pupil diameter increases. This is due to the fact that the eye's iris opens asymmetrically. In most patients, spatial shift of pupil centre was smaller than 0.3mm per eye. One patient showed a 0.6mm shift per eye. In other studies dealing with the same topic, even greater shifts were observed.

The corneal reflex is independent of the pupil size and is always located at the same position. This is an advantage. Another advantage lies in its easier localisability. In most cases, Essilor's video centration system managed to localise the exact position of the corneal reflex in a fully automated manner.

If certain effects such as the Stiles Crawford effect of the first kind, are taken into account, the corneal reflex method may be underpinned by arguments from sensory-physiological findings. The issue of finding the ideal pupillary PD measurement method was addressed in a theoretical analysis published by Wesemann in 1996.

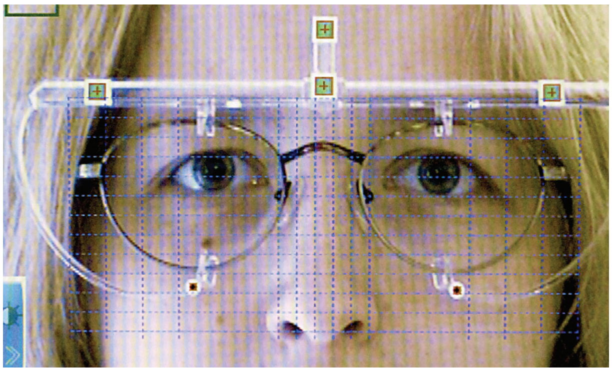


Figure 2 Screenshot of Essilor's Visioffice during measurement. The figure depicts the automatically detected red crosses on the green squares of the clip

Figure 3 Screenshot of Rodenstock's ImpressionIST during positioning of the patient. The figure shows the patient's face captured from the front as well as from below and the side

Vertical centration based on pupil centre or lower pupil margin

Different measurement philosophies also exist in vertical centration. On three devices (Visioffice, ImpressionIST and RVT), the fitting point height is calculated according to the so-called 'zero gaze direction' in distance vision. These three manufacturers assume that the fitting cross of the spectacle lens has to be centred exactly in front of the pupil centre when the wearer looks straight ahead with horizontal fixation lines.

Ollendorf's Visureal provides a somewhat smaller fitting point height in the preset mode. According to the manufacturer's specification, the calculated fitting point height corresponds to a downward gaze angle of exactly 2.25°. It is computed from the measured fitting point height by taking the vertex distance into account. This value corresponds to a 'centration relative to the lower pupil margin'. Another vertical centration method based on the 'principal gaze direction in distance vision' is also used by opticians. It corresponds to a significantly stronger downward head movement and gaze direction. Assuming that the patient's eyes are at 1.76m above floor level with the patient looking at the floor at a distance of 10m, a 10° downward head movement and gaze is required. The difference between both methods is approximately 1.1mm on average.

Practical use

Essilor Visioffice

Essilor's video centration system is very easy to use. Two video recordings are made with the patient looking straight ahead and with the head rotated 20° to the right. Analysing the video image is mere child's play. The computer automatically detects the patient's corneal reflexes as well as the green markers (squares) on the clip and the frame's horizontal line. The automatic detection of clip markers and corneal reflexes is done under real-time conditions in a highly reliable manner. In very rare instances, the markers detecting the patient's corneal reflex had to be readjusted manually. The examiner's task mainly consisted of explaining the measuring principle to the subject and aligning the rectangular measuring lines with the frame rims.

Although quite unusual, the patient is asked to actively cooperate during measurement. When looking straight ahead as well as in the lateral head position direction, the patient needs to move his head slowly from left to right and right to left. During the movement, they must constantly look in the mirror at the reflection of their nose. This task has to be carefully explained before starting the measurement. Without providing detailed instructions, the measurement process will not work properly. Our subjects, however, quickly understood what was expected.

Rodenstock ImpressionIST

The ImpressionIST is the only video centration system that captures two images with two cameras simultaneously. One camera looks at the face from the front and the other from below and the side. This is an advantage, as the patient needs to be properly positioned only once.

In order to position the subject properly, Rodenstock provides a carpet into which a line is woven that specifies the proper position of the subject's feet. Positioning the patient is relatively easy. The camera, however, does not have an autofocus system, but is set to a fixed distance.

The camera's 'direction of gaze' is also pre-adjusted. Therefore, the position of patients with large and small size shoes needed to be readjusted, to get a sharp picture of the patient's eyes on the monitor. Two light bars illuminating the patient produce very bright light and stay continuously lit. In some cases, these lights were perceived as dazzling. In the most recent version of the ImpressionIST, however, this problem has been solved thanks to the use of flash lighting.

Analysing the image via a touch-sensitive monitor is somewhat arduous. First, the corresponding part of the picture is magnified on screen. Then, the centration circle and each measuring line need to be adjusted in all directions on a step-by-step basis using a special adjustment pin. Therefore, Rodenstock's ImpressionIST required more time than the other centration systems.

Ollendorf Visureal

Ollendorf's Visureal offers the best image quality of all tested systems. Even fine details of the subject's eyes and spectacle frame are sharply rendered. Especially worth mentioning is the fact that this is achieved without using additional lighting. What is more, the patient is not bothered by continuous bright light or flash light.

Before starting the measuring process, a clip must be placed onto the spectacle frame. The clip design is very delicate compared to the clips used by Zeiss and Essilor. It is attached to the upper rim of the frame by means of two hooks and rests on the lower rim thanks to two perpendicular struts. This construction significantly reduces the clip's weight; however the advantage of such 'light-weight construction' is achieved at the expense of missing clamp holders. As a consequence, the clip dropped down several times during our measurements and had to be repositioned.

Taking side-on pictures with Ollendorf's Visureal is simplified with a remote-controlled motor providing a lateral adjustment for the camera. This is of high practical use where the patient is not exactly standing in a central position. Deviations can be easily compensated for by rotating the camera accordingly.

When taking side-on images, head position is somewhat critical. The clip should not be visible on the camera picture, ie neither obliquely from the front side nor obliquely from the rear ▶

side. In some cases, it was necessary to fine-tune the patient's position until the proper turn was achieved.

In addition, the version under test posed some 'challenges' in determining the frame wrap angle. To measure the wrap angle, a small additional clip had to be mounted onto the centration clip. In some cases, the additional clip underwent an unintended rotation. As a result, negative frame wrap angles were displayed. In these cases, the whole measurement had to be repeated. The manufacturer has presented an improved version of the measuring clip that hopefully solves the problem.

Zeiss Remote Vision Terminal

The Remote Vision Terminal from Zeiss is very easy to use. After the instument's height has been properly set, the patient looks at a flickering red fixation light (a laser speckle pattern) that does not stimulate accommodation according to the manufacturer. The patient stands at a short distance (70-150cm) away from the device. Within this range, distance can be selected as needed. The camera automatically focuses on their face.

At the start of our measurements, we often had problems with focusing. Contrast-rich objects located at a distance of 4.5m behind the patient irritated the autofocus system. We solved the problem by installing a separating wall (made of single-colour cardboard material) behind the patient. This restored the autofocus system's proper functioning.

Taking 90° side-on images was found to be more difficult with RVT than with Ollendorf's Visureal, because the patient is required to position himself at a specified place. The device requires that the patient's eye, the frame and the measurement clip are visible within a small, restricted area on the monitor. minor changes in the patient's posture (forward or backward movements) resulted in the patient's eye or the measuring clip being outside of the required area on the screen. Then, the patient had to be adjusted a second time and another picture had to be taken.

Data analysis is facilitated by the fact that the computer automatically tries to detect the patient's pupils and then aligns the fitting crosses with the pupil centre. For blue-eyed patients, automatic pupil detection works fairly well. Problems arise, however, with dark-eyed subjects. In two cases, the computer inadvertently placed the fitting crosses onto the rivet of a frame, producing a particularly strong light reflection. In some cases, automatic pre-centration was not possible.

Digital pupillometers

All digital pupillometers are manufactured outside of Europe. The PD-2 distributed by BON originates from Argentina-based 3B Optical Instruments Corporation, Essilor's Digital CRP is made in China. The two remaining devices (PM-100 from Rodenstock and PD-5 from Topcon) originate from Towa, a Japanese company. The two last-mentioned devices are of seemingly identical construction. Differences in design relate to the products' 'outer' aspects only. Interestingly, the sales price of the two pupillometers is very different.

Handling of all devices was found to be very simple. All are equipped with a 'paddle', allowing one eye to be occluded when needed. Reading of right/left PD values is done from a digital scale graduated in 0.5mm increments.

The price of video centration systems and pupillometers differs considerably. Video centration systems cost more than €5,000. In contrast, conventional pupillometers are priced below €500.

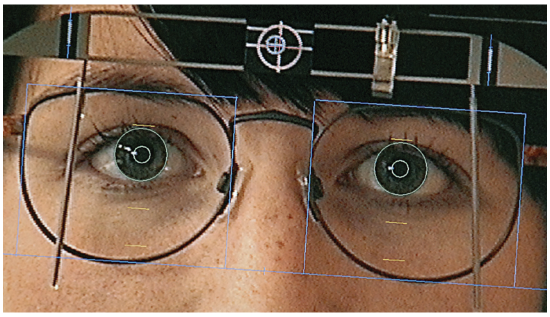


Figure 4 Screenshot of Ollendorf's Visureal during analysis The figure depicts the clip fitted onto the frame. It also illustrates the adjusting markers for the patient's pupils and boxing system

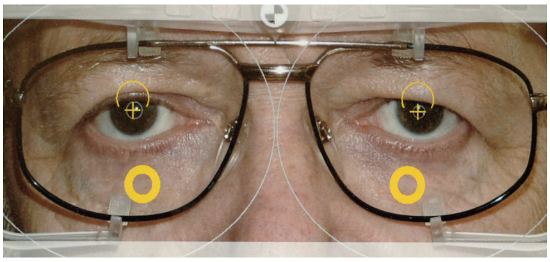


Figure 5 Screenshot taken from the RV Terminal (Zeiss RVT) during analysis

Additional functionalities of video-based centration systems

All four video centration systems offer further options, such as comprehensive eyewear consultation using frame/lens consultation modules. Practitioners can demonstrate the benefits inherent in various lenses. Video clips highlighting the respective product benefits can be presented to patients. Also, websites dedicated to ophthalmic and optometric contents may be accessed. However, these features have not been compared.

Handling problems

In most cases, measuring was easy, except in relation to a few things.

Problems associated with 90° side-on images

Two digital images are taken with the Visureal and RVT system, ie a front view and a picture with the patient's face turned through 90°. For both devices, it was found that (in the absence of further

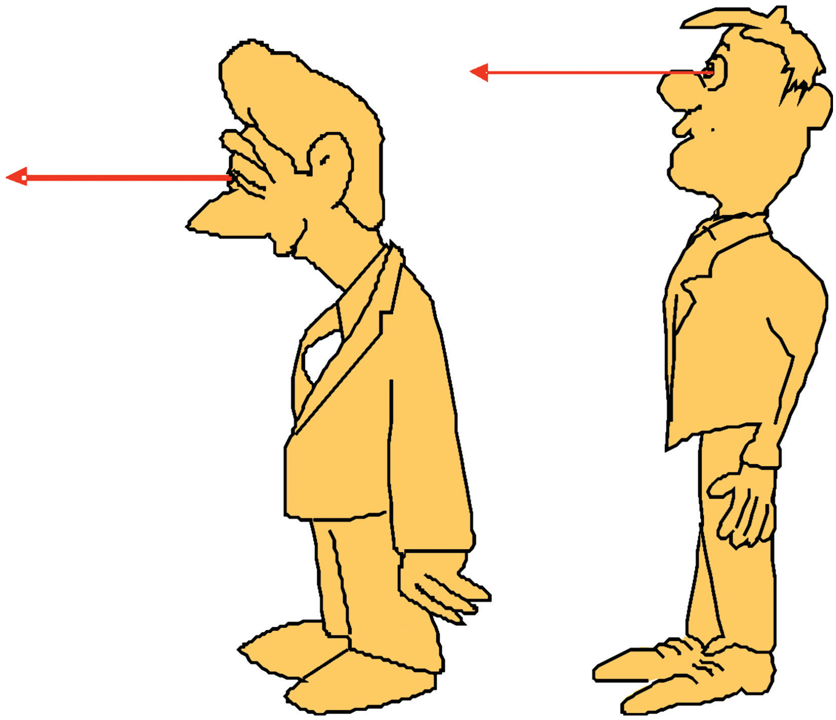


Figure 6 'Military' and 'slouching' posture (from: Essilor)

explanation) the subjects did not know in which direction to look and how to position their head. As the manufacturers did not provide a fixation target when capturing side-on pictures, our subjects were looking in completely different directions. Consequently, unreliable values for the pantoscopic angle and the fitting height were found during our first trial measurements. To remedy this problem, an additional eye chart was installed in the zero gaze direction of the subject (rotated 90°) and they were told which letter on the eye chart to look at. In this regard, manufacturers should provide better support to the practitioner.

Problems associated with 'natural head and body posture'

During measurement, patients should adopt a 'natural head and body posture'. Here, we have to cope with a major and complex problem. Often, in a real-life situation at the practice, the patient is not relaxed at all and unable to maintain their natural (habitual) posture.

Very often, they do not know what their 'normal' head posture actually is, nor do they know how to position themselves in front of the device. Some patients, for example, show the following two posture profiles (Figure 6):

a) M*ilitary posture*

The person is standing tall and upright in front of the video centration system with their arms hanging straight down to the trouser seams and with their head slightly tipped backwards. For this type of person, the measured fitting height will be too low, because the head is tilted back.

b) *Relaxed/slouching posture*

The person is standing in front of the video centration device with their stomach pushed forward, their head slightly tilted downward, and their hands pushed into the trouser pockets. For this type of person, the measured fitting point height will be too high, as the person is gazing slightly upward when looking at the centration system's fixation target.

We believe that the problem of 'natural head and body posture' cannot really be solved. The examiner should at least make sure that...

a) the person's arms dangle relaxed down both sides of his body

b) the person does not stand tall and erect like a soldier

In case of doubt, the patient should begin the measurement by walking around the room to become more relaxed.

Problems associated with special eyewear designs

Clear transparent eyewear

Big problems occurred with transparent spectacle frames, because the operator had difficulties in detecting the rim of the transparent frame. This led to errors in adjusting the centration lines.

Round/sharp-angled frame styles

Round or sharp-angled frame shapes led to problems on those video centration systems where a clip has to be placed onto the frame (Visioffice, Visureal and RVT). On frames with round-shaped upper rims, the clip suddenly slipped off, requiring the examiner to restart the measurement process. In so me cases, frames with laterally slanted upper rims were equally problematic. On so me frames with double bridges, the clip could not be attached according to the manufacturer's instructions, as the retaining clamps were located at the border of the double bridge and therefore lacked stability.

Nylor rimless designs with demo lenses

On Nylor frames with demo lenses, the subject's pupil centres were difficult to ▶

detect due to the bothering reflections produced by the uncoated dummy lenses. This problem was not investigated further as all measurements reported here were taken with frames that were not fitted with dummy lenses.

Ti me required for one measurement

The time required for the entire measurement process, from introductory explanations to the final print-out of the results, was measured with a random sample of subjects.

In unproblematic cases, the mean measuring time was approximately 2 min 40 sec, with Essilor's Visioffice, Ollendorf's Visureal and Zeiss RVT. When problems occurred, eg when a side-on picture had to be taken a second time, measuring time increased to some 3 minutes and 20 seconds on average. These values include the time needed for keyboard data entry as well as for adjusting the centration lines via mouse drag. The use of a touch screen normally requires much more time.

The shortest measuring and interpretation times were found with Essilor's Visioffice, as in most cases it automatically detected the clip markers and corneal reflexes. This device, however, required a little bit more time for introductory explanations. So, all in all, the three devices did not show substantial differences in measuring time.

With Rodenstock's ImpressionIST, a problem-free measurement took about 4 minutes and 20 seconds. This increase in measuring time was mainly due to the much more labour intensive method of adjusting both the pupil centres and the centration lines on the tactile touch screen. All centration lines need to be adjusted in an arduous step-by-step process by 'tapping' the screen with a touch pen. So, measuring time with Rodenstock's ImpressionIST is about 1 and a half minutes longer than with the three other centration devices. This is annoying when the practitioner wishes to perform numerous PD measurements in succession as we did. In most cases, however, the question of whether the whole PD measurement process (including analysis) takes 2:30 or 4:00 minutes seems to be of minor importance for the usual business in practice.

Assessment of handling aspects

Assessing the practical use of the four devices is not an easy task, since all video centration devices have left a positive impression. Table 1 provides an evaluation for eight key features. When comparing the total number of positive points, all perform almost equally well.

TABLE 1

Evaluation criteria	Essilor Visioffice	Ollendorf Visureal	Rodenstock Impressionist	Zeiss RVT
1 Adjusting the required distance is easy. The eyes are focused automatically	+	+	o	+
2 Computer assists in aligning the hairline with the corneal reflex or pupil centre	++	+	+	+
3 Image taken by the camera shows superior quality	+	++	+	+
4 Measuring time is short	++	+	o	+
5 The person quickly understands what to do	+	+	++	+
6 The eyes are not dazzled	+	++	+ (1)	+
7 Measuring clip is easy to mount and provides a secure fit	+	o	++ (2)	+
8 User instructions are informative, comprehensive and clearly arranged	+	+	+	o
Total number of good points	10	9	8	8

Short assessment of the practical use of four video centration systems (using the following evaluation scale: ++ = very good, + = good, 0 = satisfactory)
(1) remark concerning criteria # 6: Assessment of Rodenstock's ImpressionIST was based on the 2008 version equipped with light bands. In the new version, these light bands have been replaced with a flash lighting system.
(2) no measurement clip needed.

Summary of handling aspects

We did not encounter any real serious problems in operating the four video centration devices. Quite the contrary, working with them is a pleasure. All video centration devices gave a technically mature impression and strongly impressed the subjects.

It is very important that the manufacturer's staff (in charge of providing on-site training) is fully familiar with all practical (handling) tricks. Moreover, all potential users should be made aware of the utmost importance of properly adjusting the centration lines.

Many eye care practitioners are still unaware that less precise adjustments may lead to large measurement errors. In addition, written instructions for use should be provided to allow the user to reread all relevant information contained therein. Should potential users be unable to participate in the training, the practice manager should assign an employee to provide detailed explanations on the device's practical use. They should also verify, at a later time, the proper use of the device within a quality management policy. In this regard, several companies provide invaluable customer service helplines to answer all questions.

Several video centration systems can be operated either via mouse or via touch screen. Today, a touch screen looks stylish and seems to be more popular and more appealing, but in our opinion, the use of a keyboard and a mouse makes operation faster and more accurate.

All devices have their own little peculiarities you need to get accustomed to. On the RVT system, for instance, the need to confine the subject's eye and spectacle frame to a small window on-screen when taking side-on pictures was annoying at first. In the Visureal device, the typeface on the Laptop screen was very small. Older users found it difficult to read the text on the screen. With Rodenstock's ImpressionIST, the user gets nervous over the painstaking act of touch-screen 'tapping'. As to Essilor's Visioffice, the optician might be a little afraid of the customer who does not understand how to properly move their head. Fortunately this kind of situation did not arise during our study.

However all these small irritations, vanish as the operator becomes more accustomed to the use of the device.

● In the next issue, the author will take a closer look at the degree of accuracy provided by these centration devices.

● Full list of references with part 2.

● **Dr Wolfgang Wesemann** is based at the University of Cologne

● This paper has been supported by