Aniseikonia Treatment:

Are Contacts ALWAYS The Best Solution?

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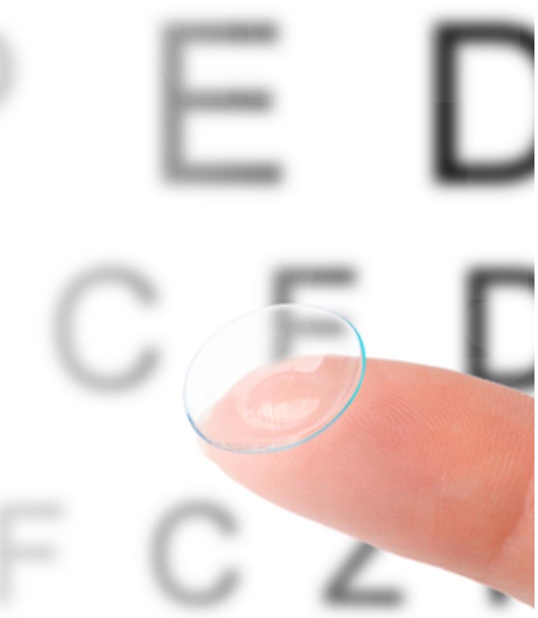

> Among eye care professionals, there exists an innate desire to improve the quality of their patients' lives by prescribing and recommending eyewear solutions that provide the best visual experience. Generally, the patient's visual needs and day-to-day visual demands dictate the most appropriate corrective device. However, in addition to a patient's practical needs, certain refractive conditions may also require careful management, to at least minimize, if not prevent, complications arising from the corrective lenses, themselves.

Both ophthalmic and contact lenses influence image size; although, contact lenses do so to a significantly lesser degree. By nature of their design, "plus" powered lenses produce positive magnification, and "minus" powered lenses, negative magnification (minification). The degree of influence lenses have on magnification is dependent on five factors:

- Lens thickness
- Lens material
- Front surface base curve
- Back vertex power of the lens
- Back vertex distance

For most patients, differences in refractive errors between each eye are relatively minor. Accordingly, although corrective lenses will result in some degree of magnification, it should, at least, be relatively similar for both eyes. On the other hand, patients with significantly different refractive errors between each eye can experience large disparities in the image size and/or shape received by both eyes; a condition known as Aniseikonia.

When a patient presents with symptoms of aniseikonia, many practitioners would stand firmly behind their recommendation for contact lenses to effectively manage such differences in image disparity. However, are they always?

ANISEIKONIA

Derived from the Greek, meaning, "without/not equal images", aniseikonia is defined as, "A relative difference in size and/or shape of the ocular images formed by the two eyes."

When aniseikonia results from anatomic conditions, such as an unequal distribution of rods and cones between both eyes or differences in cortical image size, it is referred to as anatomic aniseikonia. However, it can also be related to either the optics of the eye (inherent optical aniseikonia), or the optics of a corrective lens (induced optical aniseikonia). Regardless of cause, aniseikonia can greatly compromise stereoscopic vision.

As illustrated in Figure 1, stereoscopic vision gives a realistic impression of our environment (depth perception), when a certain degree of equality exists between the retinal images of both eyes. Actually, stereoscopic vision exists and can manifest spatial distortion when the images differ inordinately in size or shape. To produce a single mental percept from an object of regard, the images formed by the retinas of both eyes must undergo the process of sensory fusion.[3] The greater the similarity, the easier it is for this fusion to take place. In all reality, most patients likely experience a small amount of aniseikonia (less than 1%), either between the two retinas, or in the visual cortex. However, such subclinical amounts often simply present in the form of sensory eye dominance, resulting from the monocular cortical cells wired to the dominant eye slightly outnumbering those wired to the non-dominant eye.

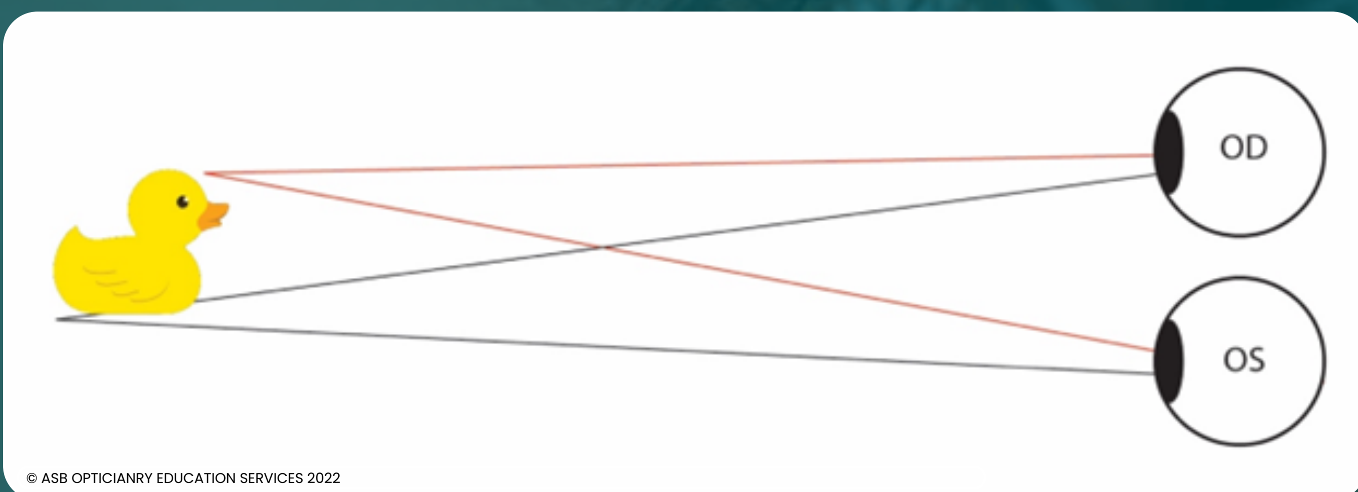

Fig. 1: Stereoscopic Vision and Depth Perception

However, when significant disparity exists, it interferes with the process of sensory fusion, resulting in anomalous spatial perception with apparent changes in one's environment. [3] In terms of the magnitude of its effect, "Aniseikonia of 2% or more is considered clinically significant, and 3-5%, highly symptomatic."

Interestingly, patients presenting with more than 10% aniseikonia are generally less symptomatic than those with smaller amounts; presumably, this is because there is no attempted fusion of images with such disparity. It is assumed, in such extreme situations, that suppression provides relief and the brain will often ignore the smaller of the two images.[4]

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MEASUREMENT OF ANISEIKONIA

While it has long been out of production, the gold standard for measuring aniseikonia is the Space Eikonometer.

Alternative methods include:

- The Awaya Aniseikonia Test, which consists of a simple book test, along the lines of the pseudoisochromatic plate tests used for color blindness
- The Aniseikonia Inspector (AI) software, available from Optical Diagnostics[6]
- An iPad system developed by Sasaki[6]
- 3D video displays that utilize circular polarizing filters[6]

However, it has been reported that most image size differences that present in clinical cases are between 1.0 and 2.0%, and therefore, too small to be detected with most screening instruments, due to their limited range in sensitivities.

As is the case with measuring axial length, most practitioners do not have easy access to such tools or programs, so being able to make estimations based on available data can be extremely helpful to the provider.

ESTIMATING ANISEIKONIA

By knowing the refractive error, it is possible to estimate the percent differences in magnification, and determine whether or not any aniseikonia present will likely result in complications for the patient. Findings indicate that patients experiencing magnification differences of 1-2% between each eye, may be symptomatic.

For estimation purposes, the industry-accepted rule of thumb is:
1D anisometropia = 1% of aniseikonia.

SYMPTOMS OF ANISEIKONIA

Patients are not always able to articulate the problems they may be experiencing, unless it's something simple like, "I can no longer read the captions on my TV."

Accordingly, it's necessary to read between the lines of what they're sharing to effectively determine the root cause(s) of their problems/concerns. Especially since patients experiencing symptoms of aniseikonia might describe how their eyes "feel", rather than a vision complaint.

Also, they may report:

- Asthenopia, giddiness, and nervousness;
- Compromised depth perception and eye-hand coordination;[11]
- Horizontal prismatic effects;[11]
- Differential vertical prismatic effects at the reading and distance level;[11] *
- Headaches, diplopia, disorientation or dizziness, tearing, eye pain or fatigue, sensitivity to light, visual acuity issues and trouble reading, as well as nausea.[11]

DETERMINING CLINICAL SIGNIFICANCE

Symptoms related to aniseikonia can often mimic those of uncorrected refractive errors or oculomotor imbalances. But, in those cases, symptoms are either not helped by the correction, or they appear as a result of correction.

However, as previously indicated, many individuals go about their daily lives unencumbered by minor, subclinical levels of both physiologic and anomalous aniseikonia. So, it's helpful to highlight certain "red flags" that can help indicate a patient's symptoms are clinically significant.

* Patients dealing with refractive anisometropia can experience significant vertical prismatic effects when viewing through a point in an ophthalmic lens other than its optical center. This is especially problematic for presbyopes wearing multifocal ophthalmic lenses, with which they are forced to look significantly down and away from the optical center to use the near reading area. With progressive addition lenses, vertical prismatic effects can also be experienced through the distance reference point.

INDICATORS FOR CLINICAL SIGNIFICANCE

- Symptoms not helped by the corrective lenses
- Symptoms present after implementation of the corrective lenses [13]
- High anisometropia or high astigmatism [13]
- Presence of physically altering factors, such as pseudophakia, monocular aphakia, scleral buckling, corneal transplant, refractive surgery, and optic atrophy [13]
- Complaints of distortion – slanting floors, walls, or the ground feeling too close or too far away [13]
- Improved visual comfort when one eye is occluded [13]

While there are a variety of different types of aniseikonia that fall under the general heading, this article will limit its discussion to the two primary forms: physiologic/non-symptomatic and anomalous.

TYPES OF ANISEIKONIA

Physiologic/Non-symptomatic: occurs in individuals whose eyes are identical, in both axial length and refractive properties, and results from a lateral change in direction of gaze.

For example: consider someone turning their eyes to the right to look at an object that's off to their right side. Their left eye will be slightly further away from the object than their right eye, so the image seen by their left eye will be slightly smaller than that seen by their right. Such small disparities are, of course, expected and normal; hence the term physiologic or natural aniseikonia. The presence of this type of aniseikonia simply serves to provide visual clues that enhance spatial awareness and eye-hand coordination.

ANOMALOUS ANISEIKONIA: Refers to the presence of any other aniseikonia and indicates an anomaly or abnormality in either the anatomic structure of the eye, or caused by the optics of the eye and/or the corrective lens.

As previously indicated, it can also be the result of modification of the retinal image due to an unequal distribution of the nerve endings (rods and cones) in the retina of one eye, compared to the other, and their representation in the visual cortex. Often, anomalous aniseikonia is simply referred to as aniseikonia.

The etiology of aniseikonia can be traced to either anatomical or optical anomalies; both will be discussed shortly.

PEDIATRIC ANISEIKONIA: Like adults, when children experience the effects of aniseikonia, the unequal focus results in persistent blur on one retina. And, as discussed earlier, when extreme aniseikonia exists sensory binocular fusion can be compromised. Unlike adults, however, in pediatric patients this can often lead to suppression of the eye receiving the smaller image, increasing the risk of amblyopia, and interfering with stereopsis.

This is yet another reason to increase societal awareness of the importance of regular eye examinations during the early years of child development.

ETIOLOGY OF ANISEIKONIA: Aniseikonia can either occur naturally, or as an unintended consequence of ocular surgery. Research indicates that cataract surgery remains the most common cause of acute aniseikonia. "When a patient with significant ametropia presents with very asymmetric cataracts, there is a danger of cataract extraction creating significant anisometropia and aniseikonia."

It can also be of sudden onset, as a result of unilateral aphakia or pseudophakia; for example, following extraction of a traumatic cataract. In addition, aniseikonia can simply be related to longstanding differences in ametropia that exist between each eye.

Regardless of its etiology, managing the condition by using the most effective approach, is our responsibility. Accordingly, it's imperative that we understand exactly what we're working with.

ANATOMICAL ANISEIKONIA: As indicated earlier, anatomical aniseikonia is influenced by the degree of separation of the retinal receptors and the functional organization of the terminal neural visual pathways in the visual cortex.

Research indicates in about 1/3 of the cases of aniseikonia, the measured image differences were seemingly unrelated to the dioptric characteristics of the anisometropia present, indicating the aniseikonia's origin to be anatomical.

OPTICAL ANISEIKONIA: Optical aniseikonia can be further broken down into two sub-categories: inherent or induced.

TYPES OF ANISEIKONIA

INHERENT OPTICAL ANISEIKONIA: By definition, inherent implies "no outside influence." Accordingly, inherent aniseikonia does, in fact, include anatomical causes like those previously discussed. However, inherent optical aniseikonia depends solely on the dioptric system of the eye.[18,20]

Induced Optical Aniseikonia is caused by the magnification properties of corrective lenses. It results when ophthalmic lenses are used to correct disparities in refractive errors between both eyes; primarily, in cases of anisometropia or antimetropia. This can be an overall aniseikonia (equal in all meridians), or meridional, which varies along the meridians and is often associated with an astigmatic refractive error (discussed later).

- Anisometropia is defined as, "A condition of unequal refractive state for the two eyes."

  For example: OD: +4.00 DS OS: +1.00 DS

- Antimetropia is defined as, "Mixed anisometropia."[21]
  For example: OD: +2.00 DS OS: -2.00 DS

While the above definitions are clear, both anisometropia and antimetropia are generally considered to be clinically significant when a spherical equivalent power difference of 1D or more exists between each eye.

NOTE: Since antimetropia is defined by The Dictionary of Visual Science and Related Clinical Terms as "mixed anisometropia," any future reference to anisometropia in this article can be assumed to apply equally to both anisometropia and antimetropia, unless stated otherwise.

AXIAL OR REFRACTIVE ANISOMETROPIA: Of course, the two primary methods to correct refractive errors involve either glasses or contact lenses. However, to determine the most effective method, when ametropias result in anisometropia, optical theory and Knapp's law recommends first determining the source of the ametropia – axial or refractive.

Knapp's law: "When a correcting lens is so placed before the eye that its second principal plane coincides with the anterior focal point of an axially ametropic eye, the size of the retinal image will be the same as though the eye were emmetropic."

To simplify Knapp's law, it basically states that contact lenses are ideal for correcting refractive-related aniseikonia, whereas ophthalmic lenses are better suited for correcting axial-related aniseikonia.[22]

Let's examine this assertion in greater detail.

AXIAL VS. REFRACTIVE AMETROPIA AND ANISOMETROPIA

As is the case for ametropia (a monocular phenomenon), anisometropia (a binocular phenomenon), can have either an axial or refractive origin and its source can greatly influence the theoretical sizes of retinal images, resulting in perceived aniseikonia; potentially hindering binocular perception.

In uncorrected axial-related anisometropia, the refractive properties provided by the cornea and crystalline lens are considered to be the same for both eyes, but optical theory states that the image size will be different from that of the normal eye because the axial length of the eyeball is different. Aniseikonia will exist if either eye is ametropic by differing degrees to its fellow eye (Table 1).

AXIAL-RELATED	REFRACTIVE-RELATED
The image size for an uncorrected myope will be larger than for an emmetrope. Image size for an uncorrected hyperope will be smaller than for an emmetrope - aniseikonia will be present.[23]	Uncorrected image size for both myopes and hyperopes will be the same size as the image for an emmetrope -aniseikonia will be absent.[23]

Table 1: Nature of Anisometropia and Related Presence of Aniseikonia

In other words, if a person's eye is too long or too short, the image size will be larger, or smaller, than it would be normally (Figure 2).

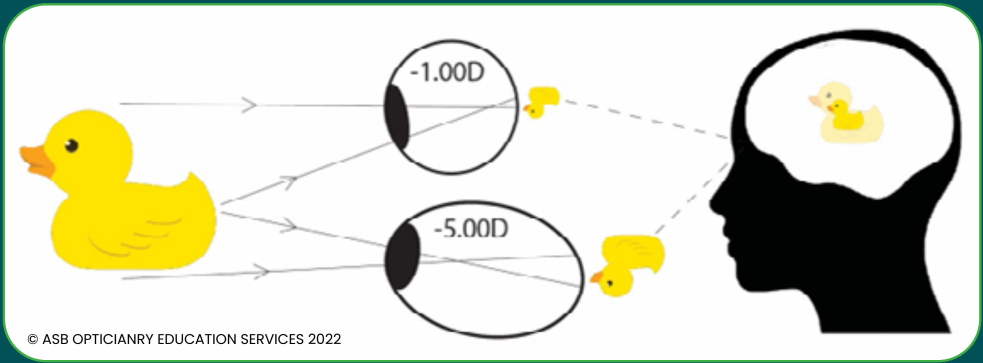

Fig. 2: Axial Related Anisometropia and Aniseikonia

In uncorrected refractive-related anisometropia, the axial lengths of each eye are considered equal, so the resulting retinal image size for each eye will also be essentially equal to that of an emmetropic eye. Subsequently, under such conditions, aniseikonia will not exist, when uncorrected.

History reports that Donders was one of the early writers aware of the dimensional changes in the retinal images induced by the correction of anisometropia. As discussed earlier, when ametropias result in anisometropia, Knapp's law can be utilized to mathematically predict the most effective optical corrective device, based on the source of the patient's ametropia.

OPHTHALMIC LENS VS. CONTACT LENS

MANAGEMENT OF AXIAL ANISOMETROPIA

According to Knapp's law, in cases involving axial anisometropia, the magnification effects provided by ophthalmic lenses will, effectively, offset those induced by axial ametropias, returning the image sizes to normal (Table 2). Such findings, indicating that ophthalmic lenses prove the most effective in the management of axial aniseikonia, question the belief that contact lenses are the best type of corrective lens for ALL patients who present with aniseikonia.

All is not lost, however. Contrary to the theories put forward by Knapp's law, clinical practice has demonstrated that aniseikonia is still found to be present when axial ametropia is corrected with ophthalmic lenses that are placed at the theoretically correct position. The cause of this prevailing aniseikonia is believed to be differential growth or stretching of the retina.

In addition, clinical practice has also demonstrated contact lenses to be "superior in the correction of all anisometropia," and ophthalmic lenses to result in "significantly greater degrees of aniseikonia than contact lenses." [26, 27]

Interestingly, Knapp's law is the subject of much debate, because for it to apply, certain conditions must be met.

These include:

- The ametropia must be strictly axial-related (no anatomic), data that's difficult for most practitioners to measure in office
- The refracting power of the eye is restricted to that of the standard emmetropic eye (58.50D)[28]
- The shape factor of the correcting lens (which we'll discuss later) must be unity. (In reality, the shape factor will be a value other than unity for both "plus" and "minus" lenses, if the front surface is convex in design).[28]

In addition, Knapp's law also overlooks the effects of any potential retina and cortex-induced aniseikonia.

When ophthalmic lenses are used to correct refractive anisometropia, their magnification effects will result in the retinal images, for both eyes, now being unequal, due to the resulting Spectacle Magnification (SM) for each eye being different from unity; so, aniseikonia will result (Table 2). In cases involving refractive ametropia, Retinal Spectacle Magnification (RSM) increases with increasing vertex distance, and is a minimum when vertex distance is also at a minimum.

OPHTHALMIC LENS VS. CONTACT LENS

MANAGEMENT OF REFRACTIVE ANISOMETROPIA

Both Spectacle Magnification and Relative Spectacle Magnification will be discussed in greater detail, shortly, but for purposes of introduction:

SM = Retinal image size in corrected
Retinal image in same uncorrected eye

RSM = Image size for a corrected ametropic eye
Image size for a standard emmetropic eye

If contact lenses are used, the vertex distance can be considered, zero (providing the cornea to entrance pupil distance is considered negligible), and the RSM will approach unity. Since contact lenses produce very little magnification, they result in the RSM differing very little from unity, and minimize the amount of aniseikonia experienced by the patient. Accordingly, contact lenses should be the recommended corrective device for both hyperopes and myopes.

Clearly, unlike axial anisometropia, with refractive anisometropia practice findings agree with Knapp's law: in cases of refractive anisometropia, contact lenses are the most effective treatment option. Of course, anisometropia can exist due to a combination of both axial length and refractive properties. The two are not always mutually exclusive.

Table 2: Presence or Absence of Aniseikonia in Uncorrected and Corrected Anisometropia

Ametropia	Uncorrected	Spectacle Correction	Contact Lens Correction
Axial Anisometropia	Present	Absent	Present
Refractive Anisometropia	Present	Present	Absent

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Let's explore Spectacle Magnification (SM) and Relative Spectacle Magnification (RSM) in greater detail, to help differentiate between the two phenomena.

SPECTACLE MAGNIFICATION (SM)

Spectacle Magnification compares the image size formed by a single eye wearing a corrective lens to the image size in the same uncorrected eye. It is defined as a type of angular magnification brought about by a single spectacle lens.

Presented in equation form:

$$SM = \frac{\text{Retinal image size in corrected eye}}{\text{Retinal image in same uncorrected eye}}$$

SM is expressed as a ratio, such as 1.10 or 0.92.

An SM > 1.0 indicates positive magnification

An SM < 1.0 indicates negative magnification (AKA, minification)

Accordingly, translating the above ratios to percentages, 1.10 indicates a 10% magnification and 0.92 indicates an 8% minification.

RELATIVE SPECTACLE MAGNIFICATION (RSM)

If an ametropic eye that is corrected by an ophthalmic lens, produces an image that is smaller than the normal image size for a standard emmetropic eye with a +58.50D refractive power, the negative magnification, or minification, produced by this ametropic eye, relative to the standard, is called the Relative Spectacle Magnification.

If we express this relationship in the form of an equation:

$$RSM = \frac{\text{Image size for a corrected ametropic eye}}{\text{Image size for a standard emmetropic eye}}$$

How is Spectacle Magnification (SM) distinguished from Relative Spectacle Magnification (RSM)?

SM compares the image size of one eye only, in both uncorrected and corrected states;

RSM compares an ametropic, but corrected eye with a standard emmetropic eye.[37]

The goal, then, in a perfect world, should be to utilize the most appropriate corrective device for all forms of ametropia that produces a normal image size and provides every patient with the best visual experience.

WHERE DOES ASTIGMATISM FIT INTO THE EQUATION?

By definition, astigmatism is a form of refractive ametropia; so, once again, both theory and practice indicate contact lenses are the best recommendation to prevent, or at least minimize, aniseikonia. The benefits of contact lenses have even been demonstrated to reduce meridional magnification differences in isometropic patients.

DETERMINING SOURCE OF ANISOMETROPIA

Hands-on access to an optical biometer allows for accurate axial length assessment. But, since most offices don't have such devices at their fingertips, there are alternative approaches to evaluate the source of a patient's ametropia, and accordingly, any presenting anisometropia.

- Keratometer readings (Ks), provide an effective tool to determine the source – axial or refractive.[31]
  - Significantly different Ks, between each eye, are good indicators for refractive-related ametropias.[31]
  - On the other hand, similar Ks between each eye would indicate axial-related ametropias. [31]
- Anisometropia due to development of a monocular cataract would also indicate a refractive-related origin. [31]
- Although spherical anisometropia may be refractive, axial, or both, clinically significant levels above 2D are typically axial in nature.
- Routine refractive changes in adults are usually refractive in origin. [33]
- Ametropia in excess of +/-4D is usually the result of abnormally long or short axial lengths.

In terms of axial length and the extent of it influence on aniseikonia, research reports the following findings:

- The average axial length is approximately 23.30mm .
- For the majority of patients, axial lengths of each eye should differ by no more than 0.3mm.[35]
- Assuming the central corneal power is the same for each eye at normal axial lengths, for every 1mm of axial length difference, you can anticipate a 3D difference in refractive error.[35]

COMBINATION OF CONTACTS AND OPHTHALMIC LENSES

Clearly, despite optical theory and Knapp's law, clinical practice indicates that contact lenses should be the primary treatment option for the management of aniseikonia. However, for your presbyopic patient experiencing aniseikonia, if a multi-focal contact lens proves unsuccessful, don't overlook the benefits of combining both single vision contacts with an ophthalmic progressive addition lens.

The contacts will balance out their distance refractive errors, eliminating the potential vertical imbalance at distance and near they might ordinarily experience with ophthalmic lenses made to provide their total corrective needs. In such a scenario, the ophthalmic progressive lens would mostly provide their near add, together with any residual cylinder.

ANISEIKONIA

CONCLUSIONS

Symptomatic aniseikonia, when left unmanaged, can result in a myriad of complications, and it's our responsibility to provide patients with the best eyewear solutions. When a patient presents with concerns and visual complaints, understandably, our first instinct is often to search back through our mental archives to ascertain the best treatment option. However, as presented here, the results of clinical practice don't always agree with theories, so it's vital to always keep an open mind.

While Knapp's law implies that the best corrective device for the management of aniseikonia should be determined by its origin, clinical practice continues to support contact lenses as the most effective, regardless of the source. Clearly, for Knapp's law to apply, relatively unrealistic conditions must be met. In clinical practice, some discrepancies between theory and real-life experiences exist that are similar for both myopic and hyperopic, axial-related, anisometropia.

So, why are contact lenses the best solution for aniseikonia? Well, if you were to imagine an infinitely thin lens, placed at the entrance of the pupil, both factors that are used to calculate lens magnification (shape and power), would be "1x", resulting in a spectacle magnification of "1x"; also referred to as unity. And, this would be independent of the patient's refractive error.

The closest we can get to this ideal, is by using either a contact lens or intraocular lens.

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