MACULAR PIGMENT OPTICAL DENSITY AND EYE HEALTH
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INTRODUCTION

The macular pigment (MP) of the human retina is composed of two carotenoids, lutein and zeaxanthin, that are exclusively obtained from dietary sources since they cannot be synthesized by the human body. These two xanthophylls absorb light maximally at approximately 446 nm, which is in the blue light range of the electromagnetic spectrum. Because the blue wavelengths of light can be damaging to retinal tissue, high MP density has been associated with reducing the risk of some eye diseases (19). Furthermore, since these wavelengths can also contribute to visual glare and photophobia, the light filtering properties of MP may contribute to improvements in some aspects of visual function (24, 26).

The macula lutea (yellow spot) is located in and around the human fovea (central retina) (Figure 1). In addition to lutein and zeaxanthin, the macula also contains a highly related xanthophyll, meso-zeaxanthin. Meso-zeaxanthin is not obtained from the diet but is converted, most likely, from lutein in the macula itself (12). The ratio of lutein, zeaxanthin and meso-zeaxanthin in the center of the fovea is approximately 1:1:1 but varies in the peripheral macula (15).

MPOD MEASUREMENT

Macular pigment optical density (MPOD) is a measure of the ability of MP to absorb (i.e., filter) blue light. Currently, there are three separate methods that are mainly being used to measure MPOD in living subjects: autofluorescence imaging, resonance Raman spectroscopy and heterochromatic flicker photometry. Each method has differences relative to ease-of-use, expense, invasiveness and the ability to spatially map MPOD to the subject’s macula.

Autofluorescence imaging. AFI is an objective test that takes advantage of the natural fluorescence of a material known as lipofuscin which is located in the retinal pigment epithelium (9). When the retina is illuminated with light at a wavelength that excites the lipofuscin, it fluoresces. However, these same excitation wavelengths are also blocked by the macular pigment. Therefore, the fluorescence of lipofuscin is attenuated in direct relationship to the amount of MP present in the macula. In this manner, AFI can be used to identify, quantify and spatially image the density of the MP in the eye.

Resonance Raman spectroscopy. RRS is an objective test that utilizes signature spectrographic properties of carotenoids to measure MPOD (4). Upon illumination of a subject’s retina with a low intensity argon laser, the MP emits scattered, resonance-shifted
wavelengths of light called resonance Raman wavelengths. The intensity of the Raman spectra is linearly associated with carotenoid content and can be used to calculate MPOD.

**Heterochromatic flicker photometry.** HFP is a subjective test that requires the subject to match stimuli flickering between blue light (the test stimulus) and yellow (or green) light (the reference stimulus) (16). The subject adjusts the radiance of the test stimulus, which is absorbed by MP, until it reaches equal luminance with the reference stimulus, which is not well-absorbed by MP. The MPOD is calculated from the level of maximum radiance of blue light needed to match the reference light and cause a “null-flicker”.

![Micrograph of a retinal cross section centered on the macula.](image)

**FIGURE 1.** The *Macula Lutea*. Left: Micrograph of a retinal cross section centered on the macula. The macular pigment, composed of lutein and zeaxanthin, appears as a yellow tint (photo under license from Dr. Max Snodderly). Right: Schematic cross section of the human eye showing how light is focused upon the macula.

**EYE DISEASE**

The most common eye disease that has been associated with MPOD is age-related macular degeneration (AMD), the leading cause of blindness in the Western world among people older than 65 (13). In 1994, a landmark study conducted by Dr. Joanna Seddon and coworkers at Harvard University compared the risk of developing AMD to nutrient intake. They showed a significant risk reduction for AMD (57%) between subjects with the lowest and the highest intake levels of lutein (23).

Subsequently, more direct links have been shown between MPOD and AMD risk. Retinas from donors who had AMD were shown to have significantly lower lutein and zeaxanthin levels than retinas from donors who did not have AMD (7). In living subjects who were not consuming high-dose lutein supplements, it was shown that average levels of lutein and zeaxanthin in AMD eyes were 32% lower than levels in healthy eyes (5). In a northern European subject group, it was found that healthy eyes known to be at high risk for developing AMD, because of evidence of disease in the fellow eye, had significantly less macular pigment than healthy eyes with no AMD risk (2).

There is also a large body of evidence that links low MPOD with various risk factors associated with AMD (for review, see (19)). Age is a major risk factor in AMD and it has been shown that MPOD significantly decreases with age (3, 5, 20). Smoking and obesity are also risk factors for AMD and decreased MPOD has been associated with heavy smoking (11, 20) and increased body fat (18). Most significantly, a
large array of studies have established that a diet high in lutein and/or zeaxanthin, whether through food or supplementation, results in increased MPOD (6, 10, 14, 17, 20, 22, 24, 27). This is notable due to the established link between a diet high in lutein/zeaxanthin and a reduction in AMD risk (23).

There is increasing interest in determining whether MPOD is associated with less common diseases of the retina. For instance, it has been found that patients with a mutation in a gene known to cause most autosomal recessive retinal degenerations (gene ABCA4) had reduced MPOD compared with healthy patients (1).

**VISUAL ACUITY**

The ability of carotenoids to filter blue light may enable the macular pigment to provide benefits to visual health and function beyond protection from retinal degeneration. The MP can be thought of as internal sunglasses. As such, MP may provide improvements in visual function both in people who have visual disabilities due to disease as well as in healthy individuals.

The Lutein Antioxidant Supplementation Trial (LAST) determined that supplementation with 10 mg FloraGLO® Lutein a day over the course of a year increased the MPOD of patients with early stage AMD. Compared to patients who received placebo, the patients who received lutein supplementation showed improvements in contrast sensitivity, glare recovery and general vision quality (21). Similarly, Cangemi (2007) showed that AMD patients who were supplemented for six months with a product containing lutein and omega-3 fatty acids showed significant improvements in visual acuity (8).

Recently, Stringham and Hammond at the University of Georgia have published two studies using healthy young adults that show a correlation between increased MPOD and improved visual performance under glare conditions in healthy subjects (age range: 17 to 41). In a 2007 study, they showed that subjects with higher MPOD exhibited a higher threshold for glare and also had lower photostress recovery times than subjects with lower MPOD levels (25). In 2008, they showed that an increase in MPOD, achieved through supplementation with FloraGLO Lutein and zeaxanthin, within the same subject correlated to decreased glare disability and a faster photostress recovery time (24).

**CONCLUSION**

At this point in time, MPOD is mainly assayed for research purposes. It is primarily employed to elucidate the function of the macula and to establish information about the relationship of MP and diseases of the macula. However, MPOD appears to be a valuable biomarker for monitoring the health and function of the eye. Therefore, as MPOD-measuring instruments become more standardized and affordable, it may become more common practice to measure MPOD in the offices of ophthalmologists and optometrists in support of disease diagnosis and preventative medicine around the world.

**REFERENCES:**


