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Precision tinted lenses in migraine

Recent research at the Institute of Optometry

The Intuitive Colorimeter, Precision Tinted lenses (PTLs), Intuitive Overlays and the Wilkins Rate of Reading test are well known for their use by optometrists and other professionals in the treatment of some people with reading difficulties. This work has been summarised in two recent books[1,2]. Some new research suggests that these treatments are also helpful for certain people with migraine. This article summarises this research and discusses the clinical implications for optometrists and dispensing opticians.

The reason why coloured filters help people with reading difficulties is likely to be related to pattern glare (**Figure 1**).

Many people find that the pattern in **Figure 1** is uncomfortable to view, causing eyestrain, headaches and visual perceptual distortions. Lines of text and letter strokes on a page can resemble a striped pattern and, therefore, text can cause pattern glare. The glare results in letters blurring, moving, flickering, etc. The reason for these symptoms is most probably cortical hyperexcitability: the pattern causes over-stimulation of a hyperexcitable visual cortex and produces symptoms, perhaps as a result of a spread of excitation causing neurons to fire inappropriately. Coloured filters reduce the excitation of the visual cortex, and specific colours might reduce the stimulation of localised areas of hyperexcitability because neurons have rather different spectral sensitivities[3].

If cortical hyperexcitability explains the benefit from coloured filters in people with reading difficulties, then coloured filters should help in other disorders. There are several disorders of the central nervous system which involve vision and in which the visual cortex may be hyperexcitable. These conditions include photosensitive epilepsy, head injury, multiple sclerosis and migraine. Is there any evidence that Precision Tinted Lenses (PTLs) help in these disorders?

Photosensitive epilepsy is rare, but a recent open trial[4] suggests that PTLs may be helpful in this condition. There are several reports of intolerance for light following head injury and even one report that coloured lenses can help[5]. There have also been isolated case reports of benefits from coloured filters in patients with multiple sclerosis. As for migraine, it is by far the most common of the above disorders and if even a fairly modest proportion of people with migraine can be helped with PTLs, then this could represent an important new treatment available to eyecare practitioners.

The first aim of the present research was to investigate whether PTLs could help people with migraine. Migraine can have many triggers, and clearly PTLs would not be expected to help someone whose migraines were caused, for example, solely by their menstrual cycle, or by chocolate or red wine. But for some people, at least one of the triggers for their migraine appears to be visual (e.g. fluorescent lights, patterns, text, computers, etc). These are the people that we sought to investigate. One of the authors (BE) has been receiving referrals for some time from a local neurologist who has a special interest in visually precipitated migraine. A sample of these patients, all seen in BE's private practice, were audited in an open trial to investigate the general usefulness of PTLs for people with visually precipitated migraine.

Retrospective audits like this are interesting, but the evidence-based approach in the healthcare sciences[6] requires that treatments are investigated using prospective double-masked randomised placebo-controlled trials (RCTs). We therefore carried out an RCT to investigate whether PTLs could be an effective treatment for some cases of migraine.

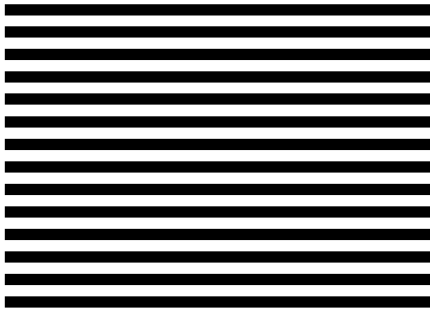

Figure 1
A pattern that may cause pattern glare, especially when viewed at a distance of about 50cm (do not stare at the pattern if you suffer from epilepsy or migraine)

Migraine is a complex condition. In a 1998 review, Ruskell[7] noted that "trigger avoidance" is "the most obvious therapy" and it is possible that other visual factors, in addition to pattern glare, might be triggers for migraine. Indeed, many optometrists will be familiar with claims that base in prisms are an effective treatment for migraine[8,9], and hyperphoria has also been implicated as a possible trigger[10]. However, all these studies suffered from major methodological limitations, so the evidence for these claims is little more than anecdotal. A secondary goal of our research was to investigate the optometric characteristics of a sample of people with migraine.

If PTLs are helpful in alleviating the symptoms of migraine, then it becomes important to establish the mechanism for this benefit. One way of investigating this is to see if the PTLs change any optometric findings. For example, if our sample of migraine patients have a decompensated heterophoria, or pattern glare, then do the PTLs help to correct this anomaly? A third aspect of our research was an investigation of the effect of the coloured filters on the optometric test results.

In summary, the aims of the research neatly split the study into four parts – open trial of PTLs, optometric correlates of migraine, randomised controlled trial (RCT) of PTLs, and effect of PTLs on optometric parameters. These four parts are summarised in **Table 1**. The different aspects of the study will be considered under these headings in the rest of this article.

The results of this study have been published recently in peer reviewed scientific journals. Full details of the randomised controlled trial (RCT) were

Table 1 Overview of research

Aims of study	Phase of study
Do PTLs seem to be of value in migraine?	Open trial
Are optometric problems (e.g. exophoria) more common in the migraine group?	Optometric correlates of migraine
Do PTLs help the migraine group more than control tints?	Randomised controlled trial (RCT)
What is the effect of PTLs on optometric test results?	Effect of PTLs on optometric function

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published in the journal of the International Headache Society, *Cephalalgia*[11]. Full details of the optometric results were published in the journal of the College of Optometrists, *Ophthalmic & Physiological Optics*[12]. The present paper is a brief summary, stressing the most relevant points for practising optometrists.

Open trial

We followed six males (age range 10 to 53 years; mean 27.8 years) and 14 females (age range 15 to 73 years; mean 36.6 years) suffering from migraine for which they had been prescribed PTLs at the optometric practice of one of the authors (BE). First, the patients underwent a detailed optometric examination to rule out ocular pathology and significant uncorrected refractive and orthoptic anomalies. PTLs were only prescribed if the patient subsequently showed a consistent response to testing with the Intuitive Colorimeter (**Figure 2**) and with precision tinted trial lenses[13]. The patients were followed up with a telephone survey at an interval after they received their PTLs of between eight months and four and a half years (mean interval two years, one month).

At follow up, 80% of patients reported that they still used their spectacles. Seventy-five percent reported a decrease in the frequency of headaches, with 20% indicating no change in frequency, and one patient (5%) saying that headaches and migraine had increased in both frequency and severity. Interestingly, 65% reported a significant reduction in their reliance on medication following the use of the glasses and 25% had stopped the medication altogether. These patients were among those who reported most benefit from PTLs. Since the direct medical costs associated with migraine are more than £25m per annum[14], this may be our most important finding when trying to persuade the General Ophthalmic Service to properly fund the provision of PTLs by optometrists.

Other findings of this study are reported in Wilkins et al[11]. In short, this open trial showed that PTLs seem to be helpful for people with visually precipitated migraine. The study also showed that the Intuitive Colorimeter and PTLs could be used for adults with visually precipitated migraine in a similar way to their use for children with reading difficulties. These results support an earlier open trial by Griffin[15] who found that for a group of 19 migraineurs, the mean number of headaches per month dropped from 10 to 3.2 after PTLs were prescribed. It was felt that these findings warranted more research, including an RCT, as described later.

Optometric correlates of migraine

The participants for this part of the research were 21 patients (age range 17 to 54 years, mean 44 years) with medically diagnosed migraine. Migraine is more common in females, and 88% of the sample were female. Migraine can be classified as with or without aura[16], and most of our sample had migraine with aura[11]. They all suffered at least two headaches a month and, when screened with coloured overlays, had chosen a coloured overlay and found it helpful for more than one month. Patients who were already using tinted spectacles were excluded, as were any patients with concurrent neurological pathology or who were currently undergoing optometric treatment. There were also 11 controls of similar age (+/- 10 years) and gender. The controls did not suffer from migraine and experienced no more than 12 headaches a year.

Table 2 Optometric correlates of selected sample with migraine (D = distance, N = near)

Not significantly more common in migraine (p>0.05)	More common in migraine (p<0.05)
Ophthalmoscopic findings, visual fields, ocular tensions, colour vision	
D&N visual acuities, refractive error, use of D&N refractive correction	
Strabismus at D or N (no cases); incomitancy (no cases), D&N vertical phorias & vertical aligning prism, foveal suppression, D phorias and aligning prism, Sheard's and Percival's criteria, D convergent fusional reserves, N phorias (size, type, variability, recovery), aligning prisms, Percival's criterion, N fusional reserves (convergent, divergent, amplitude), global and local stereo-acuity	D divergent fusional reserves (blur, break and recovery) N Sheard's criterion
Amplitude of accommodation and accommodative lag	
Contrast sensitivity, hemifield difference in pattern glare	Pattern glare

Figure 2
The Intuitive Colorimeter

The participants were given a detailed optometric examination, including the tests listed in **Table 2**[12]. This examination included the normal health checks (ophthalmoscopy, visual fields, pupil reactions, tonometry), refractive checks, and many orthoptic tests. **Table 2** shows that, of the many variables assessed, only three were significantly different (all worse) in the migraine sample.

Table 2 shows that optometric anomalies were not common in this sample of patients with migraine. Ocular pathology, refractive errors and accommodative insufficiency were not correlated with migraine. Although one or two orthoptic variables were significantly worse in the migraine group, the many other orthoptic tests did not reveal any significant differences between the two groups.

The two orthoptic variables at which the migraine group performed worse than the controls were the distance divergent fusional reserves and Sheard's criterion at near. It should be noted that these findings only just met the usual criterion for statistical significance (the p-values fell between 0.01 and 0.05) and, in view of the number of comparisons, these findings are perhaps best described as of borderline significance. The distance divergent fusional reserves is a puzzling finding, since it is unlikely to be related to the claims of exophoria being a factor in migraine. Interestingly, some studies have suggested that the ability to diverge the eyes beyond parallel might also be reduced in some people with reading difficulties[1]. Of course, the eyes are not diverged beyond parallel in everyday life, so it seems unlikely that this finding could be directly related to any causal mechanism for migraine.

The finding that more of the migraine group failed Sheard's criterion at near is more interesting. Some studies have found Sheard's criterion to be a good indicator of symptomatic heterophoria[17]. Since the vast majority of people are exophoric at near, it seems possible that our finding provides

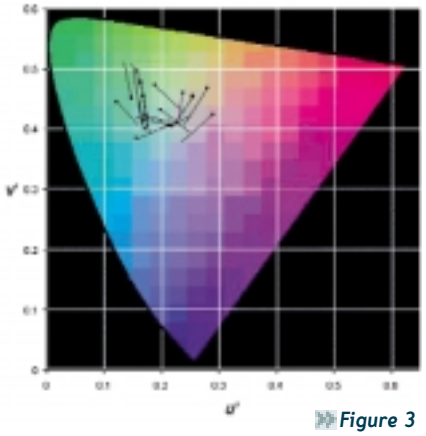

Figure 3

Chromaticities of the tinted lenses used the study, drawn in CIE u'v' colour space. The chromaticity of each patient's 'optimal' tint is shown by a square symbol and connected by a line to the chromaticity of the sub-optimal 'control' tint

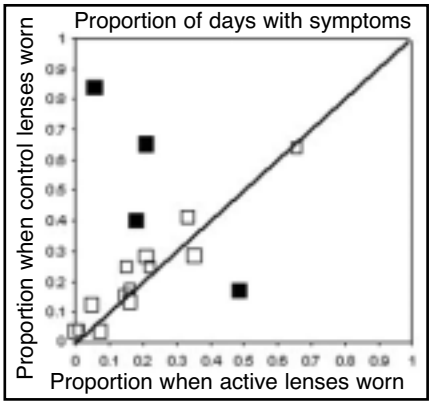

Figure 4

Each symbol represents a patient and the position of a symbol is determined by the proportion of days with symptoms when the 'optimal' tinted lens was worn (horizontal axis), and the proportion when the 'control' tinted lens was worn (vertical axis), neglecting days when no lenses were worn. The symbols above the diagonal therefore represent patients for whom wearing the 'optimal' tint was associated with fewer symptoms than the 'control' tint. The solid symbols represent patients for whom the difference between the tints was significant for that individual

support for Turville's claim[8] – that base-in prism can be an effective treatment for migraine. Interestingly, our findings also support Turville's observation that divergent fusional reserves are low in migraine, although we do not support his finding of low convergent fusional reserves. This latter point is important: other indicators of decompensated heterophoria were not present in our data. For example, cover test recovery and aligning prism (associated heterophoria on the Mallett unit) did not differ significantly in the two groups. The latter finding is especially important since one of the most thorough studies on decompensated heterophoria found that the aligning prism was the best predictor of symptomatic heterophoria[17]. So, although our findings provide some support for Turville's claim[8] that base-in prism can help in migraine, this support is equivocal and decompensated heterophoria does not appear to be a strong correlate of migraine.

One variable that did emerge from our study as a strong correlate of migraine was pattern glare. Compared with the control group, the migraine group reported many more visual perceptual distortions (p=0.004) on viewing a grating similar to that shown in **Figure 1**. To explore this further, we tested our participants with a control grating and the results with this confirmed that the pattern glare was not simply the result of a greater degree of suggestibility in the migraine group[12].

Randomised controlled trial

Of the 21 migraine patients for whom we had optometric data (from the optometric correlates study described above), 17 completed the randomised controlled trial. The methodology was similar to that used by Wilkins et al[18] in their randomised controlled trial of the use of coloured filters for people with reading difficulties. The Intuitive Colorimeter (**Figure 2**) was used to test patients to determine the chromaticity of light that most improved their perception of text[13]. When the patient looks in the viewing aperture of the Intuitive Colorimeter, the room lights are dimmed so that their entire field of view is coloured according to the instrument settings. This means that they colour adapt in the same way as if they were wearing coloured glasses.

A useful side effect of this colour adaptation is that participants will not be aware of the exact colour of the light in the instrument. Of course, they will know roughly what the colour is (e.g. that it is a blue and not a red), but they will not know the exact colour (e.g. the precise shade of blue), and the degree of saturation (strength of colour) will appear much less than it really is. It is this feature that makes a double-masked randomised placebo-controlled trial possible[6].

Once the optimal colour for a given patient had been selected with the colorimeter and the patient was no longer in the room, the chromaticity of the colorimeter setting was translated into a prescription for PTLs[13]. A computer program was used to select a second, control tint that was similar to the optimal tint but which differed in hue by six just noticeable differences (a just noticeable difference is the smallest difference between two stimuli that can be reliably detected by a normal observer). Each control tint was selected to have the same saturation as that participant's optimal tint and the mean hue of the optimal tints was the same as the mean hue of the control tints (**Figure 3**).

Three weeks after the testing, each participant received a pair of spectacles (or clip-ons if they already wore spectacles), which contained the optimal or control tint, selected at random. Neither the patient, nor their examiner knew whether they were optimal or control. Participants wore the tinted spectacles as and when they wished for six weeks and then returned them. They were re-tinted and returned to the patient at least two weeks later with the second pair of tints, which were also worn for six weeks. All through these stages, from the eye examination to the end of the wearing period of the second pair, participants completed daily diaries saying how much they had worn the spectacles and describing any headaches they experienced.

Several measures were taken to ensure that the study was double-masked. For example, the colorimetry was presented as a colour vision test, in the middle of a battery of 'genuine' colour vision tests, and participants were not told that the colorimetry results were to be used to prescribe the PTLs. Participants never saw both pairs of tinted lenses side-by-side to compare the colour. An important point is that the control tints were not ineffective placebos: they were chosen as being "not too different" to the optimal tints. Although the research would have been more likely to show a marked benefit from optimal tints compared with the control tints if they had been of a very different hue or the control tints had been grey, this would have prevented the study from being double-masked.

It was a source of anxiety to the researchers that, in our efforts to ensure that the study was double masked, by making the optimal tints similar to the control tints, we might have made it too difficult for the study to detect a clinical benefit from optimal compared with "slightly less optimal" control tints. There was also, of course, the additional worry that the control tint might not, in fact, be inert (as placebos are supposed to be) but actually aversive, and that any difference between the active and control lenses was attributable to the negative effects of the control lenses rather than the positive effects of the active lenses.

In the end, our anxieties were allayed somewhat, as **Figure 4** shows. Each point in **Figure 4** is a participant and those falling above the diagonal experienced less symptoms with their optimal than with their control lenses. As can be seen, there are 11 points above the diagonal, and six below. For some participants, the greater benefit from the active tints was individually statistically significant, but the statistical power is improved by combining the participants. The appropriate statistical test (the log odds for the distribution of points) revealed a statistically significant result (p=0.02).

Effect of PTLs on optometric function

At a follow-up appointment, we repeated the optometric tests under three

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conditions: no tint, optimal tint, control tint. For statistical reasons, the results were analysed only for the tests that had initially detected a significant difference between the migraine and control groups[12]. The results are summarised in **Table 3**.

The only orthoptic variable to be improved with the active tint is the distance divergent fusional reserves break point. Although interesting, it seems very unlikely that this finding is of any clinical significance since the eyes do not diverge beyond parallel in everyday life and cover test recovery and distance aligning prism were not significantly better with the active PTLs.

If Turville (1934)[8] and Wilmut (1956)[9] are correct, and base-in prisms are an effective treatment for some cases of migraine, then it could be hypothesised that PTLs help through somehow alleviating a decompensated exophoria. Indeed, some studies have shown that exo-deviations are commonly associated with photophobia[17]. However, our data do not support this conclusion; the mechanism for the benefit from PTLs does not appear to be via the correction of decompensated exophoria.

The only other variable that we found to be improved with PTLs was pattern glare, and this was statistically a strong effect. Participants reported significantly increasing degrees of visual perceptual distortions in the following order (**Figure 5**): active tint, control tint, no tint (Friedman test, $p<0.001$), but the pattern glare with active tints was not significantly less than with the control tints (Wilcoxon test, $p>0.05$).

The finding that the active PTLs were not significantly better at reducing pattern glare than the control tints is interesting and there are several possible explanations for this. This finding might simply reflect the fact that the control tints were not inactive placebos, but were chosen as being similar to the active tints, but just a little less beneficial, in which case the worry mentioned above about possible aversive effects of the control is unfounded. It might be that the difference between the active and control tints was enough to have a statistically beneficial effect on symptoms as assessed by the daily diaries, but was not enough to have an immediate effect on pattern glare. In any event, this finding supports recent data from a separate study by Wilkins in which it was shown that people who benefit from PTLs find that a wide range of hues are better than no tint, although this study also showed that for each person the optimal tint does indeed need to be defined with considerable precision[2].

Conclusions

Patients with migraine tend to be photophobic, not just during migraine attacks but also between episodes[19]. Patients with visual symptoms, like photophobia, might be expected to be particularly likely to consult optometrists. Indeed, according to a recent survey, 11% of men and 23% of females consulting optometrists will have experienced migraines[20].

Generations of optometrists have been taught during their training that base-in prism and a light blue tint are helpful for many patients with migraine. To what extent does our research support these anecdotal claims? **Figure 3** shows that, using the Intuitive Colorimeter, many patients will choose a blue tint. However, our research also shows that some people prefer other colours. In particular, the RCT shows that it is important to allow patients to individually select the appropriate tint, and that the method that is used for this must allow both precision and accurate reproducibility.

It is harder to comment on the claims[8,9] that base-in prism helps in migraine. Although one of our analyses did suggest that decompensated exophoria may be a correlate of migraine, other analyses did not support this hypothesis. It would be possible to carry a double-masked randomised controlled trial of base-in prism as a treatment for migraine, and this would be an interesting study. In the meantime, it would certainly be a sensible precaution for patients with migraine or other forms of headache to undergo a detailed optometric examination to rule out pathology of the eye or visual pathway, refractive errors, and orthoptic problems. If any refractive or orthoptic problems are found which seem to be related to symptoms, including headache, then of course treatment is indicated.

Our research shows, using a double masked randomised controlled design, that PTLs are effective at reducing the prevalence of headaches for some patients with migraine. Different people need different colours and the colour needs to be selected with a degree of precision. We found that the Intuitive Colorimeter and

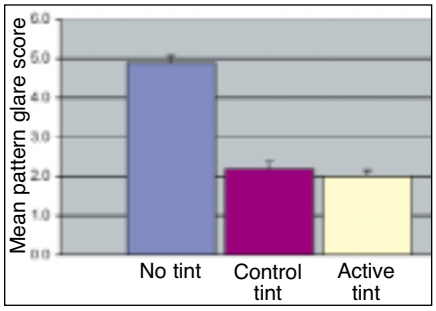

Figure 5 Effect of precision tinted lenses on pattern glare *(reproduced with permission from Evans et al, 2002)*

associated PTLs work well for this purpose.

To evaluate the role of PTLs, we deliberately selected a sample who suspected that they may have a visual trigger to their migraines and who found a coloured overlay to be helpful. This was necessary to obtain a concentrated sample of people who may be helped by PTLs. But it means that our study does not allow us to estimate what proportion of people with migraine have a visual trigger for some of their headaches. This is the subject of current research at the Institute of Optometry. This research is also evaluating the prevalence of other optometric (including orthoptic) factors in an unselected group of people with migraine. Evans et al[12] included a brief review of the literature on this subject, but a more detailed review will be completed shortly[21].

Clinical implications

Migraine is very common, and even if only a small proportion of people with migraine can be helped with PTLs, then this may still represent a significant role for the optometrist. Most of these patients can be self-selecting: with appropriate information, patients can evaluate whether their migraines seem to have a visual trigger. It is, therefore, advisable for

Table 3 Effect of PTLs on optometric function (D = distance, N = near)

Not significantly better with active tint (p>0.05)	Better with active tint (p<0.005)
N variability of dissociated phoria	Pattern glare
N convergent fusional reserves	
Fusional amplitude	
D&N aligning prism	
D divergent fusional reserves blur, recovery	D divergent fusional reserves break point
N dissociated heterophoria	
N divergent fusional reserves (blur, break, recovery)	
N convergent fusional reserves (blur, recovery)	
N Percival's criterion	
N Sheard's criterion	

Table 4 Key diagnostic features of migraine

Migraine without aura (most common)	Migraine with aura (less common)
At least five attacks which: • Last four to 72 hours • Have at least two of the following: – unilateral – pulsating – inhibits daily activities – aggravated by routine physical activity • Are associated with either nausea or vomiting	At least two attacks which have three of the following: • Fully reversible aura symptoms (e.g. vision, unilateral weakness, difficulty speaking) • At least one aura symptom develops gradually or two or more symptoms occur in succession • No aura symptoms last more than 60 minutes • Headache follows aura in less than 60 minutes

Table 5 Typical migraine symptoms and atypical symptoms which may indicate pathology

Typical migraine (pathology less likely)	Atypical symptoms (pathology more likely)
Typical migraine phases: • Prodrome (mood, heightened sensations) • Aura (if present) for five to 60 minutes • Headache for four to 72 hours (moderate or severe, pulsating) • Post-dromal (washed-out, sleep) Typical aura (if present): • Precedes headache • Evolves (spreads out over time) • Positive effect (seeing something, not usually a negative scotoma)	Brain tumour may be associated with: • Permanent field loss • Headaches worsening over time • Other neurological signs (e.g. personality change, neck stiff, seizure, papilloedema) Sub-arachnoid haemorrhage may be associated with: • Very severe (thunderclap) headache with vomiting and photophobia • Bilateral

optometrists to ask all patients about any headaches they experience, to try to determine if any are associated with visual stimuli (e.g. flickering lights, patterns, computers, fluorescent lighting, text). Lines of text can form a striped pattern that may elicit pattern glare, so the reading of text (or music) can be a visual stimulus that might trigger migraine.

These patients should undergo a full eye examination and any clinically significant pathology or refractive or orthoptic anomalies should be dealt with in the usual way. Patients with visually precipitated migraine can be assessed with an Intuitive Colorimeter to determine whether PTLs will be helpful, and to identify the appropriate colour. Patients usually know which visual stimuli or tasks precipitate their migraines, and this is when the PTLs need to be worn. In addition to the use of PTLs to "avoid triggers", some patients also find that PTLs help to reduce the severity of their symptoms during migraine episodes.

There is little data on whether the required colour of PTLs changes with time, so as a precaution it may be appropriate to check this every year or more frequently in the young.

There is one other important role for the optometrist in migraine, which applies even to cases where there is no visual trigger for the migraine. According to various studies, between 50% and 80% of migraine sufferers do not consult a medical practitioner about their migraines. Yet, migraine is a debilitating condition and major depression occurs in 22-32% of people with migraine compared with only 9% of controls[22]. Furthermore, modern drugs mean that migraine can be treated effectively in the majority of cases[23]. In other words, most migraine patients do not have to suffer and do not need to have many days of their life every year 'written off' through head pain and nausea. Optometrists can play an important role in helping these patients, simply by recognising the signs of migraine and referring the patients to their GP for modern medical management. So, even for cases who we cannot help visually, we can play a useful role by suggesting a diagnosis and referring to the GP. To help with this, the key diagnostic features of migraine are summarised in **Table 4**[16].

It is also important for clinicians to be aware of the typical signs of migraine, and of the signs which are atypical of migraine and which may be indicative of other, more serious, pathologies. Some of these are summarised in **Table 5**. Clearly, if these or other suspicious signs are present then the patient should be referred urgently. Bear in mind that the symptoms of migraine in childhood differ from those in adulthood and can be more difficult to diagnose. Relative to adults, children may be less likely to mention headaches and more likely to talk of feeling sick and having 'tummy aches'.

In summary, an important part of the optometrist's role as a primary eyecare professional is the investigation of headaches. Any patient with migraine-like headaches requires a thorough eye examination, and many will require referral for medical treatment and/or investigation. For some, there will be a visual component to the migraine, and in these cases, the optometrist may be able to treat the visual element of the disease. The Intuitive Colorimeter and PTLs are important tools for helping these patients.

Acknowledgements and ethical declaration

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References

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