

The use of prisms and botulinum toxin in the detection of binocular vision: a literature review

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Abstract

Aim: The aim of this literature review is to compare orthoptic prisms and botulinum toxin in the diagnostic testing of strabismus patients. A direct comparison will be carried out between both methods used for predicting post-operative diplopia and binocular single vision (BSV). A further comparison of the complications and cost effectiveness of both methods will be conducted.

Methods: A review of the literature was conducted using journals available at the University of Liverpool, along with the scholarly online resources PubMed, Web of Science and Google Scholar and the orthoptic search facility (http://pcwww.liv.ac.uk/~rowef/index_files/Page646.htm). Search terms included 'post-operative diplopia', 'binocular single vision', 'prisms' and 'botulinum toxin'.

Results: Botulinum toxin provides accurate positive and negative predictive responses for post-operative diplopia testing and is useful in assessing BSV potential in strabismus patients. Prisms can correctly identify patients with no risk of post-operative diplopia, but have a poor predictive outcome for diagnosing those at risk. The use of prisms to assess BSV potential in patients has not been well established in the literature.

Conclusion: Botulinum toxin appears to be more effective overall in detecting a binocular response; however, the complications and individual needs of the patient must be considered before testing. The accuracy of prisms in detecting patients who will not get post-operative diplopia, and the reduction in cost compared to botulinum, would indicate that they should be used in the first instance. If the patient detects double vision on prism testing, then an injection of botulinum toxin is indicated to determine an accurate result. Further research on the use of prisms to diagnose BSV potential compared to botulinum toxin is required in order to conclude which method is most effective in this area.

Key words: Binocular single vision, Botulinum toxin, Complications, Cost, Diagnostic, Post-operative diplopia, Prisms

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Introduction

Prisms and botulinum toxin (BT) can be used diagnostically to test for potential post-operative diplopia and binocular single vision (BSV) in strabismus patients. These tests are extremely important in deciding whether or not to go ahead with surgical management.¹ Post-operative diplopia assessments are vital for two reasons: first, diplopia can be very distressing for the patient, causing difficulties in their everyday routine, and second, the management for diplopia after surgery is frequently unsuccessful when the patient is unable to cope with it.² If the pre-operative assessment shows a possibility of post-operative diplopia, then patients will usually be discouraged from squint surgery, due to lack of fusion, unless they can find the diplopia tolerable.³

Post-operative diplopia assessment can be done using BT or clinical prisms to neutralise the angle of strabismus.^{2,4,5} This realignment of the eyes can help the patient to temporarily achieve BSV, allowing investigation of the presence of fusion.^{6,7} Often these patients will be recommended for surgery when BSV is detected.⁸ The aim of this review is to determine which provides a better diagnosis for post-operative diplopia and BSV: BT injections or prisms.

Diagnostic uses

Botulinum toxin and prisms may be used for the diagnostic purposes of detecting post-operative diplopia and potential for BSV. The most effective method, which should then be encouraged in clinical practice, will be determined by comparing each method's success rate.

The post-operative diplopia test is a pre-operative assessment of the likelihood that a patient will experience post-operative diplopia. By undercorrecting, correcting and overcorrecting the angle of deviation, the test evaluates the area of suppression and therefore the possible occurrence of diplopia at these various angles of deviation. A diplopic response can be considered a contraindication to surgical correction of the deviation, or may indicate the need to confirm with a trial with Fresnels (prism adaptation) or an injection of BT. This response could also indicate the surgical dose be calculated to allow for suppression or, if possible, to achieve BSV.

The use of clinical prisms to assess binocular vision in the presence of manifest strabismus requires the correc-

Table 1. A comparison of the success of botulinum toxin (BT) and prisms in predicting post-operative diplopia

Study	Used BT or prisms	No. of patients	Tested positive for post-operative diplopia with BT	Tested positive for post-operative diplopia with prisms	No. of patients with diplopia post-operatively
Rayner <i>et al.</i> ¹⁶	BT	82	11	n/a	1
Lawson <i>et al.</i> ²²	BT	30	15	n/a	6
Khan <i>et al.</i> ⁴	BT and prisms	195	14	195	0
Kushner ⁹	Prisms	424	n/a	143	43
Dawson and Lee ⁸	BT and prisms	3	0	3	0

tion of the angle of deviation followed by evaluation of binocular responses. Unfortunately, the review of the literature did not reveal any research on the efficacy of this method, particularly in comparison with BT.

The use of prisms in the assessment of post-operative diplopia

Prisms can be used in clinic to assess the size of the suppression scotoma by performing the post-operative diplopia test. Kushner concluded that the use of prisms diagnostically may be able to detect a small number of patients (2%) at risk of developing persistent post-operative diplopia but could detect 100% of patients with no risk.⁹ Only 3 of 143 patients who recognised double vision with prism testing went on to develop persistent post-operative diplopia. Patients who experienced diplopia in the pre-operative assessment were significantly more likely to develop diplopia than if they had not reported it before surgery. However, it would appear that although these findings were statistically significant, they were not clinically significant. The presence of diplopia when testing with prisms provided only a 2% chance of developing constant diplopia after surgery. It was also found that whilst 34% of patients were aware of diplopia when testing with prisms, there was only a 0.8% chance of developing double vision after surgery.⁹ Jenkins also concluded that diplopia is essentially a rare possibility with surgery.¹ A similar study by Khan *et al.* found that the use of prisms in testing for post-operative diplopia gave unreliable results when compared to BT.⁴ It was revealed that 93% of the patients who reported diplopia with prism testing had only minimal risk. Conversely, if patients show no recognition of diplopia with the prisms, then it provides excellent assurance that they will not develop diplopia after surgery.⁹

Table 1 shows prism testing to have a smaller chance of identifying patients who are at risk of post-operative diplopia compared with BT. Although prisms are not as successful as BT in detecting those at risk, they are extremely successful in determining which patients have a low or no risk of developing post-operative diplopia.⁹

The use of prisms in the assessment of binocular vision

Fresnel prisms can be used in the longer term if testing suggests a long-standing deviation, especially if there are signs of abnormal binocular vision. In cases of constant strabismus, a prism adaptation test can determine the possibility of suppression based on a given amount of surgery by overcorrecting the patient initially and

causing them to experience diplopia. This can in turn reveal a larger amount of latent deviation to advise the surgeon on the true angle of deviation.⁶ Prism adaptation has shown additional benefits in some cases. Nave revealed those that responded to prism adaptation progressed to surgery based on their new prism-adapted angle.¹⁰ Remarkably, all the patients in this group could demonstrate sensory fusion and stereo-acuity, and all but one were able to achieve motor fusion after surgery. Similar studies suggest the success rate of surgery increases after prism adaptation compared with those who did not partake in the treatment.¹¹⁻¹³

Fresnel prisms can further correct the angle to temporarily regain lost BSV. In cases where there is suspicion of lost or impaired ability to fuse, correcting diplopia with Fresnel prisms and leaving the patient for a period of time helps to prevent suppression and determine if they have fusional potential.¹⁴ One study describes the wear of Fresnels full time for patients with recent loss of BSV. Follow-up assessments showed an improvement in BSV and the amount of prism needed was therefore gradually reduced.¹⁴ The results revealed that prisms were helpful for diagnosis of patients with BSV potential and for concurrent treatment to re-establish binocular single vision. This same method was reported in Brown, who further stressed the importance of attempting to restore BSV with prisms before surgical correction.¹⁵ Additionally, Fresnel prisms may simply be used to establish whether diplopia is tolerable, or could be ignored or re-suppressed.¹

The literature review showed that no study has compared this method, of using prisms to artificially assess binocular potential, with that of BT, which physically alters the eyes' position, in order to assess the presence or absence of BSV. More research is needed to assess which diagnostic method provides the most reliable findings. However, it should be highlighted that although a comparison of these methods would be useful, they are not always interchangeable, as prism strength can be adjusted whereas the effect of BT cannot, and it often wears off unpredictably.

The use of botulinum toxin in the assessment of binocular vision

Patients with binocular potential can be detected as the effects of BT wear off, and the possibility of achieving BSV can be assessed. It can further assess if a small reduction in angle would allow binocular vision to be regained and lead to maintained control in the long-term. Dawson & Lee found that 10% of patients with no clinical demonstrable pre-operative binocular function

developed fusion and stereopsis post-injection.⁸ A study by Rayner *et al.* reported a 54% success rate of improving or totally restoring BSV in the long term.¹⁶ Dawson *et al.* found similar results, with 36% of their patients demonstrating improved stereopsis.¹⁷

BT is particularly useful in detecting binocular function in cases where the angle of deviation is too large to obtain an accurate result from prism testing.³ The high strength of prisms can adversely reduce visual acuity by distortion, whereas BT can correct alignment without any disruption to visual acuity. Once a deviation exceeds 75D, the angle is considered too large to obtain an accurate reading with prisms.³

Different classifications of strabismus have shown better outcomes in detecting BSV with BT. Dawson *et al.* promote the use of BT in cases of consecutive exotropia and their results show a high incidence of restored fusion with minimal complications.¹⁸ BT is more effective in cases of secondary strabismus following trauma, when the presence of BSV cannot be established.¹⁹ BT has a further role in the investigation of BSV potential in patients with infantile esotropia, mild amblyopia and small angled or decompensating deviations.^{20,21} Patients with a known history of BSV appear to respond better to BT.³

The use of BT in the assessment of post-operative diplopia

BT is useful in detecting a low or no risk of post-operative diplopia after initially finding patients to be at risk with conventional prisms.⁴ If present, it allows the patient to experience double vision in true-life situations for an extended period of time without any disruption to their visual acuity. This enables them to give an accurate response as to how well they can tolerate it, or find they can re-suppress or simply ignore the double vision.³ A study by Khan *et al.* in 2008 found just 14 out of 195 patients that reported diplopia with prism testing developed diplopia after the BT injection.⁴ Five of these were able to cope well with their double vision and chose to proceed with surgery. According to the findings, all patients who went forward for surgery were unaffected by diplopia post-operatively. A similar study reported only 3 of 31 patients to develop disturbing double vision following BT, subsequent to a previous diplopic response on prism testing.² Rayner *et al.* presented a high rate of accurate post-operative diplopia results (88%) when using BT.¹⁶ Thirty-two of their patients who found no diplopia using BT proceeded to surgery with only 1 developing intermittent double vision post-operatively. The rest experienced no post-operative diplopia, demonstrating the diagnostic effectiveness of BT. However, it is not clear whether or not they regained BSV or continued to suppress. Even in studies of small numbers, where bias could be an issue, patients with previous diplopia results show no risk after botulinum treatment and frequently proceed to surgery.

Collectively, these results postulate a high success rate for BT in detecting patients both with and without risk of post-operative diplopia. BT appears effective in reducing the number of false positives, after prisms have diagnosed patients to be at risk of post-operative diplopia.

However, BT has not always been found to be totally accurate in predicting diplopia. Lawson *et al.* reported 2 patients who proceeded to surgery despite demonstrating a risk of post-operative diplopia with BT, but experienced no symptoms after treatment.²² This is a much smaller number however, compared with those with accurate test results using BT.

Complications

Complications of botulinum toxin

The frequency of side effects from BT is relatively low²³ with an overall incidence of 12.4%. A temporary ptosis is the most common side effect with a prevalence of 8.4%.^{23,24} The effects of BT are, however, only transitory, resolving typically over 6 weeks.²³ Occasionally though, ptosis is found to last up to 16 weeks.²⁴ This, however, is rare as most studies have shown ptosis to be short-lived and tolerated by the patient.²³

The literature found an induced vertical deviation to have an incidence of just 2%,²³ but it can be a troublesome side effect especially when surgery is subsequently needed to correct it.²⁵ It can cause particular problems for patients undergoing the treatment in order to regain binocular fusion, as an induced vertical deviation can further disrupt the potential to fuse.^{20,26} In addition, long term persistence of the vertical deviation has been found after BT injections, lasting on average for 13 months.⁵ It is also apparent that these patients are more sensitive to the cosmetic outcome of a vertical deviation of the same size as the horizontal one they had presented with previously.⁵

Young children experience more frequent complications.²⁴ The incidence of ptosis with ketamine is seen to be near double that with local ocular anaesthetic. This is due to a weak electromyography (EMG) signal, without the patient's co-operation, causing inaccurate localisation of the injection.¹⁶ Other side effects of using ketamine for BT injections include increased salivation, hypertension and the emergence phenomena, which comprises hallucinations, nightmares and sleep disturbances.^{24,27} Although the age of the patient influences the choice of anaesthetic used it should be noted that, when possible, the use of local anaesthetic could potentially reduce the risk of general anaesthetic complications. Additionally, using dimmed lighting and gentle music in the recovery room reduces the likelihood of the emergence phenomena. Instructing the patient to sit up immediately after the botulinum injection, or propping up children under ketamine anaesthesia, shows a reduction in the risk of post-operative ptosis and induced vertical muscle weakness.²⁴ The incidence of complications can further be controlled using a dose of less than 10 units (U) of Dysport and 2.5–3U of Botox.^{5,25}

Further complications include subconjunctival or retrobulbar haemorrhaging, with an incidence of 1%²³ and 0.9%.²⁵ It was also reported that the use of epinephrine (0.01%) prior to the botulinum injection could reduce the incidence of conjunctival haemorrhaging.¹⁸ Globe perforation is a possible side effect, although did not occur in the papers reviewed, indicating a very low incidence.^{23,25}

Complications of prisms

The high rate of false positives when testing with prisms has been noted in various studies.^{4,9,28} All forms of prism (loose prisms, prism bars and Fresnels) are unsuccessful when used to simulate the effect of surgery in patients with high deviations.¹⁷ They can blur vision, resulting in an overestimation of post-operative diplopia.¹⁷ However, this blur can similarly diminish the second image and therefore underestimate diplopia. Kushner describes how the 'ghosting' around an image caused by this blur confuses patients into believing it is diplopia.⁹

Clinical prisms

Combining two plastic prisms results in a greater prismatic effect.²⁹ To overcome this, splitting the strength of prisms when measuring 45^Δ or more between the 2 eyes can successfully reduce the effect on visual acuity.³⁰ Additionally, the distance at which prisms are held from the eyes may overestimate the angle.³¹ More accurate assessments are obtained when prisms are held at >2 cm from the eye,³² but the amount of overcorrected prism can become quite considerable when held at >4 cm from the eye.³¹ Ideally prisms should be held at 2–4 cm from the eye.

Prisms held incorrectly will inaccurately measure strabismus angles.³² Prism bars are often made for utilisation in the Prentice position but are usually held in the frontal plane position, thus exaggerating the measured angle.³² This could affect the results when testing for post-operative diplopia or BSV if the angle is overcorrected.

Fresnel prisms

To overcome prismatic blur and help achieve binocularly, Choi *et al.* reported splitting Fresnels used in prism adaptation therapy of 10^Δ or more.²⁸ Furthermore, Cotton and Griffiths found that Trusetal prism foils reduce the adverse effect on visual acuity, more so than 3 M Fresnel prisms, in strengths greater than 30D.³³ Therefore, the type of Fresnel prism should be considered in clinical practice. In addition to splitting the strength, the larger of the two prisms should be placed in front of the fixing eye and, ensuring the prisms are kept clean, can prevent any adverse effects.⁶

Prism adaptation therapy is time consuming for both the patient and orthoptist and requires a further level of co-operation from patients.⁶ Furthermore, the prismatic effect of a patient's refractive correction must be taken into consideration when using prisms, as this can alter the true measurement of the corrected angle.³²

Cost

The aspect of cost should be considered for each method as this provides important information for choice of assessment and treatment.

Cost of botulinum toxin

The cost effectiveness of BT has not been well documented, with most papers being unable to acquire the exact cost of the treatment.^{7,34} However, where docu-

Table 2. The cost of all aspects of prism and botulinum toxin treatment (with Trusetal prisms used for prism adaptation therapy)

Expenses	Botulinum toxin	Prism adaptation therapy
Staffing	£51.00	£17.00
Botulinum injection	£71.00	n/a
Fresnel prism	n/a	£13.03 (3 M Fresnel) or £11.50 (Trusetal Fresnel)
Plano glasses (for Fresnel prisms)	n/a	£6.00
Total	£173.00	£33.11

Sources: cost of BT (Gardner *et al.*³⁶), staffing cost of ophthalmologist (<http://www.nhs-careers.nhs.uk/explore-by-career/doctors/pay-for-doctors/>), staffing cost of orthoptist (<http://www.nhs-careers.nhs.uk/working-in-the-nhs/pay-and-benefits/agenda-for-change-pay-rates/>), cost of Fresnels (Philips *et al.*⁴⁰, Thurtell and Leigh⁴¹), plano glasses (www.selectspecs.com), Trusetal prisms (www.eyesfirst.eu).

mented, the issue of cost has presented much debate between researchers. One paper reports the high cost of BT to limit the value of the toxin,³⁵ while others find the treatment to be cost effective.¹⁸ The cost of a single injection has been reported at £71.00 (c£140.00), which included the cost of the outpatient appointment and the disposable electrodes.³⁶ As BT injections are usually performed by an ophthalmologist, whereas prism testing is typically undertaken by an orthoptist, the staffing cost of each should be compared (Table 2). The cost of an ophthalmologist clinical visit in the UK is around £51.00. This was calculated using the annual salary for an ophthalmologist in 2013, taken from the NHS UK website, and dividing it into hourly sessions.³⁷ However, the treatment still requires an orthoptic assessment prior to the treatment and during the follow-up visits,³⁸ which should also be taken into account. In addition, it is difficult to estimate how many follow-up appointments are necessary for each patient as complications would require additional appointments or, further still, additional treatment for induced vertical deviation or complete ptosis.^{5,25}

Cost of prism testing

The cost of a full orthoptic assessment is approximately £17.00. Again, this was calculated using the annual salary of a band 6 orthoptist.³⁹ This is considerably cheaper than the staffing costs of an ophthalmologist performing BT injections. The cost of Fresnel prisms and plano glasses when necessary for prism adaptation therapy have further been compared against the cost of BT injections (Table 2). However, it should be highlighted that the reduced accuracy of prism therapy for detecting diplopia may result in a need for further assessments and clinical appointments, thereby adding to the cost.⁴ Additionally, the need to split the prism strength between the two eyes will result in the cost of an extra Fresnel prism. Continuously changing the prism strength for the prism adaptation test will require extra Fresnels, increasing the overall cost of the treatment.²⁹ In order to reduce the cost of prism therapy, Trusetal prisms have been recommended, as they are not only cheaper but also more effective in reducing the adverse effects of high strength prisms.³³

Clearly, prisms are the cheaper option based on

comparison of one visit only. It is difficult to definitively compare these costs for a treatment period as this depends on the individual patient, their response to the treatment and requirement for follow-up visits.

Discussion

In relation to post-operative diplopia testing, the literature suggests benefit from the initial use of prisms. This is due to the accuracy of negative responses (i.e. no diplopia detected) and the reduced cost of using prisms. If the patient does not complain of diplopia on prism testing, it can be assumed that they will not experience diplopia post-operatively. However, if the patient reports a risk of intractable diplopia, or if the angle of deviation is too large to obtain an accurate result, then BT should be used to reduce the likelihood of a false positive result. Furthermore, if BT does not produce diplopia, then it is most likely that the patient will not experience diplopia after surgery.⁹ However, it is important to highlight that many studies fail to address the fact that once prisms have predicted a risk of post-operative diplopia, surgery is adjusted and, as a result, post-operatively there is typically no diplopia. This could possibly make prisms appear less reliable than they really are.

The prism adaptation studies conclude a considerable benefit of the use of this assessment in determining the patient's precise binocular abilities and, ascertaining the amount of surgery necessary to achieve the best outcome. However, as the treatment is time-consuming and requires a higher level of cooperation, the individual needs of the patient should be taken into consideration before commencing treatment.⁶

When using prisms diagnostically, careful attention should be given to the position the prisms are held in according to their calibration. Usually in practice clinicians will hold prisms, which are calibrated for the frontal plane position, in the position of minimum deviation. The difference in measured angle is only slight, although it should be stressed that if held in the Prentice position, the calculated angle may be vastly inaccurate for large angle strabismus.³¹

BT injections can successfully assess BSV potential in patients where the angle of deviation is too large to make an accurate assessment with prisms.³ However, it should not be overlooked that BT is an expensive alternative to prism testing, and its use will depend on the financial capabilities of individual departments. This alone may explain the persistent role of prisms in clinics today despite the benefits BT has over prisms for diagnosis of binocular potential and risk of post-operative diplopia.

The authors declare they have no competing interests.

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