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The response of the anophthalmic socket to prosthetic eye wear

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Purpose: The aim of this study was to investigate the inflammatory response of the anophthalmic socket to prosthetic eye wear.
Methods: One hundred and two prosthetic eye wearers were recruited for this observational study. Photographic grading scales were used to measure the severity of conjunctival inflammation and the extent and intensity of stained deposits on the prosthetic eyes. Tear volume was measured with the phenol red thread test. For mucoid discharge, visual analogue scales were used to assess frequency of occurrence, colour, volume and viscosity. For the prostheses, assessments were made of weight, shape, wearing time and frequency of cleaning.
Results: Anophthalmic sockets had more severe conjunctival inflammation than their companion eyes ($p = 0.0001$). The difference in inflammation between the companion eye and the anophthalmic socket was associated with discharge volume ($p = 0.01$) and discharge viscosity ($p = 0.007$) with greater difference in inflammation being associated with higher levels of discharge volume and viscosity. A greater difference in inflammation was also associated with less surface deposition ($p = 0.009$). No evidence of associations was found between difference in conjunctival inflammation and the other variables.
Conclusions: Recently developed grading scales for measuring inflammation in anophthalmic sockets and deposits on prosthetic eyes were used for the first time in this study. It is recommended that in clinical practice, inflammation grades for both socket and companion eye conjunctivae be compared, when determining if prosthesis-induced inflammation is present. The finding that more discharge was associated with more conjunctival inflammation is logical but the finding that less inflammation was associated with more deposits is counter-intuitive to those familiar with the contact lens literature. The apparently benign nature of at least some deposits on the prostheses raises questions about the maintenance of prosthetic eyes. We conclude that the simple presence of deposits is unlikely to be linked with inflammation of the conjunctiva in wearers of prostheses, who like those in this study, cleaned their prostheses regularly but not frequently.

Keywords: anophthalmic socket, conjunctiva, inflammation, deposits, prosthetic eye

Two recent studies by Chang and colleagues[1] and Kim and colleagues[2] have investigated links between prosthetic eye removal, cleaning regimes and conjunctival inflammation in anophthalmic sockets. Chang and colleagues[1] used an independent ophthalmic pathologist to estimate inflammation on a 0–3 scale, while Kim and colleagues[2] used a verbally descriptive biomicroscope-based grading of bulbar conjunctival inflammation to describe degrees of conjunctival injection and oedema, together with the criteria used by Saini, Rajwanshi and Dhar[3] for tarsal conjunctival inflammation (Table 1).

Both investigations failed to find any significant link between inflammation and care regime; however, it is possible that the scales they used were too coarse for small changes in inflammation to be noticed. Bailey and colleagues[4] recommended using finer than four-point grading scales and Chong, Simpson and Fong[5] showed that scales using reference photographs have better repeatability than verbally descriptive scales. Pine and colleagues[6] developed a novel technique for staining deposits on prosthetic eyes and followed the recommendations of Bailey and colleagues[4] and Chong, Simpson and Fong[5] by creating a photographic grading scale with fine divisions for measuring conjunctival inflammation in anophthalmic sockets. Pine and colleagues[6] also created similar scales for measuring the extent and intensity of stained deposits on prosthetic eye surfaces.

This study employs these measuring tools for the first time. It uses them to compare conjunctival inflammation in the anophthalmic socket with the companion eye and to investigate associations between inflammation and some of the factors associated with prosthetic eye wear. The factors included were tear volume, mucoid discharge and for the prosthetic eye, its weight, shape, wearing time, surface deposits and frequency of cleaning.

METHODS

The New Zealand Artificial Eye Service, the Royal New Zealand Foundation of the Blind, the Accident Compensation Corporation and five District Health Boards agreed to

Grade	Number of papillae and their diameter and the presence or absence of hyperaemia.
1	Satin appearance with smooth and uncongested conjunctiva.
2	Uniform papillary appearance in which small (0.25 mm diameter) papillae were seen.
3	Non-uniform papillary appearance in which some of the papillae were 0.4 to 0.8 mm in diameter.
4	Giant papillary appearance in which papillae of 1.0 mm or more were seen.

Table 1. Criteria used by Saini, Rajwanshi and Dhar[3] for tarsal conjunctival inflammation

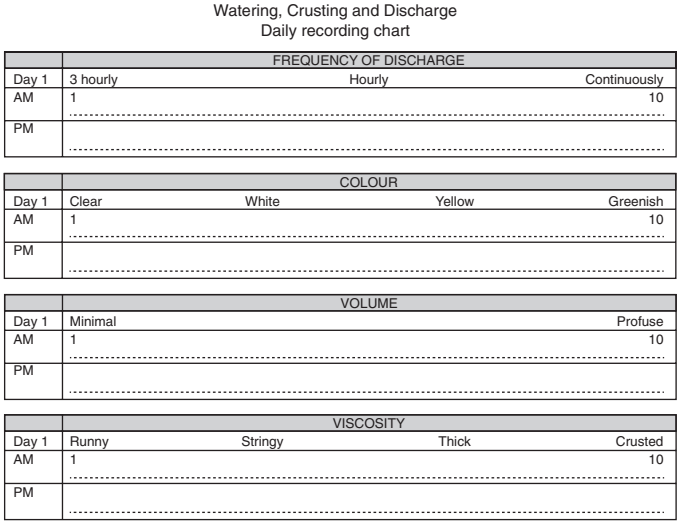

Figure 1. The four visual analogue scales used by an experienced clinician to record discharge characteristics of frequency, colour, volume and viscosity

Camera	Canon 1000D
Lens	Macro EF-S 60 mm f/2.8 USM
Flash	Cannon Macro Ring Light MR-14X
Camera setting	Manual
Exposure time	1/125 second
Aperture size	F/32
Focus	Automatic
Picture style	Faithful
White balance	Flash
Sensitivity	ISO 400
Flash setting	Manual exposure
Flash output	1/16
Distance from sensor plane to the subject for photography	22–27 cm

Table 2. Camera specifications and photographic settings

post an anonymous questionnaire to their anophthalmic patients on behalf of the authors. Three hundred and thirty-four anophthalmic patients completed the questionnaire and agreed to participate in prosthetic eye research. Of these, 108 were selected for this study on the basis that they had worn a prosthetic eye for at least six months and had easy access to research clinic sites. Provision was made to exclude ocular health issues of the companion eye, if they were identified during the clinical review.

The Multi-Regional Ethics Committee of the Ministry of Health approved the study protocols.

An open-eye phenol red thread test was used to assess tear volume on both eyes.[7] The 'Zone-quick' sterile standardised phenol red threads were provided by Showa Yakuhin Kako Company Limited of Tokyo, Japan.[8] The lower lid of each eye (chosen randomly) was gently pulled down and the folded 3.0 mm end of the thread was placed onto the palpebral conjunctiva at a point one-third medially of the lateral canthus. After 15 seconds the thread was removed and the wetted stained portion was immediately measured in millimetres.

Discharge characteristics of the anophthalmic socket with the prosthesis removed were assessed by an experienced clinician using separate visual analogue scales to grade each of the four discharge characteristics: colour, viscosity, volume and frequency (Figure 1).

The prosthetic eyes were weighed on a 100 g (0.01 g intervals) electronic scale. The shape of each prosthetic eye was assessed as belonging in one of four categories according to the shape of the posterior surface of the prosthesis. The surfaces were either convex (category 1), flat (category 2), concave (category 3) and very concave (category 4).

To grade conjunctival inflammation, the lower lids of the anophthalmic socket and the companion eye were everted over a cotton bud to fully expose the lower tarsal conjunctivae. Separate digital photographs were taken using standardised camera settings (Table 2). The photographs were coded to de-identify the participant but to allow tracking. Each photograph was copied onto the centre of separate PowerPoint (Microsoft, Redmond, WA, USA) slides. Each PowerPoint slide contained a copy of a previously developed five-photograph grading scale[6] on a grey background (Figure 2). The severity of conjunctival inflammation of the photograph in the centre of each slide was graded independently by three experienced clinicians (an ophthalmologist, an optometrist and an ocular prosthetist). The graders were instructed to use interpolated grades to the nearest 0.1, when assessing inflammation on a 0–4 scale.

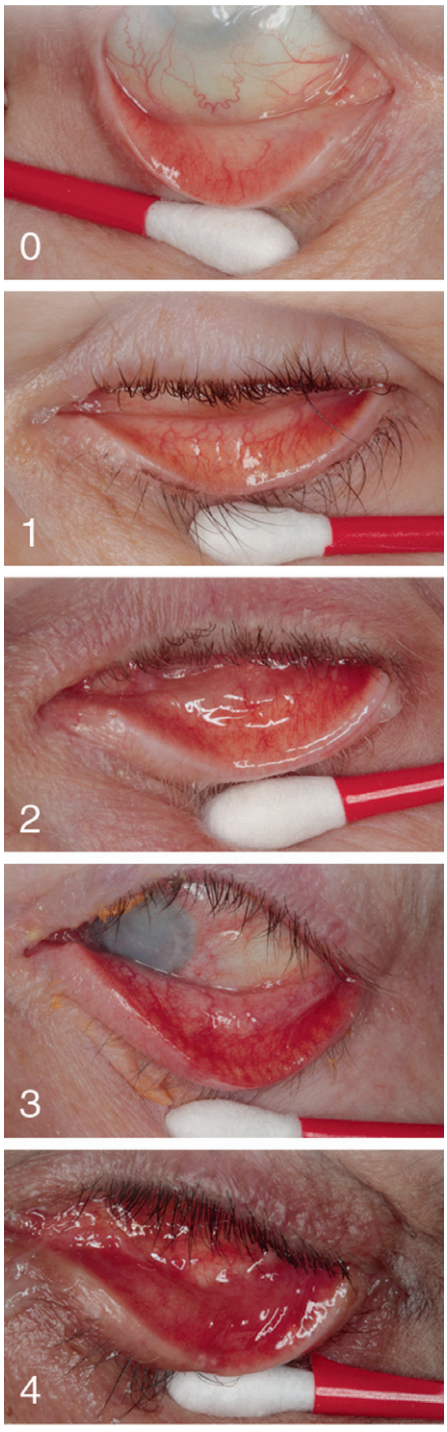

Figure 2. The five-photograph continuous grading scale used with interpolation for measuring the severity of inflammation of the palpebral conjunctivae

The severity score for the conjunctival inflammation of the anophthalmic socket of each subject was compared to the score for the companion (control) eye. The differences between socket and companion eye inflammation severity grades were used in further analyses.

Water	70–75 per cent
Ethyl alcohol	18–20 per cent
Food red 105 (Rose Bengal)	4 per cent
D sorbitol	3 per cent
Sodium carboxymethyl cellulose (CMC-Na)	2 per cent
Butyl p-hydroxybenzoate	<1 per cent
Flavouring	<1 per cent
Sodium salicylate	<0.1 per cent

Table 3. GC Corporation plaque disclosing gel ingredients

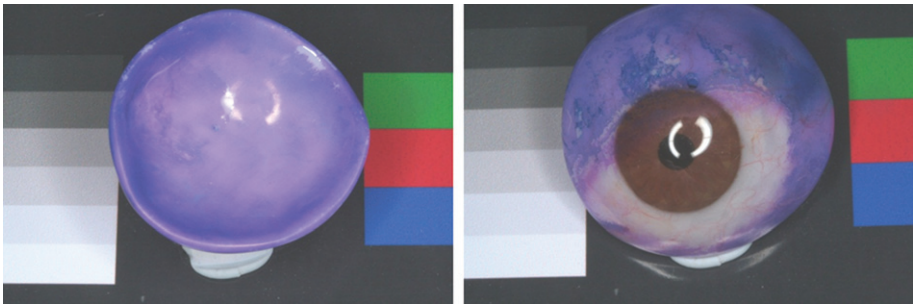

Figure 3. Posterior and anterior surface deposits stained with plaque-disclosing gel solution and photographed using a standard format

To grade the extent and intensity of surface deposits on prosthetic eyes, a staining solution was made by dispersing 5.0 g of GC Corporation plaque disclosing gel (Table 3) in 30 ml of 0.85 per cent saline solution. The prostheses were submerged in the solution at 20°C (68°F) for a period of two minutes. After removing and blotting with tissue paper, the prosthetic eyes were photographed front and back against a black background, which included a standard grey scale and colour scale to ensure the consistency of the photographic settings throughout the project (Figure 3). The prosthetic eyes were cleaned to remove the stained deposits and polished before being returned to participants.

Photographs of the stained prostheses were set up on Microsoft PowerPoint slides and graded by the same graders and in the same manner as the photographs of conjunctival inflammation described above using only the previously developed deposits grading scales[6] (Figure 4). The average of the anterior and posterior scores was used to calculate the final grade.

A general linear model was used to investigate variables associated with the difference in conjunctival inflammation in the socket compared to the companion eye. Explanatory variables included were the shape and weight of the prosthetic eye, how long the participant had worn a prosthesis, frequency of cleaning, surface deposits on the prosthesis, difference in tear volume between the prosthetic and companion eye and measures of discharge. Volume and viscosity of discharge were selected to represent the discharge properties. A sample of 100 would have 80 per cent power to detect a correlation of 0.27 at the five per cent level of significance.

Concordance correlation[9] and a paired t-test were used to investigate differences between conjunctival inflammation of the anophthalmic socket and the companion eye.

RESULTS

Six volunteers chosen for the study elected not to participate but the 102 participants who attended clinics lived in or near main urban areas (more than 30,000 population)[10] of the North Island of New Zealand.

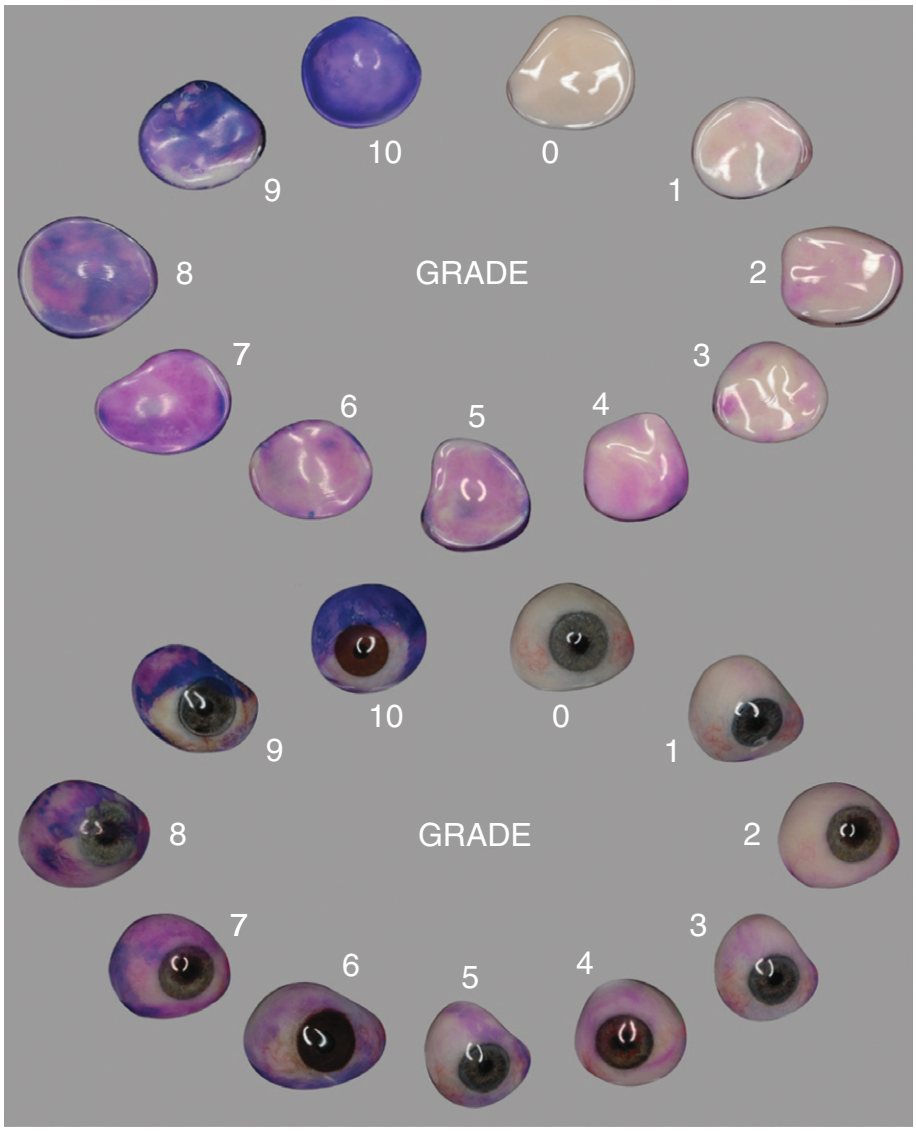

Figure 4. Posterior and anterior continuous grading scales for measuring (with interpolation) the extent and intensity of surface deposits on prosthetic eyes[6]

Sixty-three attended clinics at Auckland, 13 at Wellington, 11 at Tauranga, eight at Whangarei and seven at Rotorua. No ocular health issues were identified in the companion eye of any participant and no implant exposures or other signs of specific irritation were found in the anophthalmic sockets.

The severity of the lower palpebral conjunctival inflammation of the natural eye correlated with that of the anophthalmic socket (concordance correlation coefficient of 0.45, 95 per cent confidence interval 0.304 to 0.574);[11] however, the difference between the two was significant (mean difference 0.58 ± 0.72, $p = 0.0001$).

Associations were found between the difference in inflammation (between socket and companion eye) and discharge volume ($p = 0.01$) and viscosity ($p = 0.007$), with more severe inflammation in the anophthalmic socket compared to the companion eye being associated with higher levels of discharge volume and viscosity. Difference in inflammation was also associated with surface deposition ($p = 0.009$) with more severe inflammation in the anophthalmic socket compared to the companion eye being associated with fewer deposits. We were unable to demonstrate an association between the difference in conjunctival inflammation and prosthetic eye maintenance, period of wear, prosthesis weight or shape or tear volume in this study. The estimates of the beta coefficients and their standard errors for all variables included in the analysis can be seen in Table 4.

DISCUSSION

The study was designed to attract prosthetic eye wearers that were well dispersed throughout the North Island of New Zealand. This was to ensure (as much as possible) that a wide variety of surgical procedures and prosthesis wearing conditions were represented.

Photographic grading scales with fine grading steps were used to measure conjunctival inflammation rather than the verbally descriptive coarser scales used by Kim and colleagues[2] or the 0–3 scale used by Chang and colleagues.[1] This study did not measure cytologic change but like the studies of Kim and colleagues[2] and Chang and colleagues,[1] it did compare conjunctival inflammation of the anophthalmic socket with the companion eye and tested the hypothesis that there was no association between inflammation and aspects of prosthesis wear, including cleaning frequency. All three studies found no statistically significant associations with cleaning regime, where a questionnaire was used to determine cleaning frequency; however, cleaning frequency may not be the best method for determining prosthetic eye 'cleanness' because it does not take into account cleaning effectiveness, which is a function of how well the prosthesis is cleaned. This study graded stained surface deposits, which is a method for measuring cleaning effectiveness. Such an objective assessment of the outcome of cleaning is a more direct way of assessing different prosthetic eye-care regimes.

The finding that inflammation in the anophthalmic socket is correlated to inflammation in the companion eye was expected as socket inflammation has many causes (including sympathetic responses) other than those related just to prosthetic eye wear. The majority of anophthalmic sockets (69 per cent) had a severity grade that was greater than for the companion eye, suggesting that this increase was caused by effects related to the presence of the prosthesis. The correlation between socket and companion eye inflammation together with the observation that 31 per cent of sockets have the same or less severe inflammation

Variable	Inflammation difference per unit change	Standard error	p-value
Years wearing a prosthesis	0.006	0.004	0.13
Shape of prosthesis*			0.27
Shape category 1 versus 4	0.53	0.33	
Shape category 2 versus 4	0.22	0.34	
Shape category 3 versus 4	0.39	0.32	
Weight of prosthesis (g)	-0.09	0.08	0.26
Days between cleaning	0.001	0.001	0.11
Deposits grade (0–10 scale)	-0.08	0.03	0.009
Tears difference (mm)	0.006	0.007	0.45
Discharge volume (1–10)	0.22	0.08	0.01
Discharge viscosity (1–10)	0.22	0.08	0.007

* Shape of prosthesis was categorised according to the contour of the posterior surface

Table 4. Association of variables with difference in conjunctival inflammation between socket and companion eye using the five-photograph 0–4 inflammation grading scale

than the companion eye, suggest that both eyes should be graded when determining prosthesis-induced inflammation in clinical practice. In future studies the quantification of the inflammatory response might be improved with the use of recently introduced InflammaDry™ technology.[11] This technology could be expected to provide an objective measure of conjunctival inflammation but its limitation might be that it is able to detect only the presence but not the degree of inflammation. InflammaDry is reported to work by detecting matrix metalloproteinase enzymes that are produced by stressed epithelial cells on the conjunctival surface. The InflammaDry product was not available for this study.

The finding that the volume and viscosity of discharge in anophthalmic sockets is associated with the difference in conjunctival inflammation is not surprising as the association is well documented in the contact lens literature. For example, the symptoms of contact lens-associated papillary conjunctivitis (CLPC) have been described as excess mucous production, itching, reduced contact lens tolerance and blurred vision due to mucous smearing and deposition. This mucus is mild at first and accumulates at the medial canthus during sleep. As the CLPC progresses toward giant papillary conjunctivitis (GPC), the mucus becomes thicker and more profuse, causing the eyelids to stick together. This increase in severity of mucus is accompanied by a loss of translucency of the conjunctiva and more general conjunctival inflammation.[12]

Deposit formation on contact lens materials has been investigated[13–15] but this work has not yet extended to prosthetic eyes. Furthermore, deposits capable of being stained appear to build up in areas in continuous contact with the conjunctiva rather than in the inter-palpebral zone, which is the area occupied by contact lenses. Inter-palpebral zone deposits on prosthetic eyes are exposed to the air and the action of the eyelids and are likely to be the same or similar to contact lens deposits as described by McMonnies and Lowe,[16] who reported that deposits on non-rotating contact lenses form in the inferior area or in a horizontal band across the centre of the lens, where they have been left to dry by inefficient blinking and/or lagophthalmos. Based on contact lens experience, any deposits left to dry in the inter-palpebral zone of prosthetic eyes are not beneficial to wearing comfort; however, deposits covering those surfaces that are in continuous contact with the conjunctiva may not be harmful.

The finding of an inverse relationship between severity of conjunctival inflammation of the anophthalmic socket and surface deposition on prosthetic eyes has not been previously reported. The evidence of an association between inflammation and mucoid discharge is important because discharge is a major concern for prosthetic eye wearers.[17] These two findings together (inflammation with discharge and inflammation with fewer deposits) directly link the presence of deposits with less severe discharge; however, the correlation between more deposits and less discharge does not indicate the direction of cause and effect, as wearers who experience discharge are likely to have fewer deposits because they often clean their prostheses more frequently due to the discharge. What is apparent from the results is that the deposits themselves did not inflame the conjunctivae of the participants in this study who cleaned infrequently. This finding, while clinically counter-intuitive from the perspective of contact lens practitioners, may gain some support from the equally counter-intuitive finding of Kim and colleagues[2] that the conjunctiva of anophthalmic sockets with prostheses that were cleaned once a day or more (removing deposits), showed more cytological changes than those that were cleaned less than once a day. Furthermore, 82 per cent of the websites of ocularists recommend that prosthetic eyes never be cleaned, or only be cleaned if causing discomfort or discharge.[18] Clearly, the retention of surface deposits through infrequent cleaning is not counter-intuitive to these practitioners. Finally, if surface deposits on prosthetic eyes were harmful, it might reasonably be assumed that treatment protocols for their management would be as well established as they are for contact lenses. This is not the case.[19]

A caveat on this finding is that long-term continuous wearers of prosthetic eyes were not well represented in this study. Therefore, the finding leaves unanswered the question of how long deposits should remain on prosthetic eyes before they cause problems such as GPC.[20,21]

Time of day may influence the inflammatory response of anophthalmic sockets, as accumulated debris can conceivably irritate the conjunctiva during sleep. This possible source of increased inflammation is unlikely to have been a great influence on the results because virtually all the participants in the study were examined at least two hours after waking.

The reasons why deposits did not inflame the conjunctiva of participants in this study who cleaned infrequently have not been addressed in this study; however, possible explanations for this include better wettability of prosthetic eye surfaces in the presence of deposits and better lubrication, if deposits contain mucins, as they do in contact lens deposits.[22] The consequence of these possible properties of deposits would be that less

frictional irritation of the conjunctiva occurs when deposits are present.

CONCLUSION

Recently developed grading scales for measuring inflammation in anophthalmic sockets and deposits on prosthetic eyes were used for the first time in this study. It is recommended that in clinical practice, inflammation grades for both socket and companion eye conjunctivae be compared when determining if prosthesis-induced inflammation is present. The finding that more discharge was associated with more conjunctival inflammation is logical but the finding that less inflammation was associated with more deposits is counter-intuitive to those familiar with the contact lens literature. The apparently benign nature of prosthesis deposits raises questions about the maintenance of prosthetic eyes. We conclude that deposits are likely not linked with inflammation of the conjunctiva for prosthesis wearers who, like those in this study, cleaned regularly but not frequently. Further research on the physical, chemical and biological nature of deposits on prosthetic eyes is planned.

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