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Wavefront Aberrometry in Pseudophakic Patients Before and After Vitrectomy for Bothersome Floaters

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Abstract

Introduction: To investigate whether the outcome of patients with persistent bothersome floaters who are managed with vitrectomy can be correlated with improvements in higher-order aberrations with wavefront aberrometry. **Methods:** Pseudophakic patients who had 27-gauge vitrectomy for persistent floaters and whose clinical assessment included preoperative and postoperative wavefront aberrometry were included. The primary outcome was the change in the higher-order aberration percentage measured by wavefront aberrometry. **Results:** The study included 76 eyes of 66 patients with a mean age ($\pm$SD) of 67.8 $\pm$ 7.5 years. The Snellen visual acuity improved from 20/32 preoperatively to 20/25 postoperatively (P = .004). Wavefront aberrometry showed a highly significant reduction in the higher-order aberration percentage ($P < .000001$), with a mean preoperative percentage of 53.9 and a mean postoperative percentage of 38.3. Subgroup analysis found a significant reduction in patients with no previous posterior capsulotomy (P = .001), previous neodymium:YAG capsulotomy ($P < .000001$), a monofocal intraocular lens (IOL) ($P < .000001$), and a multifocal IOL (P = .006). There was no significant difference in the mean preoperative and postoperative pupil size, sphere, cylinder, or spherical equivalent. **Conclusions:** Wavefront aberrometry demonstrates an objective, significant reduction in higher-order aberrations immediately after vitrectomy in pseudophakic patients with bothersome floaters.

Keywords

aberrations, myodesopsia, opacities, ophthalmology, optics, PPV, refractive, retina, vitreous, vision

Introduction

Despite their prevalence, it can be difficult to objectively measure the optical disruption caused by vitreous floaters. Although symptoms in many cases improve over time, certain individuals experience persistent bothersome floaters.[1] Recent studies have identified decreases in contrast sensitivity and reported reductions in quality-of-life scores in these patients, suggesting that floaters may present a more significant negative impact on vision than previously thought.[2] In fact, many of these individuals have reported that they would give up an average of 1 of every 10 remaining years of life to be rid of their floaters.[3]

Most methods of evaluating floaters are subjective in nature, making it difficult to determine whether patients would benefit from intervention. Snellen visual acuity (VA) is often unaffected or only minimally affected, despite complaints of significant visual disturbance.[1] Contrast sensitivity measurements and quality-of-life assessments can be useful in subjective evaluation.[1,4] Objective methods that have been investigated include ultrasonography and optical coherence tomography, although each carries its own limitations.[1,2]

We investigated the use of wavefront aberrometry as an objective measure of the impact of bothersome vitreous floaters. This technique measures aberrations in a wavefront of light reflected from the eye, providing a comprehensive measure of visual quality.[5] Hartman-Shack aberrometers accomplish this by emitting a laser into the eye and then measuring the light rays that are reflected back out of the eye. The measurements are compared with the theoretical nonaberrated reference and then mathematically constructed into a wavefront, often by using the functions known as Zernike polynomials.[5] There are various ways to describe the aberrations of a wavefront, but a common method is to describe the wavefront phase (measured in microns).[5] Given that aberrations of each Zernike polynomial can be positive or negative, the root mean square is commonly used to provide a single number to represent the total magnitude of an aberration.[6]

These optical disruptions can be broadly categorized into 2 groups. Lower-order aberrations, which include defocus and astigmatism, are those that can be measured with traditional methods and corrected with spectacles. In contrast, higher-order aberrations can only be detected with wavefront aberrometry and

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have not traditionally been correctable.[7] A higher-order aberration percentage can be used to describe the percentage of total aberration attributable to higher-order aberrations.

Aberrations may be more precisely differentiated based on the mathematical order of the Zernike polynomial used, such that aberrations are categorized into various orders. Second-order aberrations (Z2) represent lower-order aberrations, and higher Zernike polynomials represent the various forms of higher-order aberrations.[5,8,9] The most commonly discussed types of higher-order aberrations are coma (Z3), trefoil (Z3), and spherical aberration (Z4); the numerous other types are likely less clinically relevant. By combining multiple Zernike polynomials, any single wavefront can be precisely described.

Although wavefront aberrometry has found powerful applications in refractive surgery, it has rarely been applied to conditions of the posterior segment. In 1 exception, the technique was used to identify a decrease in higher-order aberrations after vitrectomy for asteroid hyalosis.[10] The purpose of this study was to use wavefront aberrometry to determine whether there is an objective change in vision after vitrectomy in pseudophakic patients with bothersome floaters.

Methods

This retrospective interventional case series included pseudophakic patients who had 27-gauge pars plana vitrectomy (PPV) for persistent floaters between January 1, 2016, and December 13, 2020, and whose clinical assessment included preoperative and postoperative wavefront aberrometry. All patients signed a written informed consent before having PPV. This study was approved by the University of Arizona Institutional Review Board (IRB), adhered to the tenets of the Declaration of Helsinki, and complied with the US Health Insurance Portability and Accountability Act of 1996. Patient data were de-identified before analysis, and the IRB review included approval for the collection of the de-identified data described below for use in analysis.

The primary outcome was the preoperative and postoperative higher-order aberration percentage. Secondary outcomes included the preoperative and postoperative Snellen VA as well as other measures of higher-order aberrations, such as root-mean-square higher-order aberrations, total aberrations, and the root mean square. Demographic and clinical analysis also included age, sex, duration of symptoms, intraocular lens (IOL) type, posterior capsule opacification (PCO), previous neodymium:YAG (Nd:YAG) capsulotomy, pupil size, and refractive error (sphere, cylinder, and spherical equivalent) measured by aberrometry.

Postoperative wavefront data were collected within the first postoperative month. Clinical data were analyzed for postoperative complications that occurred within 3 months of the vitrectomy. Patients were excluded if wavefront aberrometry was not performed, if their wavefront aberrometry scans were low quality (2 out of 4 or worse), or if they were phakic. Aberrometry was performed using a Hartmann-Shack aberrometer (Wavescan, AMO).

All operations were performed by the same surgeon (D.A.) via a 27-gauge, 3-port PPV. Before each case, peribulbar anesthesia was administered and 5% povidone–iodine was applied. The Constellation Vitrectomy 27+ vitrectomy system (Alcon Laboratories, Inc) was used. Cannulas were inserted at the superonasal, superotemporal, and inferotemporal quadrants. A complete vitrectomy was performed in all cases, and a posterior vitreous detachment (PVD), if not already present, was induced intraoperatively. This strategy aimed to reduce postoperative complications that might occur in event of a future spontaneous PVD, including recurrence of bothersome floaters or the development of postoperative retinal tears and retinal detachment (RD). In patients with no previous Nd:YAG capsulotomy, any PCO was removed intraoperatively via a capsulotomy. If retinal tears were noted, they were repaired intraoperatively via laser endophotocoagulation. A widefield retinal examination with scleral depression was performed at the conclusion of each case, followed by removal of the cannulas and inspection of each sclerotomy site.

Table 1. Demographic Information and Baseline Data.

Parameter	Value
Eyes (n)	76
Mean age (y) ± SD	67.8 ± 7.5
Sex, n (%)	
Female	43 (56.6)
Male	33 (43.4)
Mean duration of symptom (mo) ± SD	14.1 ± 13.3
Previous Nd:YAG capsulotomy, n (%)	
Yes	42 (55.3)
No	34 (44.7)
Type of IOL, n (%)	
Monofocal	68 (89.5)
Multifocal	8 (10.5)

Abbreviations: IOL, intraocular lens; Nd:YAG, neodymium:YAG.

Statistical analysis was performed using Excel software (Microsoft Corp). A 1-tailed paired t test was used to compare preoperative and postoperative results. Statistical significance was set at $P < .05$. All mean values are ± SD.

Results

The study included 76 eyes of 66 patients with a mean age of 67.8 ± 7.5 years and a mean symptom duration before vitrectomy of 14 months. Table 1 shows other demographic information.

No cases of preexisting retinal breaks were identified, although 3 patients with lattice degeneration had prophylactic laser treatment during the vitrectomy. During the procedure, retinal tears occurred in 3 patients (3.9%), each of which was repaired intraoperatively with a laser. There were no cases of RD, endophthalmitis, or other postoperative complications.

The mean Snellen VA improved from 20/32 preoperatively to 20/25 postoperatively ($P = .004$). Wavefront aberrometry showed a highly significant reduction in the higher-order aberration percentage ($P < .000001$). The mean higher-order aberration percentage was 53.9 preoperatively and 38.3 postoperatively, a decrease of 15.6 (Figure 1A). Figure 1B shows the values for the root-mean-square higher-order aberrations, root mean square, and total aberrations. When individual Zernike polynomials were

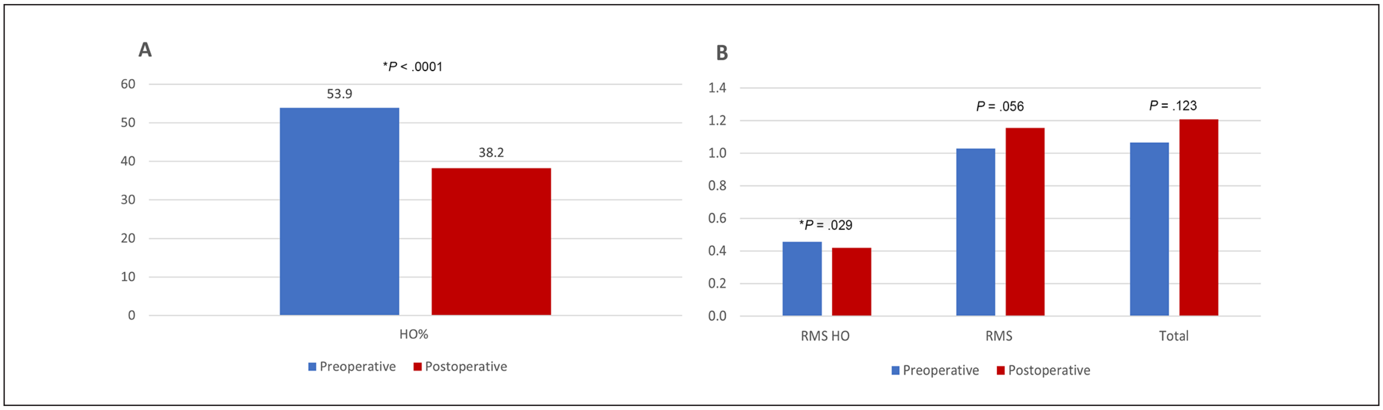

Figure 1. Mean preoperative (blue) and postoperative (red) wavefront data. (A) Higher-order aberrations percentage (HO%). (B) Root-mean-square HOAs (RMS HO), RMS, and total aberrations. *Statistically significant ($P < .05$).

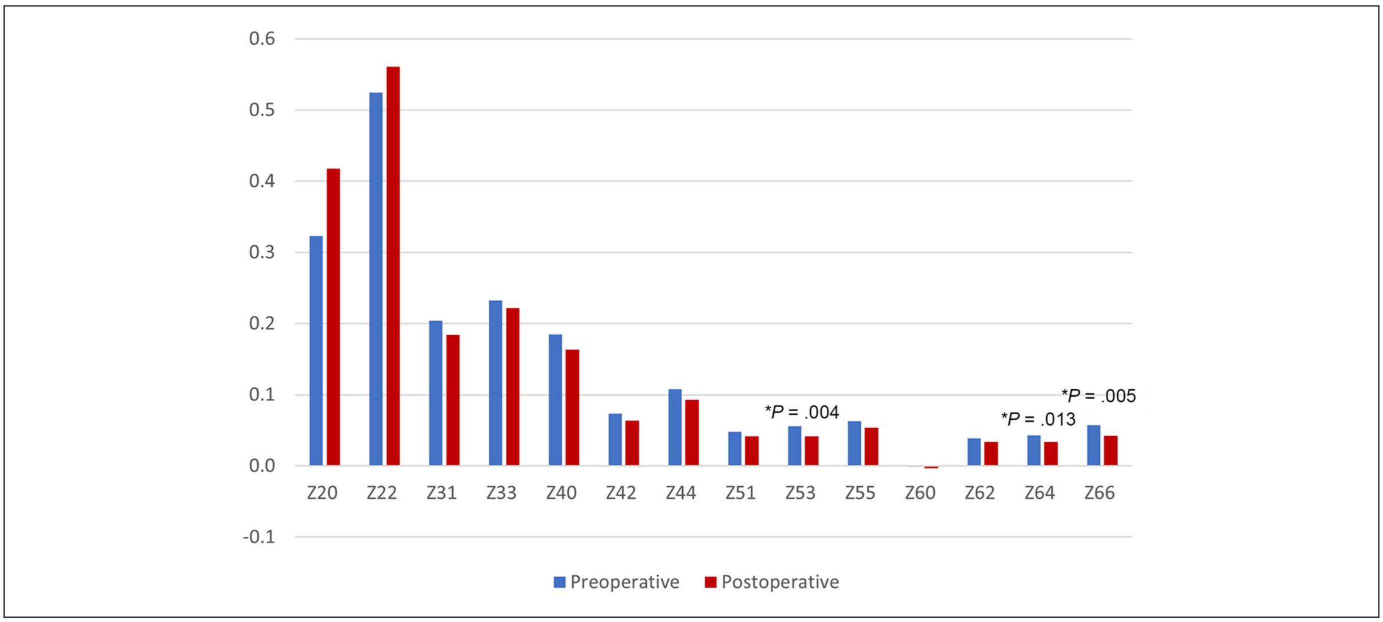

Figure 2. Mean preoperative (blue) and postoperative (red) Zernike polynomials. *Statistically significant ($P < .05$).

analyzed, 3 (Z53, Z64, Z66) showed a statistically significant decrease in the entire cohort. Changes in other polynomials were not significant (Figure 2).

The mean pupil size was 5.11 mm preoperatively and 5.21 mm postoperatively; the difference was not statistically significant ($P = .13$). Regarding refractive errors, the mean sphere was 0.35 D preoperatively and 0.16 D postoperatively; the mean cylinder was 1.69 D and 1.23 D, respectively; and the mean calculated spherical equivalent was 1.19 D and 0.78 D, respectively. There was no significant difference in these parameters between the preoperative mean and postoperative mean (sphere, $P = .33$; cylinder, $P = .18$; spherical equivalent, $P = .09$).

Of the eyes, 42 (55%) had a previous Nd:YAG capsulotomy before vitrectomy (Table 1). Table 2 shows a comparison of the mean higher-order aberration percentage for those with a previous Nd:YAG capsulotomy and those without a previous Nd:YAG capsulotomy. Subgroup analysis showed a significant postoperative reduction in the higher-order aberration percentage in both groups ($P < .0001$).

Table 2. Subgroup Analysis of the Mean Preoperative and Postoperative Higher-Order Aberration Percentage.

Parameter	Mean Higher-Order Aberration Percentage		
	Preoperative	Postoperative	*P* Value
Nd:YAG	58.4	39.5	<.0001*
No Nd:YAG	48.3	36.3	<.0001*
Multifocal IOL	51.5	28.0	.004*
Monofocal IOL	54.1	39.4	<.0001*
Total	53.9	38.3	<.0001*

Abbreviations: IOL, intraocular lens; Nd:YAG, neodymium:YAG.
*Statistically significant ($P < .05$).

Eight eyes (11%) had a multifocal IOL (Table 1). Table 2 shows a comparison of the mean higher-order aberration percentage for those with a multifocal IOL and those with a monofocal IOL. Subgroup analysis showed a significant postoperative reduction in the higher-order aberration percentage in both groups (P = .004 and $P < .0001$, respectively). The mean decrease was larger in the multifocal group than in the monofocal group (23.5 vs 14.7).

Conclusions

Wavefront aberrometry has been validated as a reliable tool to describe the fundamental visual quality of the eye.[5] Deviations in a reflected light wave are measured and mathematically integrated to reconstruct the wavefront. This is most commonly achieved using Zernike polynomials, which can then be used to classify the aberrations into lower-order aberrations and higher-order aberrations based on the polynomial used. This technique has important applications in refractive surgery, where its primary benefit is to minimize the induction of higher-order aberrations.[11] In addition, newer ablation profiles aim to go further by reducing preexisting higher-order aberrations and creating better outcomes in those with significant preexisting higher-order aberrations.[12] Other uses of the technique have been explored, including applications in cataract surgery and IOL manufacturing.[12,13]

In a notable report, wavefront aberrometry was used clinically to evaluate 3 difficult cases.[7] One of these highlights the association between vitreous floaters and HOAs. This patient developed a PVD and vitreous opacities, and wavefront aberrometry showed a significant increase in higher-order aberrations in the affected eye, despite preserved Snellen VA. The author was uncertain as to the cause of the increase in HOAs but speculated that vitreous opacities were a potential etiology. Based on our findings, we suggest that these vitreous opacities likely did cause the increase in higher-order aberrations in this patient.

In the majority of the population, baseline higher-order aberrations are low, with mean root-mean-square higher-order aberration values ranging from 0.23 μm to 0.33 μm in studies from the United States.[6,14–16] Higher-order aberrations can be induced by refractive surgery, corneal injury, keratoconus, or other disturbances to the eye.[12] They have also been shown to increase with age, a larger pupil size, and nuclear cataracts.[6,14] The significant postoperative decrease in this value suggests that vitreous opacities played a role in this finding. Although pupil size can affect higher-order aberrations, the nonsignificant difference in the preoperative and postoperative pupil sizes in our cohort suggests that this was unlikely a confounding factor in this study. Similarly, changes in the refractive error seem an unlikely confounder given the lack of significant change postoperatively.

Wavefront aberrometry has rarely been applied to conditions of the posterior segment. Yokoyama et al[10] showed its potential in this area by measuring higher-order aberrations in 3 cases of asteroid hyalosis and by identifying a reduction in these higher-order aberrations after vitrectomy. The authors reasoned that aberrometry could thus be a useful tool in evaluating whether these patients could benefit from this surgery.

In this study, we used wavefront aberrometry to investigate the optical changes in pseudophakic patients with persistent bothersome floaters and the role of vitrectomy in their management. Previous studies have supported a high subjective efficacy of this procedure among these patients. Patient satisfaction has been reported to be between 85% and 100%,[1] and improvement might be seen in other measures, such as contrast sensitivity. In a study of 145 patients with symptomatic floaters who had vitrectomy, contrast sensitivity function improved after surgery and there was no significant postoperative difference between these patients and 70 age-matched controls.[4] The study also reported a 19.3% improvement in the National Eye Institute Visual Function Questionnaire (NEI VFQ) score, suggesting that this improvement in contrast sensitivity accompanied an improvement in subjective visual quality.

Most previous studies of vitrectomy for floaters used subjective measures of visual improvement or quality of life, often including visual disturbance scores or the NEI VFQ. Although the improvements in these measures are compelling, they are limited by the inherent nature of subjective outcomes.[17] In addition, many of these studies, including ours, lacked a control group. Some have criticized this because it does not account for the possibility of a placebo effect.[18]

Others have questioned whether floaters truly represent a treatable ocular condition, hypothesizing that reports of floaters are a manifestation of psychological symptoms rather than true visual symptoms. Milston et al[1] suggested that although this may be a concern in a minority of patients, most are simply hoping to improve their quality of life. A recent review concluded that there is an association between vitreous opacities and anxiety, depression, and perceived stress in those who seek medical attention for their floaters.[19] Notably, they also reported a significant improvement in these psychological symptoms in patients who had vitrectomy. The changes in the higher-order aberration percentage in our study provide objective evidence supporting a true improvement in visual quality after vitrectomy for floaters. This finding suggests that these floaters represent an objective impairment of vision that is simply not well detected or characterized by traditional measures of vision and refutes the notion that the symptoms are completely psychological in origin.

We performed a subgroup analysis to investigate other potential influences on the findings in this study. In particular, patients with multifocal IOLs represent a group that may differ from patients with monofocal IOLs. One study found that of the 86 patients who had vitrectomy for floaters, those with multifocal IOLs had a lower contrast sensitivity function than those with monofocal IOLs.[20] Both groups had significant improvements in these scores after vitrectomy. The authors postulated that the difference in preoperative contrast sensitivity could be the result of an interaction between the multifocal IOL and vitreous opacities. Although we were limited by the small number of these patients in our study, we observed a decrease in higher-order aberrations in patients with multifocal IOLs. In view of our other findings, this may suggest that those with multifocal IOLs who pursue vitrectomy for floaters also experience an objective improvement in visual quality after surgery. Further investigation with a statistically robust sample size of patients with multifocal IOLs would be necessary to make this conclusion.

During vitrectomy, any PCO was removed in patients who had not had a previous Nd:YAG laser capsulotomy. Although this represents a potential confounding variable, subgroup analysis showed no statistically significant difference between those who had a previous Nd:YAG capsulotomy and those who did not. Interestingly, the reduction in the higher-order aberration percentage was higher in those with a previous capsulotomy. Although these patients had a higher mean preoperative higher-order aberration, that postoperative percentage was the same as in the group that did not have a previous Nd:YAG capsulotomy. Overall, the reduction in higher-order aberrations in our study was not found to be attributed to removing the posterior capsule during vitrectomy.

The incidence of complications in our study was low and was within the ranges reported in the literature. The most common complication associated with vitrectomy is progression of cataract formation, while more rare complications include hypotony, retinal tears, RDs, or endophthalmitis.[1] Phakic patients were excluded from our study to avoid confounding variables given the possibility that postoperative lens changes affected the wavefront findings. Future wavefront aberrometry studies of phakic patients with persistent floaters who have a vitrectomy would be interesting and valuable.

In addition, only complete vitrectomies were performed and a PVD, if not already present, was induced intraoperatively in all cases. This was done to prevent the recurrence of bothersome floaters in the event of a future spontaneous PVD as well as to reduce the risk for the development of postoperative retinal tears and RD. The decision of whether to induce a PVD intraoperatively can be complex. Some studies suggest that inducing a PVD increases the risk for an iatrogenic retinal break.[1] In contrast, Mason et al[21] found no increase in risk among those with induction of a PVD, although a PVD was induced in only 12 of the 168 cases described. Despite this, the rate of intraoperative retinal breaks in our study was low (3.9%) and was not higher than that reported in the literature.

This study did not consider alternative treatments for bothersome floaters, such as Nd:YAG vitreolysis. A theoretical advantage of Nd:YAG vitreolysis is that the noninvasive procedure would be associated with a reduction in complications such as endophthalmitis. However, the efficacy of Nd:YAG vitreolysis has been questioned, and some patients have reported worsening of symptoms after the procedure.[22] In addition, the concern regarding reoccurrence remains, especially in patients without a PVD. One randomized controlled trial found the procedure to be superior to a sham.[23] However, that trial was limited in size and length of follow-up and some have expressed concerns about the design.[24] Wavefront aberrometry could be a useful tool to objectively compare the change in visual quality after Nd:YAG vitreolysis in patients with bothersome floaters.

Our study was limited to pseudophakic patients who had vitrectomy for bothersome floaters. Phakic patients were specifically excluded to prevent additional confounding variables. Given this limitation, no conclusions can be drawn as to the potential benefit for phakic patients with bothersome vitreous floaters managed with vitrectomy.

Limitations also include that the study was a nonconsecutive noncontrolled review. Based on the previously mentioned exclusion criteria, not all patients of the surgeon were included in the analysis. This includes geographic limitations because wavefront aberrometry was only available at 1 office and not all patients were seen at that location. In addition, high-quality wavefront scans could not be obtained in all patients.

The primary outcome of this study represents a single comparison; however, the analysis of secondary outcomes included multiple comparisons, potentially increasing the likelihood of a type I error.[25] Although a rigorous statistical adjustment to P value thresholds is beyond the scope of this study, conclusions regarding statistical significance of our secondary outcomes should take this into account.

Further studies should be performed to support the findings in our study. Also, the use of wavefront aberrometry should be investigated in other aspects of ophthalmic care to find additional applications of clinical significance.

In conclusion, wavefront aberrometry showed an objective, significant reduction in higher-order aberrations after vitrectomy in pseudophakic patients with bothersome floaters. Vitreous degeneration in some pseudophakic patients contributes to the visual abnormalities associated with higher-order aberrations, and vitrectomy can improve the quality of vision of these patients.

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Ethical Approval

This study was approved by the University of Arizona Institutional Review Board (IRB) and was conducted in accordance with tenets of the Declaration of Helsinki. The collection and evaluation of all protected patient health information were performed in a US Health Insurance Portability and Accountability Act–compliant manner. Patient data were de-identified before analysis, and the IRB review included approval for the collection of the de-identified data for use in analysis.

Statement of Informed Consent

Informed consent, including permission for publication of all photographs and images included herein, was obtained before the procedure was performed.

Declaration of Conflicting Interests

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