Economic and Environmental Impact of Single-use Plastics at a Large Ophthalmology Outpatient Service

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Precis: The use of disposable tonometer prisms and gonioscopy lenses at a large ophthalmology outpatient service incurs significant financial and environmental waste that may not be justified given the limited data surrounding arguments for their use.

Purpose: To quantify the economic and environmental burden of single-use plastics from an ophthalmology outpatient service at a large tertiary hospital and describe the relative value and evidence for the safety of disposable versus nondisposable tonometer prisms and gonioscopy lenses.

Methods: The total number of single-use application tonometer prisms and gonioscopy lenses used per year at Boston Medical Center (BMC) was estimated, and the average dollars spent and plastic waste generated in kilograms per year were then determined. These values were compared with the total spending and waste that would be produced if the clinic were to use nondisposable tonometer prisms and gonioscopy lenses exclusively.

Results: Single-use tonometer prisms cost an average of $70,282 per year and produce ~100.8 kg of plastic waste per year at BMC. Single-use gonioscopy lenses cost ~$9,040 per year and produce ~100.8 kg of plastic waste per year at BMC. An excess of $65,185 and 109.6 kg of plastic waste could be avoided each year by only using nondisposable tonometer prisms and gonioscopy lenses at the BMC ophthalmology outpatient service.

Conclusions: Single-use plastics in ophthalmology outpatient services generate significant environmental waste and financial cost compared with nondisposable instruments. This cost may outweigh the benefits of these instruments given the limited data surrounding arguments for their use.

Key Words: single-use plastics, tonometry, gonioscopy, environment, waste

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Health care facilities in the United States generate a tenth of the country’s yearly greenhouse gas emissions, which translates to roughly 470,000 disability-adjusted life-years lost from the negative impact of greenhouse gas on health.1 Ophthalmology practices contribute to the burden, both in the operating room and in the clinic, by relying on single-use plastics for common tasks such as applanation tonometry and gonioscopy.2,3 According to 1 study, 81 of 135 (59%) ophthalmology practices in the United Kingdom reported using disposable Tonosafe (Haag-Streit Diagnostics, Köniz, Switzerland) prisms exclusively.4

Applanation tonometry and gonioscopy are essential to the diagnosis and management of glaucoma, and these procedures have traditionally been performed using non-disposable prisms and lenses. However, numerous reports of epidemic keratoconjunctivitis (EKC) associated with inadequately disinfected equipment,3–10 concern for transmission of prion disease,11,12 and studies showing similar accuracy between disposable and nondisposable devices13–16 have prompted a shift toward the adoption of single-use ophthalmic instruments. Disposable prisms and lenses guarantee zero cross-contamination among patients and eliminate the need to disinfect equipment, making them presumably safer and more convenient.

However, the cost-effectiveness of single-use versus nondisposable tonometer prisms and gonioscopy lenses remains unclear. Current available data indicate that reusable instruments are safe as long as clinicians adhere to disinfection guidelines.17 Specifically, the Centers for Disease Control (CDC) recommends the use of dilute bleach to sterilize tonometers, as this has demonstrated effectiveness against adenovirus 8, the most common cause of EKC.18–22 While prion disease poses concern, there are no published reports of transmission via ophthalmic equipment of any pathogen other than adenovirus and herpes simplex virus (HSV)-1 to date. Moreover, up to half of staff workers admit to touching the surface of disposable tonometer prisms during their use, casting doubt on their sterility in actual practice.23 Taken together, these findings question whether the economic and financial cost of single-use plastics— nota bly tonometer prisms and gonioscopy lenses—outweigh their perceived benefits.

Therefore, we measured the total financial cost and plastic waste produced per year from the use of disposable tonometer prisms and gonioscopy lenses by the Boston Medical Center (BMC) ophthalmology department. We also performed a value analysis to compare our current practice methods with the opposite alternative, the use of nondisposable lenses and prisms only. We hypothesize that single-use plastics impose a substantial economic and environmental burden and may lack justification based on available evidence and relative cost.

METHODS

The BMC Institutional Review Board ruled that approval was not required for this study. The study conformed to the tenets of the Declaration of Helsinki and Health Insurance Portability and Accountability Act regulations.

BMC is an urban teaching hospital serving the greater Boston area. The ophthalmology clinic receives ~64,000 visits each year, including 14,000 glaucoma visits each year. We contacted our vendors to define the total quantity of single-use gonioscopy lenses and single-use applanation...
Goldmann tonometer prism (Haag-Streit Diagnostics, Kôniz, Switzerland) are used exclusively, instead of reusable prisms and lenses. In addition, we contacted Volk and Haag-Streit to learn the exact weight of a single lens and prism, respectively. These numbers served as estimates for the amount of plastic waste generated with the disposal of each instrument.

To determine the theoretic costs of using only non-disposable prisms and lenses, we first identified the total number of technician and provider lanes available at the outpatient clinic as a starting point to calculate the number of prisms that would be needed at any given point in time. For nondisposable gonioscopy lenses, we assumed that each provider would have 1 lens. We then compared the yearly costs of these items using the data collected to develop a cost-benefit analysis.

Lastly, we reviewed the literature for reports of transmission via ophthalmic instruments of adenovirus, human immunodeficiency virus (HIV), HSV-1, HSV-2, enterovirus 70, hepatitis C virus (HCV), hepatitis B virus (HBV), and Creutzfeldt-Jakob disease (CJD). We then evaluated the data regarding the efficacy of various disinfection methods against these pathogens for tonometer prisms and gonioscopy lenses, specifically.

### RESULTS

Table 1 shows the dollars spent and plastic waste generated per year from single-use prisms and single-use gonioscopy lenses at BMC between 2017 and 2019. An average of 61,115 prisms and 800 lenses were purchased per year, for an average total cost of $70,282 and $9,040 per year, respectively. Since each prism weighs ~1.65×10⁻³ kg and each lens 0.011 kg, the plastic waste amounts to 109.6 kg (100.8+8.8 kg) per year.

Analogous numbers can be calculated for the hypothetical scenario in which only nondisposable instruments are used. Assuming all 40 technician and provider lanes of the outpatient clinic would be equipped with 1 Haag-Streit Goldmann tonometer prism (Haag-Streit Diagnostics, Kôniz, Switzerland) and that all 22 providers have 1 Volk G-4 glass gonio lens (Volk Optical Inc., Mentor, OH) each, a total of 40 prisms and 22 lenses would be required at any given point in time. For the first year, this amounts to a total cost of $6000 and $11,352, respectively. For the tonometer prism, if we adopt the 50% yearly replacement rate recommended by the manufacturer,²⁴ we find that each subsequent year requires the purchase of $3000 worth of new prisms. For the gonioscopy lens, if we assume a conservative yearly replacement rate of 20% (ie, replacing lenses after every 5 y of use), we find that each subsequent year requires the purchase of $2270 worth of new lenses.

To incorporate the added cost of disinfection, we assume a conservative (generous) estimate of 50 mL required to soak a single prism and 100 mL to soak a single lens in dilute bleach. One 2.4 L tub of household bleach costs $4.50 and supplies 24 L of 1:10 dilute bleach. Therefore, given the average yearly numbers of patients stated above (61,115 for tonometry and 800 for gonioscopy), disinfection with dilute bleach would cost our institution ~$5867 per year ($5717 for prisms and $150 for lenses).

Lastly, we can consider the time spent on disinfection. The American Academy of Ophthalmology recommends soaking these devices in dilute bleach for no more than 5 minutes.¹⁷ In practice, the devices can soak while the provider is seeing their next patient. In glaucoma clinic, however, all patients require applanation tonometry, and it is unrealistic for a provider in this setting to rely on a single prism. At the very least, 2 prisms are needed, so that one can soak while the other is in use. Therefore, we double our estimated yearly cost for reusable prisms at our institution from $3000 to $6000.

On the basis of these assumptions, an excess of $65,185 and 109.6 kg of plastic waste could be avoided each year by only using nondisposable tonometer prisms and gonioscopy lenses at the BMC ophthalmology outpatient service.

### DISCUSSION

Our research has demonstrated that the use of disposable tonometer prisms and gonioscopy lenses at our institution produces an excess $65,185 spent yearly, along

| Year | Quantity (No.) | Total Cost ($) | Total Weight of Plastic (kg)* |
|------|----------------|---------------|-------------------------------|
| 2019† | 800            | $9040         | 8.8                           |
| 2018  | No data        |               |                               |
| 2017  | No data        |               |                               |
| Average | 800            | $9040         | 8.8                           |

| Year | Quantity (No.) | Total Cost ($) | Total Weight of Plastic (kg)† |
|------|----------------|---------------|------------------------------|
| 2019† | 49,745         | $57,207       | 82.1                         |
| 2018  | 75,500         | $86,825       | 124.6                        |
| 2017  | 58,100         | $66,815       | 95.9                         |
| Average | 61,115         | $70,282       | 100.8                        |

*The weight of 1 Volk Single-Use Gonio Lens is ~0.011 kg.
†The weight of 1 Haag-Streit Tonosafe single-use prism is 1.65×10⁻³ kg.
‡Data for 2019 was extrapolated due to missing data for 1 to 3 months of the year.
with 109.6 kg of plastic waste, that could be avoided by adopting reusable devices. This finding mirrors that of a similar study by Jasani et al., who calculated a potential cost saving of at least £15,000 per year for a local district general hospital in the United Kingdom. Our paper, however, is the first to analyze the value of disposable versus nondisposable ophthalmic instruments in a large outpatient clinic setting within the United States.

Infection from contaminated ophthalmic instruments is an important concern and a meaningful driver for the shift toward single-use tonometer prisms and gonioscopy lenses over the past decade.4 Nosocomial outbreaks of keratoconjunctivitis occur relatively frequently worldwide. The pathogen responsible is almost always adenovirus 8, and rarely other strains are involved, such as adenovirus 7, 19, 37, and most recently, adenovirus 54.5-10,25-29 There are also a few reports of HSV-1 transmission.19,30 Laboratory studies illustrate the potential for HIV, HCV, HBV, and prion disease transmission in vitro, but there is no published report of in vivo transmission of these microbes from tonometry or gonioscopy to date.31

Case-control analyses of the EKC outbreaks have identified increased risk of infection with tonometry, as well as pneumotomometry, ophthalmic solutions, diagnostic lenses, dilating and anesthetic eye drops, and even individual clinicians and nurses.5-10,25,26,28 However, many of the studies citing tonometry also noted obvious gaps in hygiene, either from lack of handwashing or improper disinfection of the device itself.5,7,23 Indeed, data suggest that nondisposable tonometer prisms are safe as long as they are appropriately disinfected and replaced as necessary.5 The CDC “Guideline for Disinfection and Sterilization in Health Care Facilities,” last updated in May 2019, recommends the use of dilute bleach or 70% ethyl alcohol to sterilize semicritical items (ie, objects that come into contact with intact membranes), such as tonometer prisms and gonioscopy lenses.22 This recommendation aligns with several studies demonstrating the effectiveness of 1:10 or 1:20 dilute bleach against adenovirus 8.18-21 Previously, 3% hydrogen peroxide and 70% isopropyl alcohol were listed as alternative agents; however, these are no longer recommended due to mixed evidence for their efficacy against adenovirus, specifically.18,21,32 Other studies using tonometers inoculated with HIV, HSV-1, HSV-2, enterovirus 70, HBV, and HCV, have shown efficacy for a variety of disinfecting agents, including dilute bleach, 3% hydrogen peroxide, 70% isopropyl alcohol, ultraviolet radiation, and soap and water.9,33,37

One exception to this is prion disease, a type of infection contracted through misfolded proteins that causes the rare, neurodegenerative disorder CJD. Tonometer prisms may retain corneal epithelial cells that represent a potential source for prion infectivity, and no disinfecting method has proven to completely eliminate the proteinaceous material from used prisms.11,12,38 Nevertheless, <1% of all CJD is acquired.39 The vast majority of cases occur spontaneously and affect only 1 in 1 million people per year.40 While there have been a handful of reports of possible transmission from corneal transplants worldwide, only one of these was confirmed by postmortem examination of both the donor and recipient.41-44 In 1 report, recipients of corneal and scleral transplants from a donor who was later confirmed to have had CJD exhibited no neurologic symptoms 8 years after surgery.45 In fact, there has been no reported case of CJD transmission from applanation tonometry or gonioscopy to date. Moreover, studies show that dilute bleach and 70% isopropyl alcohol significantly reduce the amount of cells and protein retained on tonometers when combined with mechanical cleaning.11,38 Proper routine cleaning should thus minimize the risk of transmission should an instrument come into contact with a person with CJD. Regardless, experiments using Western blot analysis of the eyes of patients with CJD detected the infectious prion protein in the retina only, not in the cornea or sclera.46 Therefore, though it is recommended that disposable prisms and lenses be used for patients with suspected CJD, expanding this rule to all patients lacks rationale based on current evidence for such a rare disease.17

One should note that disinfectants can damage tonometer prisms and gonioscopy lenses over time.42-47 The harsh chemicals may dissolve the glue that holds pieces together and may cause tonometer prisms to swell and crack, risking patient injury.47-49 Therefore, ophthalmologists should routinely inspect these devices for defects before their use and replace older instruments periodically according to manufacturer guidelines (every 2 y for tonometer prisms or with the first signs of damage for both prisms and lenses). Our data suggest that if clinics were to cycle their reusable instruments as instructed, they could still achieve significant cost savings while ensuring the safety of these devices for their patients.

Our study has limitations. First, our calculations are based on the assumption that the quantity of instruments purchased by the clinic equals the quantity that is actually used; however, this may not be true, and the values we obtained could overestimate true usage. Second, we adopted the 50% yearly replacement rate for tonometer prisms recommended by the manufacturer; however, in actual practice, replacement rates may be closer to the 26.5% yearly replacement rate cited by Jasani et al.4 Of note, true replacement rates will depend on the type of disinfecting method used (ie, bleach or alcohol). Lastly, our paper only reflects the culture and practice of 1 institution; therefore, our findings may not necessarily extend to other ophthalmology departments. However, the experience at BMC likely resembles that of other large outpatient clinics associated with academic hospitals throughout the country.

Medical facilities in the United States generate up to 14,000 tons of waste per day, about a quarter of which is plastic.50 In our study, we estimated 109.6 kg of plastic waste generated each year by our institution from single-use ophthalmic instruments. This amounts to >120 tons of plastic waste across 100 similar institutions in a single decade. Plastics take centuries to decompose and do not ever biodegrade.51 Therefore, they accumulate in landfills and marine environments, where they kill native wildlife and produce unsafe toxins.52,53 Microplastic particles can spread over long distances and have been detected as far as the Antarctic.51 In other words, the impact of plastic waste has far reaching consequences that magnify across our ecosystem.

Our data identifies single-use plastics as a feasible and meaningful target for ophthalmologists to address, since nondisposable applanation tonometer prisms and gonioscopy lenses are less costly, environmentally friendly, and safe for patients. As industries across the world begin to reassess their environmental impact, health care should not be an exception. We believe it is important to critically evaluate the use of disposable items in our field to determine not only whether the risk of transmission of certain infections is real, but also whether that risk makes disposable materials preferable to adopting new sterilization techniques. It is our opinion that
with appropriate care of nondisposable tonometer prisms and gonioscopy lenses, disinfection with 70% isopropyl alcohol or dilute bleach (in cases of suspected adenovirus or EKC) is a safe and environmentally responsible way to use these instruments in an outpatient setting.

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