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Community health workers for prevention of corneal ulcers in South India: a cluster-randomized trial

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Abstract

Purpose: To determine whether a community health worker (CHW) program increases referrals to local eye care providers and ultimately reduces the incidence of corneal ulcers.

Design: Cluster-randomized trial performed from 2014-2017 in rural South India.

Setting: Community-based.

Study population: All inhabitants of 42 rural South Indian communities.

Intervention: CHWs were trained to diagnose corneal abrasions and assist participants in seeking care at a local vision center. The trial was not masked given the nature of the intervention.

Main Outcome Measure: Incident corneal ulcer, defined as an active infiltrate or evidence of a new opacity, assessed by penlight examination during an annual door-to-door census.

Results: 21 study clusters were randomized to the CHW intervention and 21 to no intervention. Vision centers diagnosed 195 corneal abrasions from the intervention clusters over the two-year study (rate: 223 per 100,000 person-years, 95%CI 28-1,743) and 62 from the control clusters (rate: 62 per 100,000 person-years, 95%CI 8-496); incidence rate ratio [IRR]=3.57, 95%CI 2.01-6.35; $P<0.001$. The estimated incidence of corneal ulceration over the study period was 60 per 100,000 person-years (95%CI 25 to 141) in the intervention group and 32 per 100,000 person-years (95%CI 13 to 80) in the control group (IRR 1.86, 95%CI 0.5 to 6.4; P=0.32).

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Conclusions: A CHW program resulted in 3.5 times more referrals to local eye care providers for corneal abrasions, but no difference could be detected in the incidence of corneal ulceration. CHW programs provide a mechanism for increasing referrals to eye hospitals.

Trial Registration: clinicaltrials.gov: NCT02284698.

Keywords

corneal injuries; corneal ulcer; community health workers; secondary prevention; anti-bacterial agents; antifungal agents

INTRODUCTION

Infectious corneal ulcers remain the fifth-leading cause of blindness worldwide.[1] The burden of corneal infections is greatest in low- and middle-income countries, especially in tropical areas of Asia and Africa.[1] Despite the high burden of disease, the problem of corneal ulceration in the developing world has been called a silent epidemic given the relative lack of attention paid to this infection.[2] Some have proposed naming corneal ulceration a neglected tropical disease since the burden is greatest in impoverished communities in the tropics.[3] In such places, the majority of corneal ulcers are due to trauma, often related to agricultural work.[4, 5] A lack of diagnostic facilities is a major barrier for delivering care for corneal ulcers.[6] Delays in seeking treatment are thought to be a major risk factor for developing a visually significant corneal infection.[7, 8]

New strategies to increase access to eye care are needed in order to reduce the burden of corneal ulcers in poor agricultural communities. One possibility is to employ community health workers (CHWs) to diagnose corneal abrasions, followed by prompt referral to an eye care provider if appropriate.[9-12] In order to test the efficacy of such a strategy, we performed a cluster-randomized trial in South India comparing a CHW program to no such program. Cluster-randomization was used because publicity had to be conducted at the community level, and because a CHW would need to be able to offer the intervention to all community members in order to ensure acceptability. Our objective was to determine whether communities randomized to the CHW program would have more visits to eye care providers and lower rates of corneal opacities compared with untreated communities.

METHODS

Study design.

In a community-randomized trial conducted from October 24, 2014 until June 10, 2017, 42 clusters (i.e., *panchayats*) were randomized to either a CHW diagnosis and referral program or to no intervention (Figure 1). In intervention clusters, community members experiencing eye trauma were instructed to visit a CHW for an eye exam. If the CHW identified a corneal abrasion, they helped the community member make a visit to a study vision center for confirmation of diagnosis and clinical management. CHWs were available any day of the week for the entire study period. Visits for corneal abrasions, foreign bodies, and ulcers were monitored prospectively on standardized forms at the Aravind vision centers in the study area. An annual census was performed in both treatment arms to assess for the pre-specified

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primary outcome of corneal ulceration. The Institutional Review Board Ethical Committee of the Aravind Eye Care System approved this study. The ethical committee approved verbal informed consent given the high rate of illiteracy in the study area; heads of households provided verbal informed consent at the time of the census and affected participants or their guardians provided verbal informed consent at the time of the CHW encounter. The trial was registered on clinicaltrials.gov (NCT02284698). The trial protocol is available as Supplemental File 1.

Study setting.

The trial was conducted in communities of the Peraiyur *taluk* of Madurai district, Tamil Nadu, India. The main eye care facilities in the study area consisted of three vision centers operated by the Aravind Eye Care System; these facilities employed two mid-level ophthalmic personnel (MLOP) to perform refraction and to facilitate telemedicine diagnosis and treatment. The next closest eye hospital was in Madurai (Figure 2). Ophthalmic antibiotic preparations were available without a prescription at private medical shops present in or within 3km from all study communities.

Eligibility.

The unit of randomization was the panchayat, which is a government-defined unit comprised of several villages. Panchayats, termed clusters in this study, were eligible for the trial if located in Peraiyur taluk and if the population on the 2011 government census was between 300 and 6500. Panchayats with an eye hospital or government-run primary health center were excluded.

Randomization and masking.

Study clusters were allocated without stratification in a 1:1 ratio to either the CHW intervention or to no intervention by the trial biostatistician using Stata (Statacorp, College Station, TX). Randomization was concealed by creating the randomization sequence after the baseline census and randomizing all clusters at the same time. All individuals in the cluster were eligible to participate. Randomization was implemented by the study coordinator. Because of the nature of the intervention, allocation was not masked, although the census workers and vision center clinical staff were not informed of the allocation (accomplished for census workers in part by taking down publicity materials while the census was being performed in the community). Contamination was possible since people traveling from control panchayats to intervention panchayats could have seen publicity materials, but the CHW enrolled only people living in the intervention community. Non-residents were informed about the vision centers but not offered any other specific services.

Census.

A door-to-door census was completed approximately every 12 months of the trial by trained field staff. All members of the household were enumerated on standardized paper forms and asked if they experienced eye trauma in the past year and then underwent a penlight examination of each eye with 2.5× loupes to identify corneal opacities. Before being deployed for census activities the field workers attended a 3-day training

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workshop administered at Aravind Eye Hospital-Madurai by staff ophthalmologists. The workshop taught introductory ocular anatomy and physiology as well as the basics of an eye examination, focusing especially on differences between corneal opacity, pterygium, and cataract, and included both written and photographic materials as well as patient examinations. Census workers were not allowed to begin work until the trainer was confident in their examination skills. An ophthalmologist made an unannounced spot check in the field to evaluate the work of each census worker during the first 3 weeks of the census. Census workers were not involved in any aspects of the study intervention in order to limit potential bias.

Intervention: CHWs.

17 salaried CHWs were employed for the study and their work was confined to the 21 intervention clusters. Employment prerequisites included at least a 12th grade education, residence in a study community, and agreement to refrain from holding another job. Each CHW was responsible for approximately 3000 people and covered either 1 larger cluster or 2 smaller nearby clusters. CHWs lived in their communities and worked from their homes. Community members experiencing eye trauma could either visit the CHW in person or could arrange a home visit by calling the CHW's telephone number listed on publicity materials. At the time of the encounter, the CHW reviewed the history of present illness. If the presentation was thought to be consistent with cornea trauma, the CHW used a tumbling E card to assess 6/60 visual acuity, then applied a fluorescein strip to the lower fornix of the affected eye and inspected the cornea with a blue flashlight. Participants diagnosed with an abrasion or other condition deemed urgent (e.g., corneal ulcer, corneal foreign body) were guided to the closest vision center in person. Participants with a non-urgent condition were advised to visit the vision center at their convenience. If a corneal abrasion was confirmed at the vision center the CHW made another home visit 3 days later to assess for healing with a repeat fluorescein examination. Those participants whose epithelial defect had not healed or who had developed a new corneal problem were guided in person to the closest tertiary care eye hospital (i.e., Aravind Eye Hospital Madurai). CHWs recorded data from each abrasion encounter on standardized paper forms. CHWs advertised their services at the beginning of the trial by visiting each house in the community and distributing handbills with their mobile numbers. In addition, they hung posters at post offices, libraries, community halls, and public distribution centers (i.e., facilities coordinating monthly distribution of food supplies for needy households) and conducted periodic group meetings with various stakeholders in the community. Publicity that had a high chance of contaminating the study arms (e.g., radio/television advertisements or posters on buses, vision centers, and schools) was specifically avoided. CHWs attended a 1-week training program similar to but more intensive than the census worker training mentioned above.

Intervention: Vision centers.

Three vision centers were used for the study, two of which were operational during the entire study period and one of which opened in November 2015 (e.g., approximately 10 months after the CHW intervention started). Aravind vision centers were staffed by a coordinator and a MLOP who had graduated from a 2-year training program sponsored by Aravind Eye Care System and then subsequently worked at Aravind Eye Hospital for

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≥5 years. The vision centers were connected to Aravind Eye Hospital-Madurai through a telemedicine system staffed by an ophthalmologist. Anterior segment photographs were taken with a digital camera (Canon PowerShot A1100IS or Nikon COOLPIX L31) attached to the slit lamp eyepiece and sent to the telemedicine ophthalmologist for review. All patients presenting with eye trauma or pain were screened for their panchayat of residence by the receptionist; those living in one of the 42 study panchayats had their consultancy fee waived and were issued a standardized form to record the corneal findings. The receptionist became aware of the randomization allocation because the CHWs accompanied patients to the center, but the MLOP and treating ophthalmologist were kept masked to intervention allocation. The presence of a corneal abrasion or ulcer, as confirmed by the telemedicine ophthalmologist in Madurai, was specifically noted on the standardized study form. Abrasions were treated with 3 days of thrice daily chloramphenicol 1% applicaps and twice daily itraconazole 1% ointment (each supplied by Aurolab, Madurai, India) free of charge, regardless of randomization allocation. Medication concentration and dosing was based on commercially available drugs and reflected routine clinical practice. The first dose was applied at the vision center. Corneal ulcers were referred to Aravind Eye Hospital-Madurai, and transportation costs were reimbursed.

Outcomes.

The pre-specified primary outcome was incident corneal ulcer at an annual census, defined as an active ulcer or an incident opacity (i.e., the lack of an opacity at the baseline census and presence of opacity at either of the follow-up censuses). A non-pre-specified secondary outcome was a corneal ulcer diagnosis at the local vision centers and at Aravind Eye Hospital, collected passively through international classification of disease (ICD) codes in the existing integrated hospital management system (IHMS). The intermediate outcome of interest was corneal abrasion diagnosed at one of the local vision centers, assessed from study forms. All outcomes were expressed as counts per cluster to account for cluster-randomization.

Statistical analysis.

The number of events (e.g., census-assessed corneal opacities, vision center-confirmed corneal abrasions, IHMS-assessed corneal ulcer diagnoses) was summed per randomization unit and modeled in a cluster-level negative binomial regression as a function of study arm, using the person-time at risk over the study period as an offset. Assuming 2750 participants per cluster based on census data, an annual incidence of corneal ulceration in the control arm of 100 per 100,000 person-years based on previous studies,[13] an intra-class correlation coefficient (ICC) of 0.00015, an alpha of 0.05, and two years of follow-up, then 21 villages per arm provided 80% power to detect a 40% difference between the two arms.

RESULTS

Baseline characteristics of the 42 study clusters were well balanced in the two treatment arms (Table 1). CHWs underwent training in January 2015 and were deployed after completion of the baseline census for their assigned cluster(s). All CHWs had started

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activities by March 2015, and worked until the final census was performed in their cluster(s) (i.e., between January and June 2017).

In the 21 intervention clusters, CHWs recorded a provisional diagnosis of corneal abrasion for 177 encounters from 175 unique participants (mean age 40 years [SD 15]; 85 [49%] women), with 2 participants presenting on two separate occasions. The most common occupations of the 175 participants with an abrasion were agricultural worker (N=101; 58%) and manual laborer (N=49, 28%). No adverse events were reported. CHWs accompanied participants to the vision center for 124 (70%) of these encounters. A corneal epithelial defect was confirmed at the vision center for all 177 referrals, and 3 of these were also diagnosed with a corneal ulcer and referred to the eye hospital. Of the 174 referrals with an abrasion only, all were provided a course of study medications and 172 had repeat fluorescein testing performed 3 days later, of which 155 (90%) had a healed corneal surface. The 17 referrals whose corneal abrasion had not healed despite 3 days of study medications were referred to the eye hospital.

During the study period, the three vision centers in the study area used a standardized form to collect data on all corneal abrasions from the 42 study communities—regardless of whether a patient was referred by a CHW. Corneal abrasions were diagnosed at 195 encounters in 190 unique participants from the intervention clusters and at 62 encounters in 62 participants from the control clusters (incidence rate ratio [IRR]=3.57, 95%CI 2.01-6.35; P<0.001; pre-specified secondary analysis; Table 2). A non-pre-specified, retrospective query of the IHMS of the 3 vision centers and Aravind Eye Hospital-Madurai detected 8 corneal ulcer diagnoses in the control group and 10 in the intervention group (IRR = 1.07 comparing the intervention to control clusters, 95%CI 0.36-3.32). All ulcers except one were diagnosed at the vision centers.

A new corneal opacity was found at a follow-up census over the 2 years of the study in 54 people in the intervention clusters (60 per 100,000 person-years, 95%CI 25 to 141; intra-study cluster ICC 0.002) and 28 in the control clusters (32 per 100,000 person-years, 95%CI 13 to 80; ICC 0.005); IRR 1.86, 95%CI 0.5 to 6.4; P=0.32; pre-specified primary analysis; Table 2.

DISCUSSION

In this cluster-randomized trial of a corneal ulcer prevention program, community-based vision centers saw more patients with corneal abrasions from intervention communities than control communities, although the penlight examinations at the annual follow-up censuses found no evidence of a significant reduction in corneal opacities in the intervention clusters. Despite the null primary outcome result, it is encouraging that a community health worker program was effective for identifying corneal abrasions in the community and linking patients to care, which is an important health systems outcome in and of itself.[14-16]

A series of studies conducted in Southeast Asia over a decade ago investigated a CHW approach for preventing corneal ulceration.[9-11] Those studies provided training in corneal abrasion diagnosis and allowed CHWs to directly provide treatment with topical

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antimicrobials. These studies found very low rates of corneal ulceration in communities treated with the CHW program, although the absence of an untreated control group prevented a fuller assessment of the effectiveness of the program. The present trial has two important design elements that contrast with these prior studies: first, the inclusion of an untreated control group, and second, the intervention's design as a referral program instead of a treatment program. The control group allows a less biased assessment of the effectiveness of the program. The referral program design, while conceivably resulting in a slight delay to treatment compared with a direct treatment program, is likely more generalizable to settings that would not allow a CHW to dispense regulated medicines, and also ensures confirmation of pathology and earlier referral of corneal ulcers or other pathology missed by the CHW.

The present trial's key finding—namely, that a CHW program significantly increased referrals of corneal abrasions to eye care providers relative to communities without such a program, suggests that such community-based referral programs may be an effective solution for improving linkage to care in places with relatively poor access to the health care system. Abrasion diagnoses made by CHWs were overwhelmingly confirmed on examination at the vision center, suggesting the program did not result in false positives that might burden the health care system. A CHW program may reduce reliance on potentially detrimental traditional health practices and promote confidence in local eye care providers.[17] Even a program focused on a single eye condition, as was implemented in the present study, likely increases awareness about eye diseases in general, and thus may improve health-seeking behaviors for a variety of eye conditions. The improved linkage-to-care almost certainly reduces the delay to initiating care, and hopefully motivates community members to seek care earlier in the disease course for future eye complaints. These potential indirect benefits may increase such a program's cost-effectiveness, although formal studies are lacking.

This study's CHW program had well-trained workers, with clear referral guidelines, timely referrals, and the support of an experienced eye care system—all of which are thought important for reducing the incidence of infectious keratitis.[18] Yet despite the effectiveness of the CHW program for corneal abrasion referral, the door-to-door census failed to find a difference in incident corneal opacity at the end of the two-year study. Several explanations are possible. Ophthalmic antibiotics and antifungals were widely available without prescription at medical shops in the study area. Medical shop workers are likely to recommend and dispense topical antibiotics, so it is possible that people with corneal abrasions in control communities were appropriately treated in a prompt manner outside of the CHW program.[19] Contamination could have played a role if community members from control villages saw publicity materials when traveling to intervention villages. Corneal opacity assessment was done by penlight examination, which may not be sensitive enough to capture subtle opacities. Moreover, although the field staff were purposefully not informed of the randomization allocation, the intervention could not be masked. It is possible that community members in the intervention group had greater awareness of eye conditions in general and thus reported more eye trauma, leading to more vigorous attempts at detecting an opacity on the part of the field staff. The preponderance of incident corneal opacities in the intervention arm would be consistent with such an explanation. It is also possible that the

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incidence of corneal abrasions was too low to provide enough eyes at risk for developing a corneal opacity, and that a much larger study would be needed to determine effectiveness for corneal ulcer prevention.

This study has limitations. Corneal ulceration is a relatively uncommon outcome, which limits statistical power. As stated above, the design as a referral program may have resulted in a slight delay before receiving antimicrobial treatment or prevented some people from seeking care if they viewed the referral process as being too complicated. This limitation will be addressed by a forthcoming trial that several of the authors recently completed in Nepal (where diagnosis and management of infectious keratitis is similar to that in India) that had a similar design except that antimicrobials were distributed directly by the community health worker, potentially resulting in prompter initiation of antimicrobial prophylaxis.[20] Publicity for the program deliberately excluded mass media like radio and television in order to limit contamination, but this may also have reduced awareness of the intervention and biased toward the null. The main means of publicity were written materials, which may not have been accessible to illiterate people in the community. The final corneal opacity assessment was based on penlight examination due to feasibility and available funding. Slit lamp examination would have provided a more accurate assessment, and corneal photography would have more easily allowed a masked comparison. It is also important to note that corneal ulceration and subsequent corneal scarring are important chiefly because of their effects on visual acuity and quality of life, and that the effects of a scar are dynamic due to corneal scar remodeling over time.[21, 22] While visual acuity and quality of life are certainly important outcomes, they were not assessed in the present trial given the large scale of the study. The unmasked nature of the intervention may have resulted in differential co-interventions and/or responses at the annual census, although bias was limited for the primary outcome by examining all community residents as opposed to only those with eye symptoms. Finally, it is unclear whether the results are generalizable to more urban locations, to places with less support from an established eye hospital, or to settings that institute a more multi-faceted program in an attempt to improve its cost-effectiveness.

In summary, this cluster-randomized trial found that a CHW program was an effective strategy for increasing referrals of corneal abrasions to an eye care provider. Although the trial was unable to detect a difference in rates of incident corneal opacities between the two groups, use of outreach activities to increase linkage to care is an important outcome in its own right, and a necessary step for improving eye care of the population. Such referral programs may provide a relatively simple strategy for an eye hospital seeking to better engage with the communities it serves.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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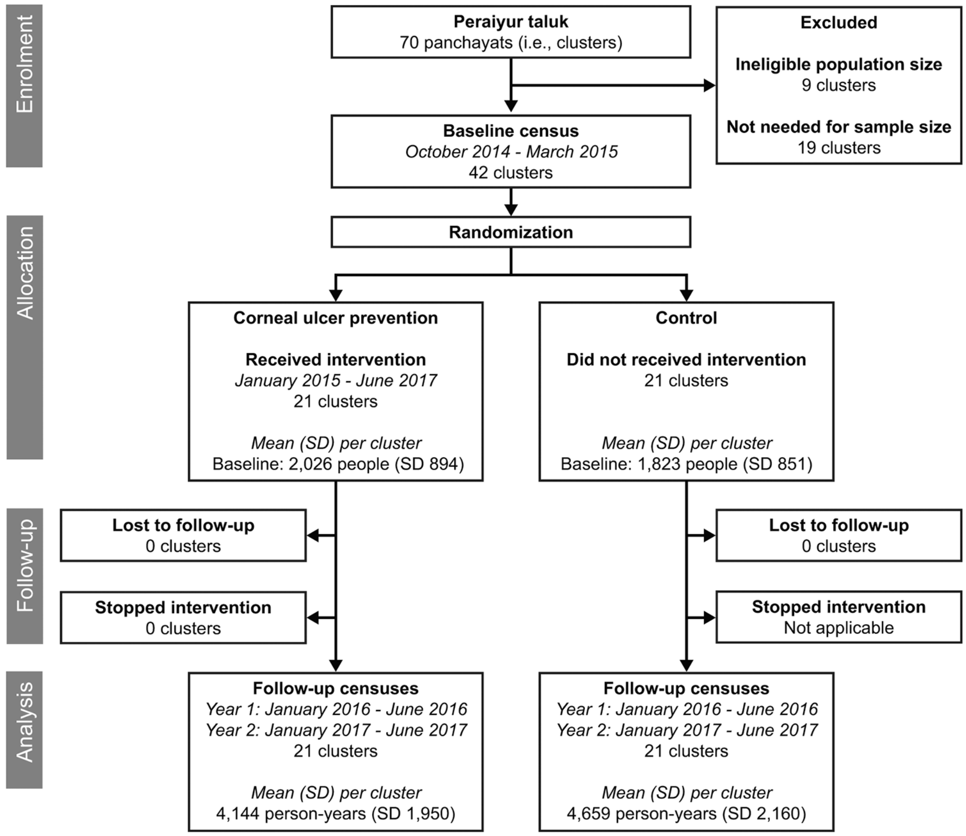

Figure 1. Trial Flow.

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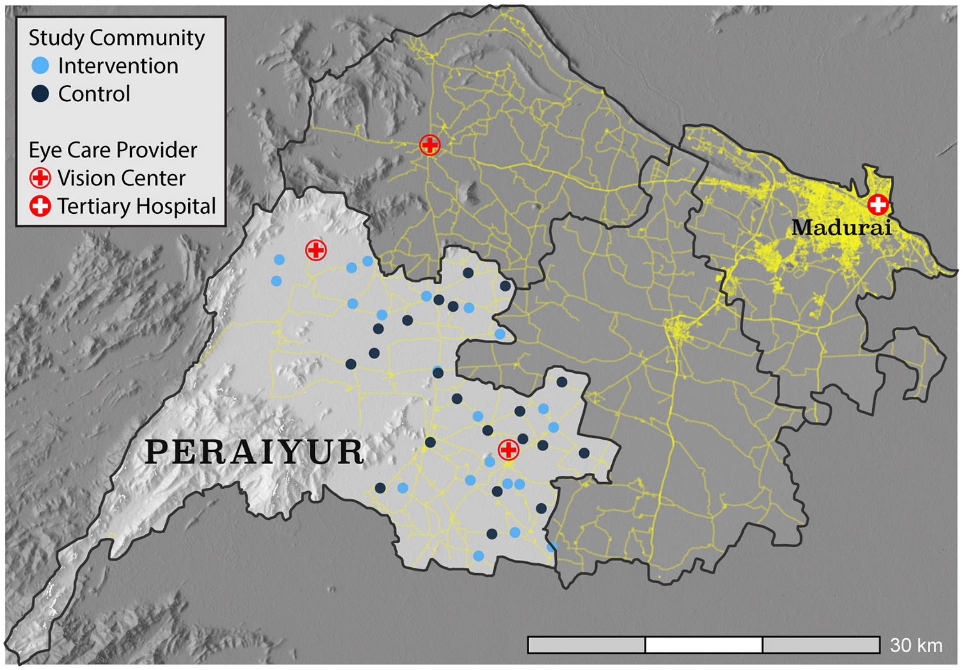

Figure 2. Map of study area.

Administrative boundaries and roads sourced from OpenStreetMaps.

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Table 1.

Baseline characteristics of study villages.

Values represent the mean and standard deviation (SD) of cluster-level numbers or proportions.

	Control N=21	Intervention N=21
Population	1823 (SD 851)	2026 (SD 894)
Fraction female	50% (SD 2%)	50% (SD 1%)
Age distribution		
0-19y	28% (SD 3%)	29% (SD 2%)
20-39y	34% (SD 2%)	34% (SD 2%)
40-59y	25% (SD 3%)	24% (SD 2%)
60-79y	12% (SD 2%)	12% (SD 2%)
≥80y	1% (SD 1%)	1% (SD 1%)
No. people with corneal opacity	6 (SD 7)	8 (SD 12)
Distance from Madurai, km	39.2 (SD 5.0)	41.4 (SD 5.2)
Distance to nearest vision center, km	7.6 (SD 3.4)	6.1 (SD 3.1)

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Table 2.

Trial outcomes

Outcome	Control			Intervention			Incidence rate ratio[b]
	Events	Time at risk[a]	Rate[b]	Events	Time at risk[a]	Rate[b]	
Primary (census)							
Ulcers[c]	28	87,023	32.1	54	97,836	59.9	1.86 (0.5-6.4)
Secondary (clinic)							
Abrasions[d]	62	87,023	62.4	195	97,836	222.7	3.57 (2.01-6.35)
Non-pre-specified (clinic)							
Ulcers[e]	8	87,023	9.1	10	97,836	9.8	1.07 (0.36-3.32)

[a] Estimated from the annual census

[b] Modeled with negative binomial regression of cluster-level data using the time at risk as an offset. Negative binomial regression was chosen due to anticipated overdispersion of count data. Rates are expressed per 100,000 person-years

[c] Active corneal ulcer at the time of the census or evidence of new scar since the baseline census.

[d] Prospectively collected for the study

[e] Non-pre-specified outcome; collected retrospectively from the integrated health management system of the vision centers and tertiary eye hospital