Safety and effectiveness of primary transscleral diode laser cyclophotoablation for glaucoma in Nigeria

Mohammed M Abdull, FWACS, PhD[1,3], mohammed.abdull@lshtm.ac.uk, Corresponding author
David C Broadway, MD[2], david.broadway@nnuh.nhs.uk
Jennifer Evans, PhD[3], Jennifer.Evans@lshtm.ac.uk
Fatima Kyari, FWACS[3,4] Fatima.Kyari@Bazeuniversity.edu.ng
Fatima Muazu, BSc[1], fatimahmraz@yahoo.com
Clare Gilbert, MD[3] Clare.Gilbert@lshtm.ac.uk

1. Ophthalmology Department, Abubakar Tafawa Balewa University Teaching Hospital, PMB 0117, Bauchi, Nigeria. +2348037420779. (Where work was carried out)
2. Directorate of Ophthalmology, Norwich and Norfolk University Hospital NHS Foundation Trust, UK
3. Department of Clinical Research, London School of Hygiene & Tropical Medicine, Keppel Street, London, WC1E7HT, United Kingdom
4. Baze University, Abuja FCT, Nigeria

Corresponding author
Mohammed M Abdull

Word count: 2,701 words

Competing interests

No conflicting relationship exists for any author

Funding

Funding for this project was provided by:

1. British Council for Prevention of Blindness PhD grant number ITCRBY80
2. Seeing is Believing Innovation Fund by Standard Chartered Bank grant number ITCRZD61

ABSTRACT

Importance: To investigate the safety, effectiveness and follow up rates after transscleral diode laser cyclophotocoagulation as primary treatment for seeing eyes with primary open angle glaucoma in Bauchi, Nigeria.

Background: There is a high prevalence of primary open angle glaucoma in Africa where adherence to medical treatment and acceptance of surgery are poor.

Design: Prospective case series

Participants: New glaucoma patients where surgical intervention was recommended.

Methods: A diode 810nm laser G-probe was used under retrobulbar anaesthesia to deliver approximately 20 shots for 2000ms, titrating the power. If both eyes were treated the first treated was the study eye. Repeat treatment was offered if the intraocular pressure (IOP) was >21mmHg on two consecutive visits.

Main outcome measures: Intraocular pressure <22mmHg, change in ≥2 lines of Snellen visual acuity, and complications.

Results: 201/204 eyes with complete data were analysed. Mean age 52 years, 17 (8.3%) eyes were re-treated. Mean pre-treatment IOP was 39 (SD 11) mmHg. 106 (53%) attended at 12 months when the mean IOP was 19 (7-45) mmHg; 77 (73%) had IOP <22mmHg. Visual acuities were better in 13 (12.3%) and worse in 23 (21.7%) eyes. Post-operative complications included mild uveitis (5.5%), corneal oedema (2.5%), severe uveitis (0.5%) and transient hypotony (2.0%). No hypotony at 12 months.

Conclusion: Transscleral diode laser cyclophotocoagulation controlled IOP in almost three quarters of eyes at 12 months with short-term preservation of vision and minimal complications. Poor follow-up in this setting highlights the need for an effective, safe and acceptable treatment where regular follow-up is less critical.

Keywords: Glaucoma, Diode laser, Cyclophotocoagulation, Africa

BACKGROUND

Africa is the region with the highest prevalence of primary open angle glaucoma (POAG) affecting an estimated 7 million people aged 40-80 years.[1] The predisposition to POAG in Africa is likely due to variation in genetic susceptibility.[2] Glaucoma is responsible for a higher proportion of blindness in Africa than in other regions (range 8-22.9%)[3],[4, 5] being 16.3% in Nigerian adults aged 40 years and above.[6]

There are two disease-related factors which increase the life-time risk of blindness from glaucoma in Africa: an earlier age of onset [7],[8] and a more aggressive course[9]. In Africa, most people with glaucoma present very late, often blind in one eye[10,11] and there is poor awareness of the disease.[12,13] Services for eye care, particularly for primary eye care and specialist glaucoma care, are inadequate and mainly located in cities.[14,15] A high proportion of the population are poor and cannot afford the cost of treatment or follow-up,[16] and adherence to systemic or topical medication is often low.[11,17] Acceptance of glaucoma surgery is also low, <2% in a study in the same hospital as this case series,[11] as it does not improve visual function, and patients fear surgery on their only seeing eye. Although trabeculectomy can provide stable, long term IOP control in people of African origin,[18] ophthalmologists in Africa[19] are often reluctant to offer trabeculectomy for fear of complications, including visual field “wipe-out” in advanced cases[20] and the variable outcomes.[21-25]

There are only a few studies comparing outcomes of surgical interventions for glaucoma in patients of African descent, including laser procedures.[26,27] In a recent review, the authors concluded that there was no evidence that any procedures are superior to trabeculectomy, and there is compelling evidence that the outcomes of trabeculectomy are less good than for Caucasian eyes, particularly if antimetabolites are not used.[28] Given the relatively low uptake of surgery, poor outcomes and inadequate follow-up, laser treatment could be considered as a primary treatment for glaucoma in Africa despite the limited reported evidence.

In a review of 18 studies of transscleral diode laser cyclophotocoagulation as (TDLC) treatment, the number of eyes treated ranged from 8-263, and follow-up was 9-66 months.[29] The studies had different indications for treatment and often included different types of

glaucoma. The proportion of eyes in which intraocular (IOP) was controlled (i.e. <22mmHg) ranged from 38% to 88.1%.[29] There are only a few studies of TDLC for seeing eyes, or as a primary treatment, or which were undertaken in Africa.

With respect to studies on seeing eyes (Table 1 and 2, see Appendix), in a retrospective study in the UK, the indication for treatment was uncontrolled glaucoma. 46 eyes were treated, 52% had POAG and the mean pre-treatment IOP was 24 (12-35mmHg). At 2 years 80% of eyes had an IOP of <22mmHg with or without additional topical treatment: 23.9% of eyes lost more than two lines of VA[30]. In another UK study, 49 seeing eyes were treated for uncontrolled glaucoma and at five years IOP was controlled (6-21mmHg) in 79.6% of eyes; 30.6% lost ≥2 lines of VA.[31]

Primary TDLC treatment has been reported in several studies (Table 1 and 2, see Appendix). For example, a study in Germany recruited individuals who refused surgery or where follow-up could not be guaranteed: among the 25 eyes treated, retreatment was required in 3 eyes.[51] In another study for a range of different types of glaucoma in Germany, 193 eyes were treated: at follow-up 90% of eyes with POAG had IOPs of 10-22mmHg after single or multiple treatments.[42]

There are only four studies reporting TDLC treatment outcomes in Africa, from Cameroon,[34] Malawi,[35] Ghana[52] and Tanzania,[33] which had different indications for treatment, varying outcomes, small sample sizes and poor follow-up.

The studies demonstrate that TDLC laser treatment is relatively safe, with mild post-operative uveitis being the commonest complication (Table 1, see Appendix). Other less common complications, such as conjunctival or scleral burns, hyphaema, atonic pupil, choroidal detachment, hypotony and visual loss, ~~which in some cases were associated with visual loss. Most of the more serious complications~~ were more common in studies of patients with intractable or complex glaucoma.

Given the encouraging results of TDLC in seeing eyes and the need for an acceptable one-off treatment in Africa, a prospective study of TDLC was undertaken for POAG in seeing eyes as an alternative to standard care. The purpose of the study was to explore the safety and

effectiveness of TDLC in terms of IOP lowering, and to provide data on the rate of follow up at one year. All the findings will be used to design a clinical trial. The study was undertaken in a university teaching hospital in north-east Nigeria.

PATIENTS AND METHODS

All patients provided written informed consent for the procedure. The study adhered to the tenets of the Declaration of Helsinki.

Glaucoma was diagnosed on the basis of vertical cup-disc-ratio (VCDR), IOP and visual field analysis, where possible. Presenting visual acuity (VA) was measured in each eye using a Snellen E chart and categorized using World Health Organization definitions. Consecutive new patients with a range of severity of POAG but who had a VA of 3/60 or better in one or both eyes and where surgical treatment was the treatment of choice, were recruited for primary TDLC. The following patients were excluded: previous glaucoma surgery, mature cataract, diabetic retinopathy, corneal opacities, those already bilaterally blind from glaucoma (VA <3/60), and those who preferred topical medication. Patients treated with TDLC for blind, painful eyes were also excluded. Given the lack of nomenclature for lasers in the local language the procedure was described in Hausa as “special computer light treatment”. Data are presented on individuals who had a presenting VA of 3/60 or better in the treated eye and who were followed up for 12 months.

TDLC treatment was performed under retrobulbar anaesthesia with lignocaine and adrenaline 2% in the operating theatre using the G-probe of the Iridex diode 810nm laser (IridexCorporation.1212 Terra Bella Avenue Mountain View, CA 94043, USA) in continuous mode. The probe heel was placed at the edge of the limbus matching the contour of the scleral curvature so that the small 0.7mm protrusion indented the sclera approximately 1.2mm posteriorly to optimize energy delivery to the ciliary body. Transillumination was not routinely used. Approximately 20 shots were delivered for 2000ms. The power was reduced by 50mW from the last audible pop to reduce the risk of inflammation and postoperative hyphaema.[53] Treatment was given over 360 degrees, avoiding the ciliary vessels at 3 and 9 o’clock, sub-

conjunctival dexamethasone 2mg was given and the eye padded for four hours. Oral diclofenac potassium 50mg was prescribed twice a day and G. dexamethasone 0.1% four times a day for one month, tailing off thereafter over a few weeks. On the first post-operative day, VA was measured using a Snellen E chart, patients underwent slit-lamp biomicroscopy and IOPs were measured using Goldmann applanation tonometry.

Patients were reviewed at one day, one week and at one, four, six and 12 months when VA and IOPs were measured and anterior segments were examined at the slit lamp for complications. Patients were given dates for follow-up but were not actively traced. If the IOP was raised (>21mmHg) topical medication was initiated and if the IOP was still high at the next visit TDLC retreatment was offered. A second session of laser was given to those who consented.

The outcomes of the study were IOP control, defined as less than 22mmHg and >30% IOP reduction from presenting values, measured on the day laser treatment was offered.[43,46] Other outcomes were change in VA, defined as at least two lines change in Snellen VA, and complication rates. Uveitis was defined as mild if there was anterior chamber flare, or severe if flare and cells were present.

If both eyes were treated, the first eye was the study eye. Data were entered into a database created in Epidata and exported into Stata/IC 14.1 statistical software (StataCorpLP TX 77845 USA) for analysis. Follow-up, IOP and VA findings at presentation and on the first postoperative day, at one week and at one, four, six and 12 months are presented. We calculated a Pearson's correlation coefficient to assess the relationship between change in IOP and presenting IOP.

RESULTS

204 seeing eyes (of 204 patients) with glaucoma that had not previously had surgical or laser treatment underwent TDLC. 201 eyes were included in the analysis as presenting IOP data were missing for three. 17 (8.3%) eyes were retreated. The average power setting was 1770mW (range 1100-2300mW) with duration of 2000ms. The average number of laser spots was 20 (range 15-25) per eye.

The mean age of the 201 patients was 52 (range 12-85) years and 69% were male. The mean vertical cup disc ratio (VCDR) in treated eyes at presentation was 0.9 with 44% having a VCDR of 1.0. Visual field analysis was only possible in 65 (32%) eyes. Not all patients attended every follow-up appointment. A total of 106 (53%) attended at 12 months (Table 1). There were no differences in the age, sex or mean presenting IOP between those who attended the one year follow up and those who did not (Table 1).

Table 1. Comparison between patients followed up and not followed up at one year

	Followed up n=106	**Not followed up n=95**
Mean age in years (range)	51 (12 to 83)	52 (14 to 85)
Male n (%)	72 (68%)	66 (69%)
Mean presenting IOP, mmHg (range)	38 (22 to 72)	39 (22 to 70)

Intraocular pressure

The mean IOP before treatment (201 eyes) was 39 (SD 11; range 22-72) mmHg (Table 2) and the median was 37 (interquartile range 29-46) mmHg. On the first postoperative day, the mean IOP was 12mmHg. IOPs at week one, and after one, four and six months were 11, 15, 18, 19 and 19mmHg, respectively. At 12 months, mean IOP among the 106 (53%) patients who attended was 19 (range 7-45) mmHg: 72.6% (77/106) of eyes had an IOP of <22 mmHg and 83% had a drop in IOP of >30%. The proportion of eyes on topical glaucoma medication at follow-up ranged from 1%-11% over the 12 months, being 9% at 12 months. Follow up of the 17 retreated eyes was 41% (7 eyes) at 12 months. In the retreated eyes, mean IOP was 22mmHg, 57% had an IOP of <22mmHg and two were on topical medication.

Table 2: Presenting and post-operative IOP and topical medication use after TDLC treatment

Time period	Eyes	Follow up	IOP			IOP <22mmHg		On topical medication		IOP drop >30%	
	N	%	Mean	SD.	Range	N	%	N	%	N (%)	Mean (range) %
Presenting	201	100	39	11	22-72	201	100	0	0	0	0
1 day	191	95	12	5	2-30	186	97.4	1	1	188 (98)	-67 (-37/-94)
1 week	177	88	11	5	1-28	170	96.1	5	3	176 (99)	-68 (31-97)
1 mon	156	78	15	7	1-48	135	86.5	15	10	144 (92)	-59 (-14-97)
4 mon	131	65	18	8	2-50	108	82.4	15	11	117 (89)	-52 (-11-97)
6 mon	118	59	19	8	3-52	89	75.4	13	11	103 (87)	-51 (-23-92)
12 mon	106	53	19	7	7-45	77	72.6	10	9	88 (83)	-48 (-7-87)

mon =months

There was a strong correlation between change in IOP between presentation and follow up at 12 months, and presenting IOP (correlation coefficient 0.44, p<0.001)(Figure 1).

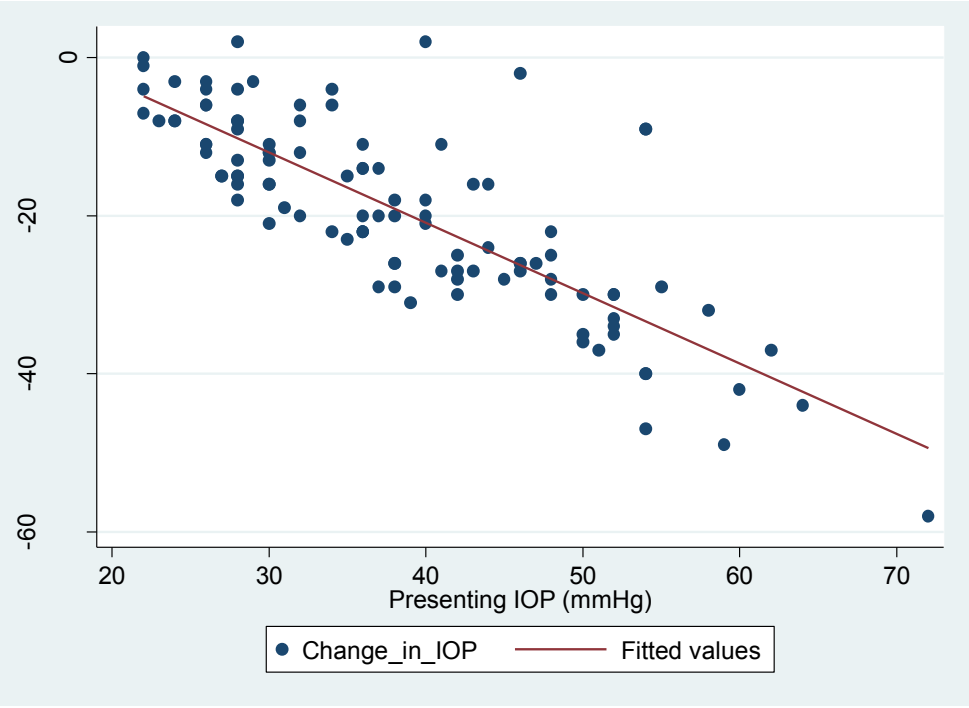

Figure 1. Scatterplot of change in IOP between presentation and follow up at 12 months, and presenting IOP in 106 eyes.

There was no significant associations between presenting and final IOP with the laser energy used nor the number of laser spots delivered. There were no age or gender differences in IOP at presentation or at 12 months.

Visual acuity

The majority of eyes (83/106, 78%) either retained their presenting VA (70, 66%) or the VA had improved by two or more lines at 12 months (13, 12%). Visual acuity deteriorated by two or more lines in 23 eyes (22%): these eyes had slightly higher pre-treatment IOPs (mean 41; range 26-72 mmHg) than those not losing VA (mean 37; range 22-60 mmHg). At 12 months the mean IOP in the eyes that lost VA was 29 (range 8-45) mmHg compared with 19 (range 7-30) mmHg in eyes with stable VA. In addition, 12 (52%) eyes losing VA had a pre-treatment VCDR of 1.0 compared with 28 (39%) of eyes not losing VA. Four eyes losing VA had progression of cataract, and six had corneal oedema before TDLC which persisted after treatment. There were no new cases of corneal oedema. Visual loss in the remaining eyes was attributable to glaucoma progression.

Safety and complications

A few patients had mild anterior uveitis on the first postoperative day, which resolved with topical steroids (Table 3). No eyes developed hyphaema or other serious complications. Transient hypotony (IOP <6 mmHg), developed in four eyes during follow-up but no eyes had hypotony at 12 months. Eyes that were retreated had slightly higher complication rates, with one eye developing severe uveitis.

Table 3. Complications after first and second treatment with transscleral diode laser cyclophotocoagulation

Complications	First treatment (201 eyes)		Second treatment (17 eyes)	
	N	%	N	%
Mild anterior uveitis	11	5.5%	2	11.8
Severe uveitis	1	0.5%	1	5.9
Hypotony (<6mmHg) - temporary	4	2.0%	0	0
Hypotony (<6mmHg) - persistent	0	0.0%	0	0
Corneal oedema	5	2.5%	1	5.9
Cataract progression	4	2.0%	0	0

DISCUSSION

This is the largest case series of TDLC as a primary treatment for seeing glaucomatous eyes in Africa. Unlike other studies from Africa the inclusion criteria were clearly defined, as were the outcomes. A standard treatment protocol was used and one ophthalmologist who had been trained in TDLC in the United Kingdom treated all the patients. TDLC was effective at attaining IOP <22mmHg in a high proportion of treated eyes with follow up data at 12 months, the majority not requiring additional treatment, with good preservation of VA in the short term. Our study suggests that the proportion of eyes with an IOP <22mmHg is a better outcome measure in this population, where values at presentation were high, than the proportion achieving >30% reduction in IOP.

Our findings need to be considered in the context of the glaucoma patients who present to ABTUTH most of whom have advanced glaucoma i.e., they rarely accept incisional surgery nor adhere to topical medication or regular follow-up after surgery. Laser treatment was, therefore, offered to patients where it was considered the only viable alternative. As in other TDLC studies, immediate post-treatment complications were minimal, but were slightly higher in retreated eyes.

There was good acceptance of TDLC, which may be explained by the term used to describe it, which avoided the local Hausa term for surgery, “fidar ido”, which means “butchering”. TDLC was described as a once-off, but repeatable treatment, which is desirable in settings where there is a fear of surgery and hospitalization, and a culture of not attending follow-up. For service providers TDLC is easy to learn and the solid-state laser used is cheaper, and more reliable and versatile than other lasers.

Poor follow-up is a challenge in glaucoma care in Africa, as in this study, where patients either did not return for follow-up at all, or did so at irregular intervals. Despite this, in our study over half returned at 12 months which was a marked improvement from an earlier study in the same hospital.[11] Retreated eyes had poorer follow up and poorer IOP control than eyes that were not retreated. However, poor follow-up may have biased the findings, since those who did not return may have lost vision and hence faith in the service. However, patients in whom vision had

stabilised or improved may have failed to return, believing that they were 'cured'. Poor follow-up emphasizes the need in rural Africa for a procedure that maintains IOP control, which has few postoperative complications and where regular follow-up is less critical.

Comparison of our findings with other studies from Africa is difficult given the variation in study designs, indications for and methods of treatment, outcome definitions and follow-up rates. For example, the study in Ghana was a clinical trial to assess different laser power settings. Treatment was offered as a primary treatment and 92 eyes were treated: at three months 38 of the 79 patients who attended (48%) had an IOP of 22mmHg or less; 16 of these eyes had been retreated and topical medication was being used in 68 eyes.[52] The study in Tanzania was a retrospective review of 179 treated eyes only 49 of whom had at least one follow-up visit. At the 3-6 month follow-up 4/12 eyes had an IOP of ≤21mmHg and 9 eyes were retreated.[33] The study in Cameroon used a 910nm laser (not the usual 810nm laser) to treat 272 eyes but only 26 (<10%) attended at 12 months when the average IOP reduction was 7.5 mmHg i.e., lower than in our study.[34] In the Malawi study, a low dose of 900mW was used to treat POAG and pseudoexfoliative glaucoma. At 3 months mean IOP had fallen from 38.5 to 35.6mmHg. In 50% of treated eyes the IOP returned to pre-treatment levels.[35] These poor outcomes are probably explained by the low power setting used. In the present study IOP control was defined an IOP of <22 mmHg, a target used in other studies. However, the natural history and optimal target IOP to control glaucoma in Africa is not known.

Most glaucoma patients of African ancestry lose vision rapidly if they are not treated or have poor IOP control.(54) In our study the majority of treated eyes either maintained their presenting VA or their acuity improved. The latter has been reported before.[55] The majority of patients lost vision from progression of age related conditions such as cataract, or progression of glaucoma in end-stage eyes, rather than as a direct result of the procedure.

Complications following treatment were minimal in the present study, and compared well with other studies on seeing eyes, but severe uveitis was higher following retreatment, but numbers are small. TDLC has had a relatively bad press in industrialized countries, probably

because it is usually offered as the treatment of last resort. Failure rates and high complications rates are much more likely in these eyes.[49]

A limitation of this study was that visual fields, vertical cup:disc ratios and other parameters were not used to monitor disease progression. There are several reasons for this. Firstly, reliable assessment of visual fields is very difficult amongst uneducated African patients, as many have extensive visual field loss and are not familiar with interacting with technology. Second, many patients had corneal oedema at presentation, which prevented optic disc imaging at presentation, and lastly, optical coherence tomography was not available, which would have provided objective data to monitor structural changes at the optic nerve head. However, monitoring optic disc change in eyes with very advanced disease would be challenging, as in the present study, where almost half the eyes had a cup:disc ratio of 1.0 before treatment.

The findings of the present study may be generalisable to other parts of Africa where challenges faced by most glaucoma patients are similar. TDLC appeared to be acceptable, provided reasonable IOP control after one or two sessions and preserved vision at least in the short term for patients who would otherwise be without treatment.

Implications for service delivery / research

TDLC is a simple, quick and minimally-invasive and could be delivered by general ophthalmologists as a primary treatment[(56)] or as an alternative to surgery in low-income settings.[(37)] The low cost, acceptability and ease of delivering TDLC, offers some promise in the otherwise bleak landscape of glaucoma care in Africa. Given that a once-off treatment is the desired approach to glaucoma control in Africa, and that acceptance of trabeculectomy (standard of care)[(11,19)] is very low in our setting, clinical trials are needed to compare the effectiveness, acceptability, cost and safety of other forms of laser treatment as a primary treatment for glaucoma. These trials need to use standard definitions of control in terms of IOP lowering, together with robust methods to assess disease progression in terms of functional and structural parameters, although the latter will be challenging in this setting, requiring objective methods such as serial optic disc imaging. The sample size calculation will need to take account

of loss to follow up, after pilot testing different approaches to maintain follow up, such as reimbursement of travel expenses, and fast tracking on arrival at the eye clinic.

CONCLUSIONS

TDLC controlled IOP in almost three quarters of eyes at 12 months among the 50% of patients who were followed up, with short-term preservation of vision and minimal complications. Poor follow-up in this setting highlights the need for an effective, safe and acceptable treatment where regular follow-up is less critical. Randomized clinical trials of TDLC in Africa are warranted.

AUTHORS CONTRIBUTIONS

CG, MA, DB and FK conceived the study and review to finalise the methodology. MA drafted the paper under with contributions from CG, DB, JE and FK. Data was collected by MA and FH, analysis was led by JE with contributions from FK, MA, CG and DB. All contributed in the analysis of the results and discussion. CG was the overall guarantor of the project

ACKNOWLEDGEMENTS

We wish to acknowledge and appreciate the following:

1. Colleagues and other staff of Eye Clinic ATBUTH, Bauchi for their support in the course of the research.
2. Colleagues in International Centre for Eye Health, London for valuable inputs and assistance.

REFERENCES

1. Tham YC, Li X, Wong TY, Quigley HA, Aung T, Cheng CY. Global prevalence of glaucoma and projections of glaucoma burden through 2040: a systematic review and meta-analysis. Ophthalmology. 2014;121(11):2081-90.

2. Abu-Amero K, Kondkar AA, Chalam KV. An Updated Review on the Genetics of Primary Open Angle Glaucoma. International journal of molecular sciences. 2015;16(12):28886-911.

3. Bucher PJ, Ijsselmuiden CB. Prevalence and causes of blindness in the northern Transvaal. Br J Ophthalmol. 1988;72(10):721-6.

4. Cook CD, Knight SE, Crofton-Briggs I. Prevalence and causes of low vision and blindness in northern KwaZulu. S Afr Med J. 1993;83(8):590-3.

5. Kyari F, Abdull MM, Bastawrous A, Gilbert CE, Faal H. Epidemiology of glaucoma in sub-saharan Africa: prevalence, incidence and risk factors. Middle East Afr J Ophthalmol. 2013;20(2):111-25.

6. Kyari F, Gudlavalleti MV, Sivsubramaniam S, Gilbert CE, Abdull MM, Entekume G, et al. Prevalence of blindness and visual impairment in Nigeria: the National Blindness and Visual Impairment Study. Invest Ophthalmol Vis Sci. 2009;50(5):2033-9.

7. Quigley HA, Broman AT. The number of people with glaucoma worldwide in 2010 and 2020. Br J Ophthalmol. 2006;90(3):262-7.

8. Sommer A, Tielsch JM, Katz J, Quigley HA, Gottsch JD, Javitt JC, et al. Racial differences in the cause-specific prevalence of blindness in east Baltimore. N Engl J Med. 1991;325(20):1412-7.

9. Wormald R, Foster A. Clinical and pathological features of chronic glaucoma in north-east Ghana. Eye (Lond). 1990;4 (Pt 1):107-14.

10. Cook CF. Glaucoma in Africa: Size of the Problem and Possible Solutions. Journal of Glaucoma. 2009;18(2):124-8.

11. Abdull MM, Gilbert CC, Evans J. Primary open angle glaucoma in northern Nigeria: stage at presentation and acceptance of treatment. BMC Ophthalmol. 2015;15(1):111.

12. Tenkir A, Solomon B, Deribew A. Glaucoma awareness among people attending ophthalmic outreach services in Southwestern Ethiopia. BMC Ophthalmol. 2010;10:17.

13. Balo PK, Serouis G, Banla M, Agla K, Djagnikpo PA, Gue KB. [Knowledge, attitudes and practices regarding glaucoma in the urban and suburban population of Lome (Togo)]. Sante. 2004;14(3):187-91.

14. Patel D, Mercer E, Mason I. Ophthalmic equipment survey 2010: preliminary results. Community Eye Health. 2010;23(73):22-5.

15. Olatunji FO, Ibrahim UF, Muhammad N, Msheliza AA, Ibrahim UY, Rano BT, et al. Challenges of glaucoma service delivery in Federal Medical Centre, Azare, Nigeria. Afr J Med Med Sci. 2008;37(4):355-9.

16. Omoti AE. A review of the choice of therapy in primary open angle glaucoma. Niger J Clin Pract. 2005;8(1):29-34.

17. INVESTIGATORS* TA. The advanced glaucoma intervention study (AGIS): 7. the relationship between control of intraocular pressure and visual field deterioration. American Journal of Ophthalmology. 2000;130(4):429-40.

18. Shah P, Agrawal P, Khaw PT, Shafi F, Sii F. ReGAE 7: long-term outcomes of augmented trabeculectomy with mitomycin C in African-Caribbean patients. Clin Experiment Ophthalmol. 2011.

19. Kyari F, Nolan W, Gilbert C. Ophthalmologists' practice patterns and challenges in achieving optimal management for glaucoma in Nigeria: results from a nationwide survey. BMJ Open. 2016;6(10):e012230.

20. Costa VP, Smith M, Spaeth GL, Gandham S, Markovitz B. Loss of visual acuity after trabeculectomy. Ophthalmology. 1993;100(5):599-612.

21. Yorston D, Khaw PT. A randomised trial of the effect of intraoperative 5-FU on the outcome of trabeculectomy in east Africa. Br J Ophthalmol. 2001;85(9):1028-30.

22. Egbert PR, Williams AS, Singh K, Dadzie P, Egbert TB. A prospective trial of intraoperative fluorouracil during trabeculectomy in a black population. Am J Ophthalmol. 1993;116(5):612-6.

23. Kirwan JF, Cousens S, Venter L, Cook C, Stulting A, Roux P, et al. Effect of beta radiation on success of glaucoma drainage surgery in South Africa: randomised controlled trial. BMJ. 2006;333(7575):942.

24. Kim, Kim HY, Egbert PR, Singh K. Long-term comparison of primary trabeculectomy with 5-fluorouracil versus mitomycin C in West Africa. J Glaucoma. 2008;17:578-83.

25. Lawan A. Pattern of presentation and outcome of surgical management of primary open angle glaucoma in Kano, Northern Nigeria. Ann Afr Med. 2007;6(4):180-5.

26. Babalola OE. Micropulse diode laser trabeculoplasty in Nigerian patients. Clinical Ophthalmology. 2015;9:1347-51.

27. Onakoya AO, Olowoyeye AO, Onyekwelu OM, Abikoye TM. Intraocular Pressure Changes Post Selective Laser Trabeculoplasty in the Contralateral Untreated Eyes of Nigerian Patients With Primary Open Angle Glaucoma. Nig Q J Hosp Med. 2015;25(2):133-8.

28. Taubenslag KJ, Kammer JA. Outcomes Disparities between Black and White Populations in the Surgical Management of Glaucoma. Semin Ophthalmol. 2016;31(4):385-93.

29. Vernon S, Koppens J, Menon G, Negi A. Diode laser cycloablation in adult glaucoma: long-term results of a standard protocol and review of current literature. Clin Experiment Ophthalmol. 2006;34(5):411-20.

30. Ghosh S, Manvikar S, Ray-Chaudhuri N, Birch M. Efficacy of transscleral diode laser cyclophotocoagulation in patients with good visual acuity. Eur J Ophthalmol. 2014;24(3):375-81.

31. Rotchford AP, Jayasawal R, Madhusudhan S, Ho S, King AJ, Vernon SA. Transscleral diode laser cycloablation in patients with good vision. Br J Ophthalmol. 2010;94(9):1180-3.

32. Egbert PRMD, Fiadoyor SMD, Budenz DLMD, Dadzie PRN, Byrd SMD. Diode Laser Transscleral Cyclophotocoagulation as a Primary Surgical Treatment for Primary Open-angle Glaucoma. Archives of Ophthalmology. 2001;119(3):345-50.

33. Mavrakanas N, Dhalla K, Kapesa I, Alibhai A, Murdoch I. Diode laser transscleral cyclophotocoagulation for the treatment of glaucoma in East Africa. Eye (Lond). 2013;27(3):453-4.

34. Preussner PR, Ngounou F, Kouogan G. Controlled cyclophotocoagulation with the 940 nm laser for primary open angle glaucoma in African eyes. Graefes Arch Clin Exp Ophthalmol. 2010;248(10):1473-9.

35. Schulze Schwering M, Kayange P, Klauss V, Kalua K, Spitzer MS. Low-dose transscleral diode laser cyclophotocoagulation (TSCPC) as a potential single treatment for primary open-angle glaucoma (POAG) in Malawi? Graefes Arch Clin Exp Ophthalmol. 2013;251(10):2389-93.

36. Kuchar S, Moster MR, Reamer CB, Waisbourd M. Treatment outcomes of micropulse transscleral cyclophotocoagulation in advanced glaucoma. Lasers Med Sci. 2016;31(2):393-6.

37. Butt JBY, Qureshi TM, Khan MT, Ahmad A-u-H. Diode Laser Trans-Scleral Cycloablation as Surgical Treatment for Primary Open-Angle Glaucoma after Maximum Tolerated Medical Therapy. Pak J Ophthalmol 2014,. 2014;30(2):90.

38. Bloom PA, Clement CI, King A, Noureddin B, Sharma K, Hitchings RA, et al. A comparison between tube surgery, ND:YAG laser and diode laser cyclophotocoagulation in the management of refractory glaucoma. Biomed Res Int. 2013;2013:371951.

39. Ansari E, Gandhewar J. Long-term efficacy and visual acuity following transscleral diode laser photocoagulation in cases of refractory and non-refractory glaucoma. Eye (Lond). 2007;21(7):936-40.

40. Spencer AF, Vernon S. "Cyclodiode": results of a standard protocol. Br J Ophthalmol. 1999;83(3):311-6.

41. Martin KRG, Broadway DC. Cyclodiode laser therapy for painful, blind glaucomatous eyes. British Journal of Ophthalmology. 2001;85(4):474-6.

42. Kramp K, Vick HP, Guthoff R. Transscleral diode laser contact cyclophotocoagulation in the treatment of different glaucomas, also as primary surgery. Graefes Arch Clin Exp Ophthalmol. 2002;240(9):698-703.

43. Murphy CC, Burnett CA, Spry PG, Broadway DC, Diamond JP. A two centre study of the dose-response relation for transscleral diode laser cyclophotocoagulation in refractory glaucoma. Br J Ophthalmol. 2003;87(10):1252-7.

44. Lai JSMFF, Tham CCYF, Chan JCHM, Lam DSCFF. Diode Laser Transscleral Cyclophotocoagulation as Primary Surgical Treatment for Medically Uncontrolled Chronic Angle Closure Glaucoma: Long-Term Clinical Outcomes. Journal of Glaucoma. 2005;14(2):114-9.

45. Grueb M, Rohrbach JM, Bartz-Schmidt KU, Schlote T. Transscleral diode laser cyclophotocoagulation as primary and secondary surgical treatment in primary open-angle and pseudoexfoliatve glaucoma. Long-term clinical outcomes. Graefes Arch Clin Exp Ophthalmol. 2006;244(10):1293-9.

46. Vernon SA, Koppens JM, Menon GJ, Negi AK. Diode laser cycloablation in adult glaucoma: long-term results of a standard protocol and review of current literature. Clin Experiment Ophthalmol. 2006;34(5):411-20.

47. Iliev ME, Gerber S. Long-term outcome of trans-scleral diode laser cyclophotocoagulation in refractory glaucoma. Br J Ophthalmol. 2007;91(12):1631-5.

48. Raivio VE, Puska PM, Immonen IJ. Cyclophotocoagulation with the transscleral contact red 670-nm diode laser in the treatment of glaucoma. Acta Ophthalmol. 2008;86(5):558-64.

49. Frezzotti P, Mittica V, Martone G, Motolese I, Lomurno L, Peruzzi S, et al. Longterm follow-up of diode laser transscleral cyclophotocoagulation in the treatment of refractory glaucoma. Acta Ophthalmol. 2010;88(1):150-5.

50. Zhekov I, Janjua R, Shahid H, Sarkies N, Martin KR, White AJ. A retrospective analysis of long-term outcomes following a single episode of transscleral cyclodiode laser treatment in patients with glaucoma. BMJ Open. 2013;3(7).

51. Becker M, Funk J. [Diode laser cyclophotocoagulation as the primary surgical intervention in glaucoma]. Ophthalmologe. 2001;98(12):1145-8.

52. Egbert PR, Fiadoyor S, Budenz DL, Dadzie P, Byrd S. Diode laser transscleral cyclophotocoagulation as a primary surgical treatment for primary open-angle glaucoma. Arch Ophthalmol. 2001;119(3):345-50.

53. Rebolleda G, Muñoz FJ, Murube J. Audible Pops During Cyclodiode Procedures. Journal of Glaucoma. 1999;8(3):177-83.

54. Pleet A, Sulewski M, Salowe RJ, Fertig R, Salinas J, Rhodes A, et al. Risk Factors Associated with Progression to Blindness from Primary Open-Angle Glaucoma in an African-American Population. Ophthalmic Epidemiol. 2016;23(4):248-56.

55. Spaeth L, Ichhpujani P. Visual Improvement in Patients with Far-Advanced Glaucoma. Journal of Current Glaucoma Practice. 2009;3:36-8.

56. Shahid H, Samia-Aly E. The Effectiveness of Trans-scleral Cyclodiode Treatment. European Ophthalmic Review. 2013;07(01):17.

APPENDIX

Table 1. Transscleral diode laser cyclophotocoagulation treatment studies: indications for and methods of treatment, participants and outcome measures

Author, country (ref)	Study design	Type of glaucoma	Indications for treatment	Number treated	Definition of outcome	Preoperative IOP (mmHg) (range)
Studies in Africa						
Egbert, Ghana(32)	Trial of laser power	POAG	Primary treatment	92 eyes	Final IOP <22 mm Hg	Mean 29.3 (16-66)mmHg
Mavrakanas, Tanzania(33)	CS: retro-spective	POAG (seeing and non seeing)	Uncontrolled IOP	49 eyes	Lower IOP	Mean 53mmHg
Preussner, Cameroon(34)	CS - prospective using 910nm laser	POAG	IOP reduction; reduction in medication	272 eyes; 26 followed up	IOP reduction at 1 year	Mean 31.2mmHg
Schulze, Malawi(35)	CS: prospective	POAG; PXE	IOP reduction	47 eyes	Mean IOP reduction	Mean 38.5mmHg
Studies in other countries						
Rotchford, UK(31)	CS: retro-spective	POAG seeing eyes	Primary treatment	49 eyes	Loss of 2 or more VA line IOP 8-21	28mmHg (16-50)
Ghosh, UK(30)	CS: prospective	POAG seeing eyes	High IOP	46 eyes	At 24 months	Mean 24mmHg
Kuchar, USA(36)	CS: prospective (micropulse laser)	Advanced	Uncontrolled IOP	19 eyes	6-21 mmHg/20% lower at last visit	Mean 37.9 mmHg
Butt, Pakistan(37)	Quasi-experimental	POAG	POAG on maximum medication; Primary Rx	60 eyes	IOP reduction	Mean 41.62 (28 – 60) mm Hg
Bloom, UK(38)	CS: prospective. YAG laser	Any type	Refractory glaucoma after multiple procedures	45 eyes	Not defined	Mean 32mmHg
Ansari, UK(39)	CS: retro-spective	Non refractory	Poor control; painful, blind eye allergies; refused surgery;	74 eyes	Lower IOP fewer medications	Mean 40.3mmHg
Spencer, UK(40)	CS: prospective	Refractory	Uncontrolled IOP: surgery refused or unlikely	58 eyes	Fewer glaucoma mediccations	Mean 33.0 mmHg

Martin, UK(41)	CS: prospective	Painful blind eyes	Pain	30 eyes	IOP reduction; pain relief	Mean 51 mm Hg
Kramp, Germany(42)	CS: retro-spective	109 POAG; 84 secondary	Uncontrolled glaucoma	193 eyes	IOP 10-22 mmHg	Mean 24.6+/-6.7 mmHg
Murphy, UK(43)	CS: retro-spective	Refractory: 46% neovascular	Uncontrolled glaucoma	263 eyes	IOP <22 mm Hg or > 30% drop in IOP	Mean 40.7 mmHg
Lai, Hong Kong(44)	CS: prospective	CACG	Medical uncontrolled CACG	13 eyes	IOP <21mmHg with or without medication	Mean 36.4 +/- 12.6 mm Hg
Grueb, Switzerland(45)	CS: retro-spective	POAG, PXEG	POAG, PXEG	90 eyes	4-18mmHg or 20% reduction	Mean 21 mmHg (12–36 mmHg)
Vernon, UK(46)	CS: retro-spective	Refractory; 19% 19%	Poor control	42 eyes	IOP<22; reduction in medicine	Mean 31.4mmHg
Iliev, Switzerland(47)	CS: retro-spective	Advanced, refractory: 3% POAG; 61% neovascular	Refractory glaucoma	131 eyes	IOP 6-21 at last visit	Mean IOP 36.9mmHg
Raivio, Finland(48)	CS: retro-spective	1/3 PXE; POAG/ complex	Poor control; refractory glaucoma	60 eyes	8-21mmHg	IOP 27 ± 11 mmHg
Frezzoti, Italy(49)	CS: prospective	Advanced/refractory: 36% POAG; 64% complicated	Refractory	124 eyes	IOP 5-21; pain relief	Mean 29.9 +/- 8.4 mmHg (17-58 mmHg)
Zhekov, UK(50)	CS: retro-spective	Refractory. One treatment only. 45 POAG/PACG	IOP maintained; visual acuity	87 patients	Not defined	IOP 39.5mmHg

CS = case series; IOP = intraocular pressure; POAG = primary open angle glaucoma; PXEG = primary exfoliative glaucoma; CACG = chronic angle closure glaucoma

Table 2. Transscleral diode laser cyclophotocoagulation treatment studies: outcome of treatment and complications

	Follow-up	Outcome: Post op IOP	Outcome: Visual acuity (change)	Complications (n) Number of eyes	Comments
Studies in Africa					
Egbert (32)	Mean 13.2 months	≥20%mmHg drop in 47%; 48% final IOP <22 mm Hg	Worse in 23% but not defined	Atonic pupil (92) 28%; transient hyphaema (3), severe iritis (2). No hypotony, phthisis or sympathetic ophthalmia.	
Mavrakanas (33)	Variable	At last visit 51% eyes had >50% lower IOP	Not reported	No serious complications	
Preussner(34)	1 year, 26 eyes	Mean reduction: 7.5mmHg	Not reported	No serious complications	Medication reduced from 1.5 to 1.2.
Schulze(35)	3 months	Mean 35.6mmHg	Not reported	Atonic pupil (4) 10.6%; transient iritis (1) (2.1%)	Low dose diode used
Studies in other countries					
Rotchford(31)	5 years	79.6% controlled at final follow-up	≥2 lines: worse 30.6% (15 eyes): 9 glaucoma progression.	Vitreous haemorrhage (1); retinal detachment (1); macula oedema (4)	
Ghosh(30)	24 months	Mean 17.2 (12-28); 84.8% IOP<21mmHg	>2 lines: same 76.1%; worse 23.9%; (11 eyes); 9 glaucoma progression.	Macula hole (1); retinal detachment (1); macula oedema (2). No hypotony.	
Kuchar(36)	Mean 60.3 days	22.7 mmHg at last follow-up, 40.1 % decrease.	One line of VA: better 21%; worse 21%.	Hypotony (1).	
Butt(37)	12 months	Mean 15mmHg at 6 mon; 14.15mmHg at 1 year	Not reported	Anterior uveitis, cataract (8) 13.3% each; hyphaemia (5) 8.3%; hypotony (6) 10%	45% of eyes retreated. 6% had three treatments.
Bloom(38)	No data	Mean 19.3mmHg. 71% treatment success	≥2 lines: worse 9%	Phthisis (1); chronic hypotony (2); hyphaema and vitreous haemorrhage (1)	
Ansari(39)	12.5 (4–30) months	Mean: reduced by 45.1% to 21.1 mmHg at final visit.	Mean VA preserved in those with good VA; worse in 13% (glaucoma progression; lens opacity, chronic uveitis)	Hyphaemia (3); chronic iritis (3); corneal oedema (1). No hypotony or other serious complications.	58% reduction in medication. All with iritis had peripheral iridectomy

Spencer(40)	Mean 19 (6-37) months	Mean 16.7 mm Hg at final visit	>2 lines: worse 32%	Rubeotic eye developed endophthalmitis. Chronic hypotony (2) no phthisis (8) 13.3%	Fewer medications: from 2.4 to 1.4. Up to 5 treatment sessions
Martin(41)	6 months	26 mm Hg. Pain relief in 73.3%	Not reported	Hypotony (3); phthisis (1); uveitis (2); hyphaema (1)	
Kramp(42)	Mean 13.9 (6 to 48) months	Success 76.4%. Mean 19.3+/-5.7 mmHg. Best results in POAG	No reported	Mild anterior uveitis (31); hyphaema (1); phthisis bulbi (3)	≤6 sessions. 2 phthisical eyes had neovascular glaucoma and PXG
Murphy(43)	17 months (6-46)	Mean 17.7 mmHg. Reduction of 52.6%. Success 89%	Not reported	Hypotony ranged from 0% in POAG to 18.8% in uveitic glaucoma. Persistent uveitis 1.6%: most in complicated glaucoma	A third of eyes were retreated
Lai(44)	Mean 26.5 (+/- 4.2) months	Success 92.3%. Mean 18.7 +/-12.2 mm Hg at final visit	≥2 lines: same 15.4%; better 46.2%; worse (5 eyes).	No hypotony. Atonic pupil (7)	
Grueb(45)	≥24 months	Mean 16 (9–27) mmHg. Success 36.7% all 40.9% POAG	Not reported	Hyphaema (1); anterior uveitis (10). No phthisis.	
Vernon(46)	Mean 65.7 (36-84) months	88.1% success. 50.3% reduction in IOP. Mean 15.6 +/-6.3 mmHg	Same 26.2% Better 9.5% Worse 64.3%	Transient hypotony (2)	Fewer medications: from 2.6 to 1.7. ≤6 sessions. Focus on maintaining acuity
Iliev(47)	Mean 30 months (no range)	Success in 69.5%. 45.8% IOP controlled with 1 treatment	Not reported	Hypotony (23) 17.6%. 74% of these eyes had neovascular glaucoma. Chronic uveitis (1); severe dry eye (1); hyphaema (1) vitreous haemorrhage (1).	Fewer medications: mean from 2.97 to 1.39. Multiple eyes were retreated.
Raivio(48)	26 (3–75) months	18±5mmHg at 6months, 19±7mmHg at 1year, 80% had 30% reduction in IOP at last follow-up	Not reported	Mild anterior uveitis 25%; hyphaema (2 eyes), vitreous haemorrhage (1). No hypotony.	
Frezzoti(49)	17 (3-42) months	20.8mmHg (range 6-45) last visit	Loss of two or more lines: 12.9%	Mild anterior uveitis (3) 2.4%; hypaema (2) 1.6%. No hypotony or phthisis	

Zhekov(50)	3 years	17.8mmHg at 6 weeks maintained over 3 years	Same or better: 83.6%	Hypotony 5%; no uveitis	

IOP = intraocular pressure