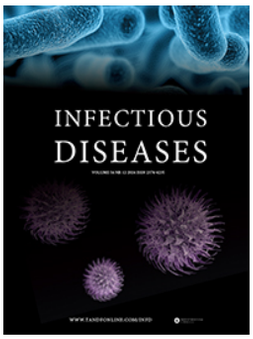

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RESEARCH ARTICLE

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Operational feasibility and multi-centric evaluation of 'TB*Detect* sputum microscopy kit' for the direct detection of *Mycobacterium tuberculosis* in field settings

Keerti Chauhan[a]*, Rakesh Kumar Gupta[a]*, Divya Anthwal[a], Nikita Panwalkar[b], Prabha Desikan[b], Manpreet Bhalla[c], Ritu Singhal[c], Vithal Prasad Myneedu[c], Khalid Umar Khayyam[c], Siva Kumar Shanmugam[d], K. Silambu Chelvi[d], A. Radhakrishnan[d], Padmapriyadarsini Chandrasekaran[d], Sidhartha Giri[e], Jyotirmayee Turuk[e], Dasarathi Das[e], Sanghamitra Pati[e], Abhinav Goyal[f], Ashawant Gupta[f], Nalini Kant Gupta[f], Manjula Singh[g], Jaya Sivaswami Tyagi[h] and Sagarika Haldar[a]

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ABSTRACT

Background: India relies primarily on direct smear microscopy for tuberculosis (TB) diagnosis. However, the low sensitivity of smear microscopy emphasizes the need to improve its performance. We recently described the development of 'TB*Detect*' kit which showed improved performance over direct smear microscopy at National Reference Laboratories (NRLs) in India.

Methods: The present study was aimed to assess the operational feasibility of 'TB*Detect*' microscopy in field settings. This was evaluated by (i) assessing the performance of 'TB*Detect*' microscopy *vs.* LED-fluorescence microscopy (LED-FM) on consecutive presumptive pulmonary TB patients ($n = 5300$) who attended Designated Microscopy Centres (DMCs, $n = 13$) under 4 NRLs at Bhubaneswar, Bhopal, Chennai, and New Delhi, and (ii) obtaining feedback from Scientists ($n = 10$) and laboratory technicians ($n = 42$) using semi-structured questionnaires under the following parameters: feasibility of initiation of 'TB*Detect*' microscopy in DMCs, sample preparation and testing, training, time-to-result, logistics, and troubleshooting. A scoring questionnaire was also used to assess 'TB*Detect*' microscopy *vs.* LED-FM and statistical significance of the scores was calculated using paired *t*-test.

Results: The overall positivity of 'TB*Detect*' microscopy was 10.32% (547/5300) *vs.* 8.96% (475/5300) of LED-FM at all sites and the increment in positivity was significant ($p = 0.019$). In addition, 'TB*Detect*' microscopy yielded an increment in smear grade status over LED-FM ($p = 0.043$). The feedback from the study-in-charge and kit users indicated that 'TB*Detect*' microscopy was easily adapted in point-of-care settings. An analysis of scoring feedback suggested that it was easy to perform and observe in comparison to LED-FM ($p < 0.005$).

Conclusions: This study established the feasibility of 'TB*Detect*' microscopy in field settings.

KEYWORDS
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diagnosis
fluorescent smear microscopy
TB*Detect* kit
filter-membrane

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Introduction

Globally, an estimated 10.6 million people were infected with tuberculosis (TB) in the year 2022. Amongst them, more than 3 million people were missed due to a lack of proper diagnosis [1]. Most of the TB high-burden countries, including India, rely primarily on direct smear microscopy [Ziehl-Neelsen (ZN) staining or direct light emitting diode-fluorescence microscopy (LED-FM), World Health Organisation (WHO) endorsed test] to detect acid-fast bacilli (AFB) in sputum, despite its low sensitivity. The WHO recommends replacing smear microscopy with molecular tests like Xpert MTB/RIF or Ultra. However, in a resource-limited, high-TB-burden country like India, this is difficult to achieve. In 2023, the number of patients examined by smear microscopy was 1.89 crores (18.9 million) in comparison to 37.19 lakh (3.719 million) patients by Cartridge-based nucleic acid amplification test (CBNAAT, Xpert MTB/RIF or Ultra) and 31.13 lakh (3.113 million) patients by Truenat assay for TB diagnosis in India [2]. This indicate that <20% coverage was achieved by Xpert or Truenat assay in comparison to smear microscopy. Smear microscopy is the most frequently used test to this day and the National Tuberculosis Elimination Programme (NTEP) primarily relies on it for case detection in India [2]. This scenario emphasises the need to improve the performance of smear microscopy in the network of Designated Microscopy Centres (DMCs; $n = 24{,}573$) in India under the NTEP for improved TB diagnosis in the community [2].

Towards accomplishing this aim, we developed a bio-safe 'TB*Detect*' microscopy kit that achieves equipment-free concentration of sputum using a Bio-FM filter device that retains bacilli on the filter membrane, see supplemental Figure S1 [3]. The concentrated AFB bacteria captured on the filter membrane can be observed under a LED microscope with increased sensitivity in comparison to direct smear microscopy [3]. In the first study (development and evaluation study), 'TB*Detect*' microscopy showed an increase in sputum smear positivity of 7% and 4% over ZN microscopy and LED-FM, respectively, in a 2-site evaluation on 1190 sputum specimens from presumptive TB patients. An assessment of bio-safety in this study established the efficacy of the 'TB*Detect*' kit to disinfect sputum upto 8-logs of *M. tuberculosis* [3]. In a subsequent multi-centric validation study on 2086 sputum samples performed at 5 National Reference Laboratories (NRLs) and 1 Intermediate Reference Laboratory (IRL), a significant increment in positivity (4%, $p < 0.05$) over direct smear microscopy (ZN microscopy and LED-FM) was observed by 'TB*Detect*' microscopy [4]. Also, using phenotypic culture as the reference standard, 'TB*Detect*' microscopy had a sensitivity of ~55% vs. 52% for LED-FM ($p = 0.14$) and 50.9% for ZN smear ($p < 0.05$). A bio-safety evaluation confirmed efficient sputum disinfection (99.95%) by 'TB*Detect*' kit at all 6 sites. Feedback from Scientists and lab technicians at the NRL/IRL study sites pointed to the ease of use and convenience of 'TB*Detect*' microscopy.

The above two studies [3,4] were performed at NRLs/IRLs. However, it was essential to assess the 'TB*Detect*' kit in terms of its robustness and performance under field conditions. The present study was accordingly designed to evaluate the performance and operational feasibility of 'TB*Detect*' microscopy in comparison to LED-FM at DMCs under programmatic field settings.

Materials and methods

Ethical clearance

The ethical approval for this study was obtained from the individual Institutional Ethics Committees of all NRL sites [Bhopal Memorial Hospital Research Centre, Bhopal (BMHRC; BMHRC/IEC/43/Micro/20), National Institute of Tuberculosis and Respiratory Diseases, New Delhi (NITRD; NITRD/EC/2020/A85), Indian Council of Medical Research (ICMR)-National Institute for Research in Tuberculosis, Chennai (ICMR-NIRT; 154/NIRT-IEC/2020), ICMR-Regional Medical Research Centre, Bhubaneswar (ICMR-RMRC; ICMR/-RMRCB/IHEC-2020/10)] for the collection of sputum samples at their associated DMCs.

Study population and design

All consecutive patients attending the DMCs were enrolled in the present study. As per NTEP guidelines, all patients are subjected to direct microscopy testing (ZN microscopy or LED-FM) at DMCs. These patients include presumptive TB patients and presumptive multidrug-resistant TB (MDR-TB)/extensively drug-resistant TB (XDR-TB) patients. Presumptive MDR-TB/XDR-TB patients are defined according to the Programmatic Management of Drug Resistant TB guidelines [5]. An informed consent was taken (consent was taken from the guardian in case of a minor, see supplemental Appendix S1) and clinical data were collected (see supplemental Appendix S2) from each patient. This study was conducted according to Standards for Reporting Diagnostic Accuracy (STARD) guidelines (see supplemental Appendix S3).

The operational feasibility and performance of 'TB*Detect*' microscopy was evaluated in comparison to

LED-FM at 13 DMCs associated with 4 NRLs under NTEP in field settings. This study was supervised by the Post Graduate Institute of Medical Education and Research (PGIMER), Chandigarh. A hands-on training on 'TB*Detect*' kit protocol was provided to laboratory technicians (NTEP staff) at all DMCs ($n = 13$) prior to the study. LED-FM and 'TB*Detect*' microscopy were performed simultaneously on the same sputum samples by laboratory technicians at DMCs (Figure 1).

Sample collection

Sputum samples ($n = 5300$) were collected from all consecutive presumptive pulmonary TB patients attending selected DMCs ($n = 13$) under 4 NRLs: BMHRC, Bhopal ($n = 1621$), NITRD, New Delhi ($n = 1216$), ICMR-NIRT, Chennai ($n = 1503$) and ICMR-RMRC, Bhubaneswar ($n = 960$, see supplemental Table S1). These $n = 13$ DMCs were selected on the basis of availability of a LED microscope at these sites (essential for 'TB*Detect*' microscopy).

Sample size

The sample size was calculated based on 85% power, alpha of 5% and pooled sensitivity of 55% and 52% of 'TB*Detect*' microscopy *vs.* LED-FM, respectively (on the basis of multi-centric validation study data of 'TB*Detect*' kit) [4]. The sample size was estimated using G*Power 3 software [6].

LED-FM microscopy

LED-FM slides were prepared by taking a loopful of sputum (~20 µL), stained and graded as per NTEP guidelines [7]. All the slides were observed under the LED microscope at 40× magnification (LaboMed LX-200 LED microscope, Ambala, India).

'TBDetect' kit-based BioFM-Filter microscopy

To the sputum dissolution tube (containing lyophilised powder) from the 'TB*Detect*' kit, 400 µL of 'Dissolving solution' and 100 µL of sputum were added, mixed and incubated for 30 min for liquefaction [3]. Three hundred microliters of liquefied sputum was filtered through the BioFM-Filter without using any equipment. The pre-filter was removed after complete filtration. BioFM-Filter-adsorbed bacilli, if present in the sputum sample, were stained using the solutions provided in the 'TB*Detect*' kit. The BioFM-Filter slide was observed at 40X magnification under LED microscope and the slides were graded as per NTEP guidelines [7]. All the BioFM-Filter slides were stored at ambient temperature till the end of the study. The results of both 'TB*Detect*' microscopy and LED-FM were arbitrarily rechecked for a total of $n = 200$ samples at all sites by using 'TB*Detect* microscopy-Restaining kit'.

Data compilation and analysis

Data was collected at each DMC on the study clinical proforma (supplemental Appendix S2). All patient data (clinical information and test results) were compiled in a data collection sheet at each NRL and communicated to PGIMER, Chandigarh on a weekly basis through e-mail (see supplemental Appendix S4). All the results were analysed at the end of the study.

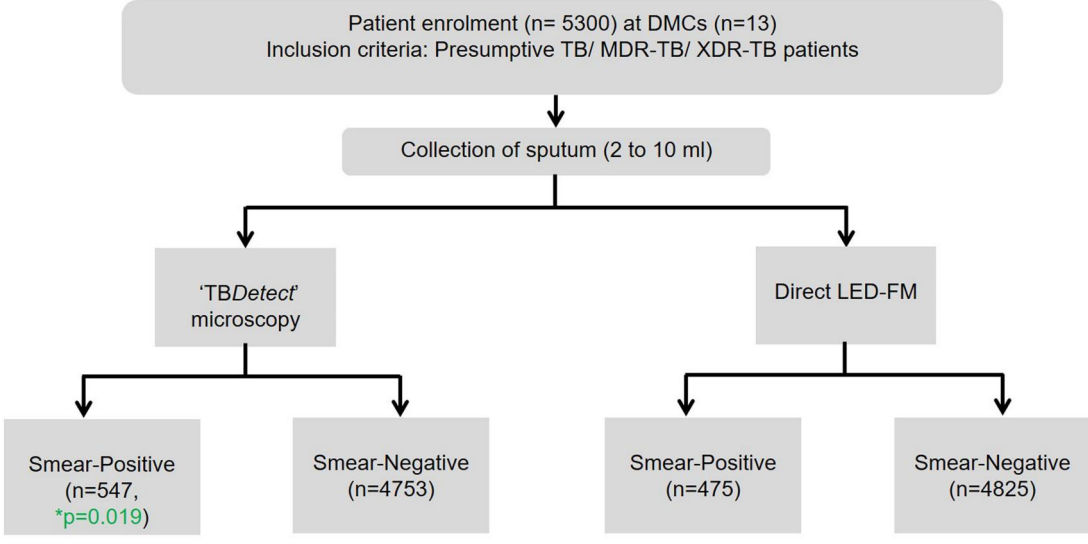

Figure 1. Summary of study workflow and microscopy results. The increment in smear positivity using 'TB*Detect*' microscopy vs. LED-FM was statistically significant ($p < 0.05$).

Operational feasibility

The operational feasibility of the kit was evaluated in two ways: (a) by assessing the performance of 'TB*Detect*' microscopy *vs.* LED-FM at DMCs in field settings, and (b) by obtaining feedback from users. For (a), a head-to head comparison was performed between 'TB*Detect*' microscopy and LED-FM for AFB detection, wherein the positivity and smear grade status of the former was compared with that of the latter for each sputum sample. For (b), feedback was obtained from Scientists/study-in-charge ($n = 10$) and laboratory technicians ($n = 42$) using a semi-structured questionnaire that included the following parameters: feasibility of adopting 'TB*Detect*' microscopy in DMCs, training for kit protocol implementation, time required for 'TB*Detect*' microscopy, logistics, and troubleshooting. The questionnaire also included the assessment of the kit user manual and its components, and user's feedback on the feasibility of amalgamating 'TB*Detect*' kit in the NTEP. In addition, at the end of the study, a scoring questionnaire (on a scale of 1–5) was used to assess 'TB*Detect*' microscopy *vs.* LED-FM in terms of (i) ease of performing the protocol, (ii) ease of observation under the microscope, (iii) ease of handling and storage of BioFM-Filter slides, (iv) time-saving and (v) operator fatigue (see supplemental Appendix S5).

Statistical analysis

The positivity of 'TB*Detect*' microscopy was directly compared with that of LED-FM and was calculated as [Number of positive samples]/[Total number of samples]. Chi-square test was used to estimate the statistical significance (p-value <0.05) of the increment in positivity and smear grade by 'TB*Detect*' microscopy and LED-FM (GraphPad Prism 5 for Windows ver. 5.01). The statistical significance of scoring feedback between 'TB*Detect*' microscopy and LED-FM was calculated for each parameter using paired t-test (GraphPad Prism 5 for Windows ver. 5.01). Samples with missing results were excluded from the analysis.

Results

Study population

Study subjects enrolled in this study were in the age range of 1–99 years (including 452 children, aged between 1 and 17 years), who visited the DMCs ($n = 13$) from May 2022 to December 2022. Of $n = 5300$ participants, $n = 2894$ were treatment-naïve patients, $n = 518$ were follow-up cases, $n = 12$ were MDR-TB contacts, $n = 35$ were relapse cases and status was not available for $n = 1841$ cases. Around 52% (2755/5288) of patients were males. The most common clinical symptoms were cough (~78%, 2971/3783), fever (~61%, 2309/3779), weakness (~55% 2099/3780), weight loss (~28%, 1055/3783), and loss of appetite (26%, 982/3778) (see supplemental Table S2). The HIV status of $n = 2128/5300$ enrolled subjects was available and 10/2128 participants were found to be HIV-positive. Clinical characteristics data of enrolled patients ($n = 1503$) at ICMR-NIRT, Chennai site was not available for this analysis.

Operational feasibility

Performance of 'TBDetect' microscopy vs. LED-FM

The overall positivity of 'TB*Detect*' microscopy at all sites ($n = 13$ DMCs) was 10.32% ($n = 547/5300$) *vs.* 8.96% ($n = 475/5300$) of LED-FM. The increment in positivity at all sites of 'TB*Detect*' microscopy over LED-FM was significant ($p = 0.019$, Table 1). A NRL site-wise analysis indicated an increment in the positivity of 'TB*Detect*' microscopy over LED-FM at Bhopal ($p = 0.001$), New Delhi ($p = 0.412$) and Chennai ($p = 0.454$, Table 1 and Figure 2) sites. However, there was no increment observed at Bhubaneswar site and no specific reason could be assigned for it. A DMC wise analysis is complied in Table 1.

An increment in smear grade status was also noted with 'TB*Detect*' microscopy as compared to LED-FM (supplemental Table S3) and this overall increment at all sites was significant ($p = 0.043$, Figure 3). On site-wise analysis, the increment in smear grade status was significant at three sites [Bhopal; Bhubaneshwar; and Chennai, ($p < 0.05$)]. At New Delhi site, it was found to be not significant ($p = 0.287$, Figure 3).

In follow-up cases ($n = 518$), there were $n = 17$ patients who were negative by LED-FM and were found to be positive by 'TB*Detect*' microscopy at Bhopal site. All HIV-positive participants ($n = 10$) were AFB-smear negative by both LED-FM and 'TB*Detect*' microscopy. Among children ($n = 452$), the positivity of 'TB*Detect*' microscopy was 8.8% ($n = 40/452$) *vs.* 6.2% (28/452) of LED-FM (p value $= 0.165$).

User feedback

The laboratory technicians and study-in-charge at all the sites had a median work experience of 12 years (interquartile range [IQR] 4.0–18.0) and 21 years (IQR 10.5–23.7), respectively. They confirmed that adequate training of 'TB*Detect*' kit was provided before the start of the

Table 1. Performance of 'TB*Detect*' and LED-FM microscopy at all DMCs ($n = 13$).

NRL	DMC	'TB*Detect*'			LED-FM		
		Pos	Neg	Positivity[#] (%)	Pos	Neg	Positivity (%)
All sites	**Total ($n = 5300$)**	**547**	**4753**	**10.32***	**475**	**4825**	**8.96**
BMHRC, Bhopal	**Total ($n = 1621$)**	**157**	**1464**	**9.68****	**107**	**1514**	**6.6**
	Vidisha ($n = 94$)	12	82	12.76	12	82	12.76
	Hoshangabad ($n = 495$)	29	466	5.85	26	469	5.25
	Jawaharlal Lal Nehru Hospital, Bhopal ($n = 800$)	83	717	10.37***	36	764	4.5
	Dhar ($n = 232$)	33	199	14.22	33	199	14.22
NITRD, New Delhi	**Total ($n = 1216$)**	**120**	**1096**	**9.86**	**112**	**1104**	**9.21**
	Safdarjung ($n = 633$)	62	571	9.79	58	575	9.16
	DMC, NITRD ($n = 583$)	58	525	9.94	54	529	9.26
ICMR-NIRT, Chennai	**Total ($n = 1503$)**	**177**	**1326**	**11.77**	**163**	**1340**	**10.84**
	Pulianthope ($n = 333$)	17	316	5.1	15	318	4.5
	Kodungaiyur ($n = 264$)	12	252	4.54	12	252	4.54
	Aminijikerai ($n = 83$)	1	82	1.2	1	82	1.2
	Otteri ($n = 823$)	147	676	17.86	135	688	16.40
ICMR-RMRC, Bhubaneswar	**Total ($n = 960$)**	**93**	**867**	**9.68**	**93**	**867**	**9.68**
	Dhenkanal ($n = 145$)	11	134	7.58	11	134	7.58
	Kendrapara ($n = 262$)	6	256	2.29	6	256	2.29
	Capital Hospital ($n = 553$)	76	477	13.74	76	477	13.74

[#]Rows showing values in bold are overall values at all 13 sites (in 1st row) and NRL wise total values. Increment in positivity of 'TB*Detect*' kit as compared to LED-microscopy was significant *($p < 0.05$, $p = 0.019$); **($p < 0.05$, $p = 0.001$); ***($p < 0.05$, $p = 0.0001$).

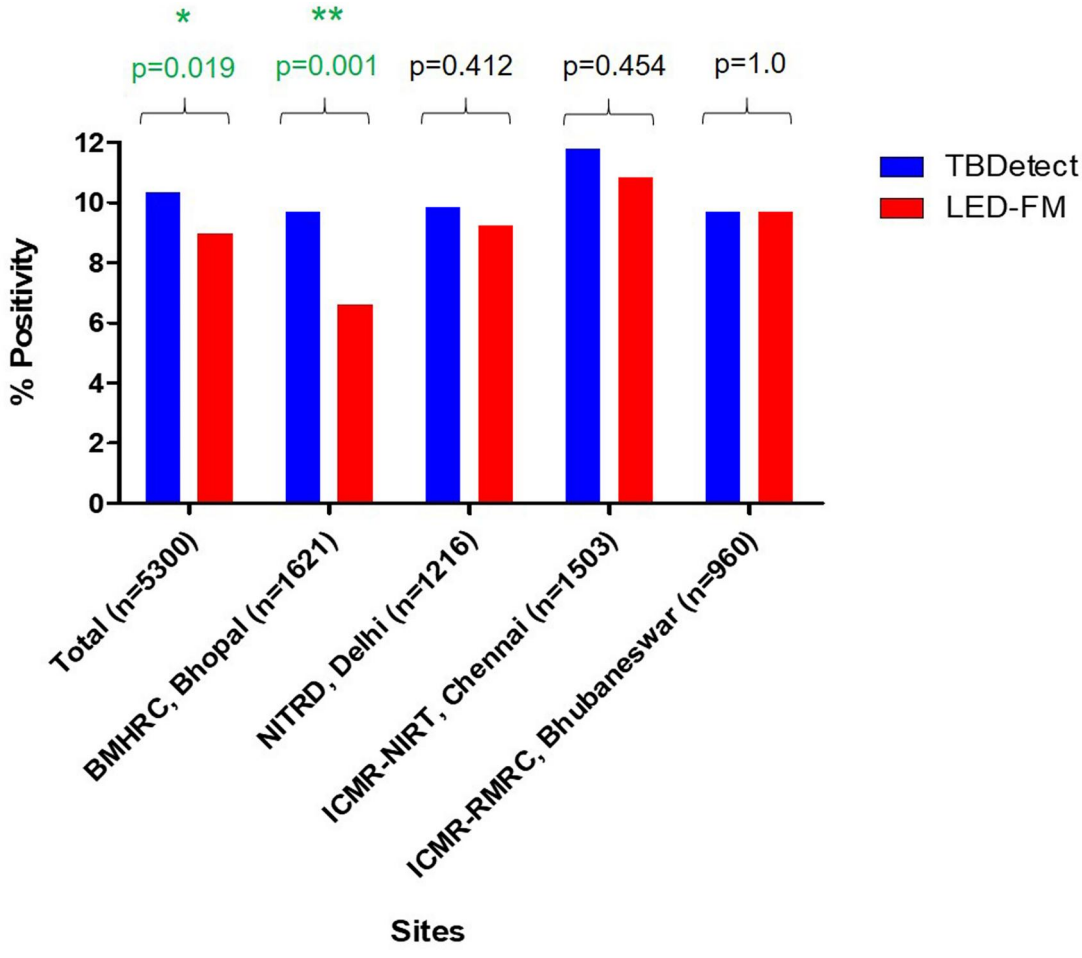

Figure 2. Positivity comparison of 'TB*Detect*' microscopy and LED-FM. *increment in the positivity of 'TB*Detect*' microscopy (overall increment at all sites) and **increment in the positivity of 'TB*Detect*' microscopy at BMHRC, Bhopal was significant ($p < 0.05$).

study. It took laboratory technicians a median of five samples (IQR 4.0–10.0) to become comfortable in performing 'TB*Detect*' microscopy.

On analysing the obtained feedback, 75% users reported that 'TB*Detect*' kit microscopy was easy to perform, BioFM-Filter smears took less time to observe under

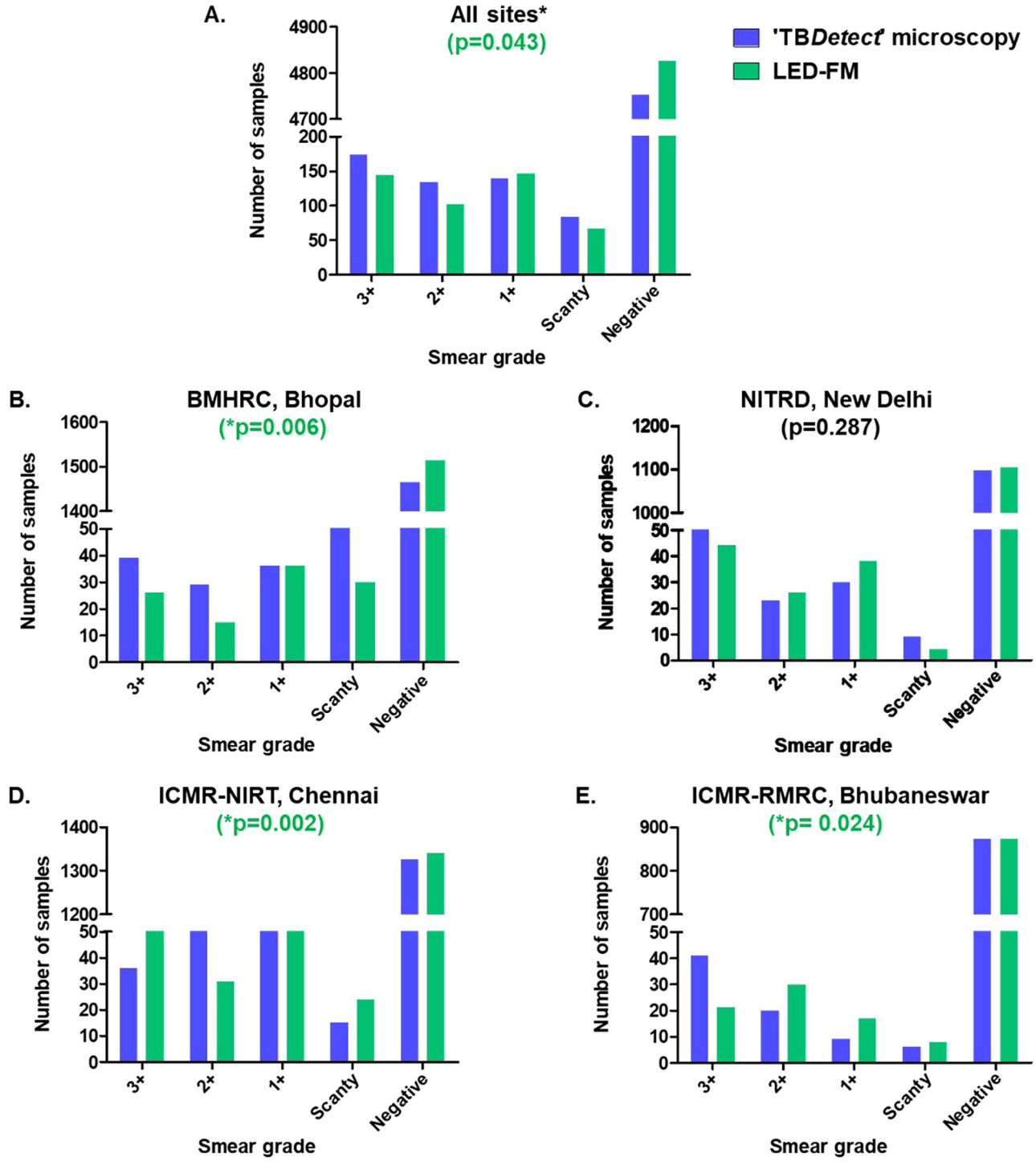

Figure 3. Smear grade status of 'TB*Detect*' microscopy and LED-FM. *Increment in smear grade status of 'TB*Detect*' microscopy *vs.* LED-FM was significant.

the microscope and were easier to read in comparison to LED-FM. Ninety percent users perceived that the accuracy of 'TB*Detect*' kit microscopy was higher than LED-FM and can replace the latter at DMCs. On analysing the scoring feedback, there was a significant difference in the scores for 2 parameters i.e. ease in performing the protocol ($p < 0.0001$) and ease of observation under the microscope ($p < 0.009$) in comparison to routine LED-FM. For other parameters i.e. ease of handling and storage ($p = 0.368$), time-saving ($p = 0.172$) and operator fatigue ($p = 0.172$), the differences in scores for 'TB*Detect*' microscopy and LED-FM were not significant. An examination of

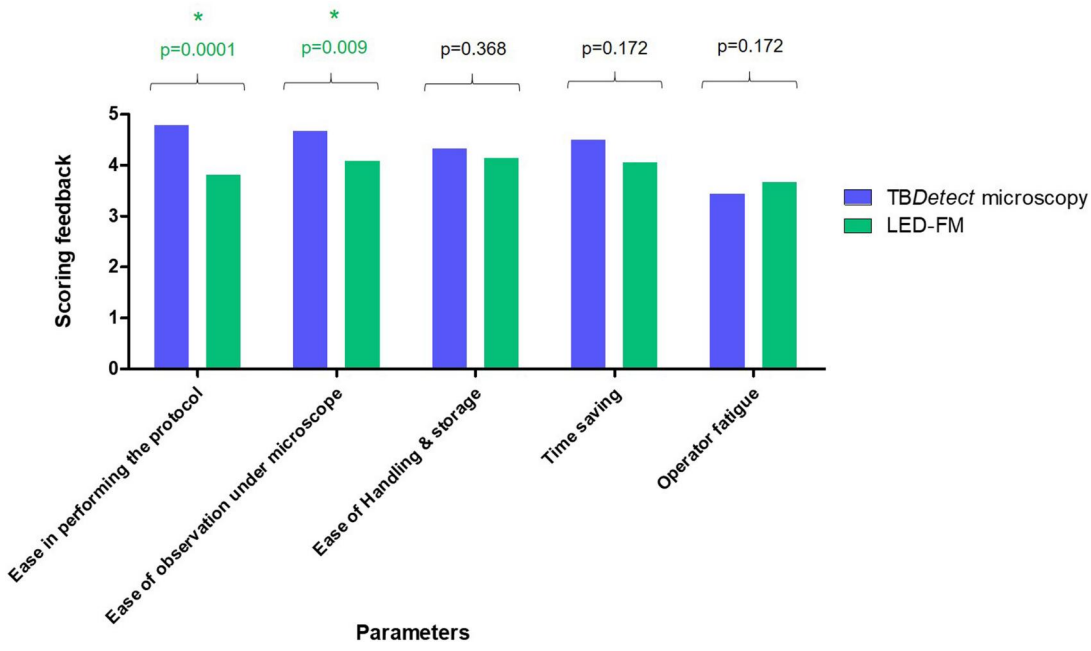

Figure 4. Scoring feedback of 'TB*Detect*' microscopy *vs.* LED-FM. *Scores assigned by the laboratory technicians and study-in-charge at all sites were significantly different for 'ease in performing the protocol' ($p < 0.0001$) and "ease of observation under the microscope' ($p < 0.009$) for 'TB*Detect*' microscopy in comparison to LED-FM.

the compiled scores indicated that 'TB*Detect*' microscopy was superior to LED-FM (Figure 4, supplemental Figure S2).

For quality assurance purposes, 'TB*Detect* microscopy-Restaining kit' was available at all sites and was found to be useful for reanalysing BioFM-Filter slides. At the end of the study, biomedical waste management guidelines for 'TB*Detect*' kit were included in the kit user manual.

Discussion

In the present study, we evaluated the feasibility of the 'TB*Detect*' microscopy kit in field settings, and a head-to-head comparison of its performance was undertaken against LED-FM. 'TB*Detect*' microscopy showed an overall positivity of 10.32% *vs.* 8.96% of LED-FM, which was lower than that of our previously published studies undertaken at NRLs (positivity of 26% [3] and 20% [4]). This is attributed to the higher positivity rate observed in tertiary care centres in comparison to primary health-care centres. Importantly, the increment in positivity of 'TB*Detect*' microscopy over LED-FM was significant ($p = 0.019$, Table 1). However, the increment in positivity (~1.4%) was comparatively lower in the present study as compared to previous studies (~4%, [3,4]), which may be due to the fact that previous studies were done at NRLs/IRLs and this study was conducted at DMCs.

The increment in the positivity of the 'TB*Detect*' kit over LED-FM ranged between 0.65% and 3.08% (New Delhi, Chennai and Bhopal sites). The increment in positivity was significant only at Bhopal site ($p = 0.001$, Table 1 and Figure 2). However, there was no increment observed at Bhubaneswar site (both 'TB*Detect*' and LED-FM showed similar positivity). The site-wise variation in the performance of 'TB*Detect*' microscopy in terms of positivity increment could potentially be resolved by providing more training to laboratory technicians to fully adapt to 'TB*Detect*' microscopy.

Similar to our previous studies, an increment in smear grade status with 'TB*Detect*' microscopy over LED-FM was observed in the present study [3,4]. The increment in smear grade status was significant at 3 sites i.e. Bhopal, ($p = 0.006$), Bhubaneswar ($p = 0.024$) and Chennai ($p = 0.002$), however, it was not significant at New Delhi site ($p = 0.287$, Figure 3).

Based on the feedback obtained from study-in-charge and laboratory technicians, we concluded that (i) the 'TB*Detect*' microscopy kit is self-sufficient (all the reagents and materials are provided in the kit) and convenient to use, (ii) sputum concentration by the filter device renders the test more sensitive, and (iii) the fluorescent bacteria are more easily visualised due to minimal background, leading to less time to read each slide due to bacteria being concentrated in a smaller reading area. A 'TB*Detect*' Re-staining kit was also assessed at all DMCs for quality assurance purposes and was found to be useful. This re-staining kit was developed as a result of feedback obtained in the previous study [4].

LED-FM microscopy was recommended for use over ZN microscopy on account of its higher sensitivity in 2011 [8]. In this context, it is noteworthy that the present study has indicated the 'TB*Detect*' microscopy kit to be superior to LED-FM in terms of overall performance (positivity and smear grade status) and operator convenience. Additionally, the number of DMCs with microscopy set up ($n = 24{,}573$) greatly surpasses the number of NAAT facilities ($n = 6496$ i.e. Cartridge-based Nucleic Acid Amplification Testing (CBNAAT) and Truenat testing facilities) in India [2]. Therefore, the deployment of the 'TB*Detect*' kit in DMCs network under NTEP is expected to improve TB diagnosis at peripheral healthcare centres. Room temperature stability, bio-safety features and waste management practices (similar to the general NTEP guidelines that are in place at DMCs for waste management of contaminated plastic waste and non-contaminated waste) are other notable positives of the 'TB*Detect*' kit. The limitations of the 'TB*Detect* kit' include a longer time-to-result compared to direct smear microscopy (30–40 mins *vs.* 1 h due to the 30 min sputum liquefaction step), and higher cost/sample (USD 1.44/INR120 *vs.* USD 0.60/INR 50), which are offset by its superior performance, user-friendly and bio-safety features. In addition, displacement of filter-membrane was observed in a few BioFM-Filter devices before use at 1 DMC, however, this was rectified by the industry partner (Advanced Microdevices Pvt. Ltd., Ambala, India) during the study.

Conclusions

On the completion of this study, the funding agency of this study i.e. Indian TB Research Consortium (ITRC), Government of India, reported that the use of 'TB*Detect*' microscopy kit is feasible in field settings and it can be deployed under the NTEP for use in DMCs to improve TB diagnosis at peripheral healthcare centres. This kit is bio-safe, which makes it suitable to use at lower-level laboratories where bio-safety facilities are not available, hence promoting the safety of laboratory workers. The 'TB*Detect*' microscopy kit is useful in low-income low-resource high TB burden countries as it is inexpensive and provides a bio-safe method for improved TB diagnosis.

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Author's contribution

Data curation: KC, RKG, NP, RS, KUK, CP, KSC, AR, JT, DS; Formal analysis: KC, RKG, DA, SH; Investigation: KC, RKG; Methodology: KC, RKG, A Goyal, SH; Conceptualisation: DA, SH, JST, AG, NKG, MS; Writing– original draft: KC, DA, SH; Writing– review & editing: KC, RKG, DA, SH, JST, NP, RS, KUK, CP, KSC, AR, JT, DS, PD, MB, VPM, SS, SG, SP, A Goyal, AG, NKG, MS; Project administration: NP, RS, KUK, CP, KSC, AR, JT, DS, PD, MB, VPM, SS, SG, SP, SH, JST, AG, NKG, MS; Resources: NP, RS, KUK, CP, KSC, AR, JT, DS, PD, MB, VPM, SS, SG, SP, SH, JST, MS; Supervision: NP, RS, KUK, CP, KSC, AR, JT, DS, PD, MB, VPM, SS, SG, SP, SH, JST, AG, NKG, MS; Study design: DA, SH, PD, MB, VPM, SS, SG, SP; Project implementation: KC, RKG, A Goyal; Funding acquisition: SH, PD, MB, VPM, SS, SG, SP.

Ethical approval

The ethical approval for this study was obtained from the Institutional Ethics Committees of all NRL sites (BMHRC/IEC/43/Micro/20, NITRD/EC/2020/A85, 154/NIRT-IEC/2020, ICMR/-RMRCB/IHEC-2020/10) for the collection of sputum samples at their associated DMCs.

Disclosure statement

AG and NKG manufactured the 'TB*detect*' kits and A Goyal from mdi participated in the training of laboratory technicians at DMCs who used the kit. AG and NKG were not involved in conducting the study and analysing the results. DA, RKG, VPM, AG, NKG, SH, and JST are joint inventors in an Indian Provisional Patent application named 'Apparatus and method for processing a sample for rapid diagnosis of tuberculosis and safe transport of bacteria' (Patent application number- 201811042155). KC, NP, PD, RS, KUK, MB, CP, KSC, AR, SS, SG, JT, DS, SP, and MS have nothing to disclose.

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Data availability statement

The data used or analysed during the present study are available from the corresponding author on reasonable request.

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