Integrating Digital Adherence Tools in TB Care: Comparing GRVOTS with Standard DOT in Malaysia

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ABSTRACT

Tuberculosis (TB) remains a significant global health challenge, with Malaysia experiencing persistent mortality despite declining incidence rates. This study aimed to assess treatment adherence among patients with pulmonary TB (PTB) diagnosed and managed using traditional directly observed treatment (DOT) and gamified reality video-observed treatment systems (GRVOTS) in public healthcare facilities. A cross-sectional study was conducted in five health clinics in Selangor and Negeri Sembilan, Malaysia. The participants included 142 patients with PTB aged between 18 and 64 years, matched by age and capable of smartphone use, with data sourced from the Tuberculosis Information System (TBIS) and an existing GRVOTS research team. Sociodemographic and treatment adherence data were analyzed using descriptive statistical methods using IBM SPSS software version 28.0. Approximately 90.1% of patients in the GRVOTS group completed treatment compared with 83.3% in the DOT group, indicating significantly higher adherence to GRVOTS. Facility characteristics varied widely, from large urban clinics with robust digital infrastructure to smaller clinics with limited resources, highlighting the adaptability of GRVOTS across diverse settings. Overall, GRVOTS demonstrates potential as an effective and scalable adjunct to traditional TB treatment supervision, enhancing adherence and continuity of care across various healthcare settings. Thus, digital tuberculosis (TB) adherence solutions should match clinic capacity and patient demographics. Large clinics should implement comprehensive digital tools, whereas smaller facilities require simpler versions.

Keywords: Pulmonary Tuberculosis, Gamified Reality Video-Observed Treatment Systems (GRVOTS), Direct-Observed Therapy (DOT), Treatment Adherence, Health clinics

INTRODUCTION

Tuberculosis (TB) is a serious public health problem that affects people worldwide. The World Health Organization (WHO) estimates that 10.6 million individuals worldwide contracted TB in 2021, an increase of 4.5% from the previous year(Bagcchi, 2023). This large number of cases demonstrates that TB remains one of the world's leading causes of mortality. It is caused by the bacteria *Mycobacterium tuberculosis*, which mostly affects the lungs but can also affect other parts of the body. The disease spreads through the air when an infected person coughs, sneezes or talks(Natarajan et al., 2020). In Malaysia, the situation regarding TB is also a concern. According to the Ministry of Health (MOH) in Malaysia, the TB incidence rate decreased to 66.53 per 100,000 population in 2021, compared to 80.88 per 100,000 population in 2019. However, the TB mortality rate increased from 3.69 per 100,000 population in 2019 to 7.01 per 100,000 in 2021(Centre, 2022). This means that while the number of new TB cases may be decreasing, the mortality rate is still high and requires further attention.

The WHO has defined tuberculosis treatment adherence as taking more than 90% of medications while being directly observed by another individual (World Health Organization, 2017). Instead of focusing only on adherence to pharmacologic therapy, adherence is best when TB medicines are administered as part of a complete, patient-centered approach that raises patient understanding and reduces barriers to adherence. Directly observed treatment (DOT), in which a health professional, family member, or community member witnesses the patient taking TB drugs, is one of the most often utilized adherence treatment management

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strategies(Müller et al., 2018).Video-observed treatment (VOT) has become more popular as a substitute for traditional DOT in recent years(Garfein & Doshi, 2019). Other interventions aimed at promoting adherence through DOT include incentives such as material or monetary rewards given to patients who adhere to their treatment regimens(Pradipta et al., 2020).Technology in treatment management has made it easier to follow and manage patients throughout their treatment. For example, digital platforms can be used for patient management and drug-resistant TB care (World Health Organization, 2017). Telemedicine can also increase the availability of TB care in isolated and underserved areas. These technological advancements contribute to the efficiency and effectiveness of TB control initiatives and have the potential to save lives(Guo et al., 2020). Gamified-reality video observation therapy system (GRVOTS) is a form of therapy that uses video games and virtual reality to help patients improve their physical and cognitive abilities. It is more engaging and motivating than traditional direct observation therapy (DOT) but may be more expensive and require specialized equipment. Its effectiveness in the context of TB treatment is not yet clear, and it has not been widely studied or used. However, it may have potential as a supplement to traditional DOT to improve patient adherence and engagement during the final stages of treatment. Thus, this study aimed to assess the level of treatment adherence among patients under DOT and GRVOTS in public healthcare facilities.

MATERIALS AND METHODS

A cross-sectional study was conducted in five healthcare facilities, specifically healthcare clinics, in two selected states in Malaysia, Selangor and Negeri Sembilan, in 2022. The study included health clinics or *Klinik Kesihatan* classified from Type 1 to Type 5, representing varying levels of service capacity. Type 1 clinics manage more than 800 attendances per day and provide a full range of services, including OPD, MCH, Dental, Pharmacy, X-ray, Laboratory, Rehabilitation, and Home Nursing. Type 2 and Type 3 clinics manage 500 to 800 and 300 to 500 daily attendances, respectively, with service scopes similar to Type 1. Type 4 clinics handle 150 to 300 daily attendances and offer most Type 1 services, although some rehabilitation services may be limited. Type 5 clinics manage 100 to 150 attendances per day and provide OPD, MCH, Dental, Pharmacy, Laboratory, and Home Nursing services but do not offer X-ray or Rehabilitation(Keluarga, 2019).

The study population comprised tuberculosis patients on treatment who could speak and read in English or Malay language, aged between 18 to 64 years old, newly diagnosed with Pulmonary TB on first-line treatment, had completed the in-person DOT (at least two times) and had knowledge of smartphone and app usage. Patients with drug-resistant TB and health conditions that disallowed them to use smartphones such as severe arthritis and vision impairment were excluded.

Sampling of the patient population was performed using convenience sampling. The sample size of a single proportion was calculated using the highest proportion of loss to follow-up in Malaysia from 2010 to 2015 among the general TB population which was 4.8% (Sharani et al., 2022) with the OpenEpi online application. Thus, a total of 100 samples were needed after accounting for a 20% attrition rate. Matching was applied between the GRVOTS and DOT participants based on age range to ensure a relevant and balanced comparison between the two datasets, as the GRVOTS data were obtained from an existing study, while the DOT data were derived from the Tuberculosis Information System (TBIS). This approach minimized potential bias related to age distribution and enhanced the validity of the comparative analyses between the two groups.

Data was collected from 2 sources; the first source was obtained with permission from the research team of the GRVOTS study and the second one was extracted from the Tuberculosis Information System (TBIS database) owned by the Ministry of Health for Selangor and Negeri Sembilan states. The information presented in the data collection form for every patient was coded into different variables individually. Continuous data, including age and income level, were coded into different variables individually to facilitate the analysis needed to achieve the study objectives. Age was grouped statistically into less than 32 years old, 32 to 41 years old, 42 to 53 years old and more than 53 years old. For data storage, a soft copy version was used with two backup storages. Data will be stored for 5 years post-study and then destroyed after 5 years of storage.

Data analysis was performed as narrative analysis for the selected five healthcare facilities, and for the quantitative data, analysis was done using IBM SPSS software version 28.0 for descriptive analysis. Pearson chi square test was used to assess for any association of other patients' characteristics between GRVOTS and DOT groups.

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RESULTS

Healthcare Facilities Characteristics for TB treatment services

The five government health clinics selected for this study began their operations between 1997 and 2012, reflecting different stages of infrastructure development and service expansion. The distance to the nearest tertiary care center ranged from 0.8 km to 10 km, indicating that all facilities had relatively accessible referral pathways to higher-level specialist care when required. Table 1 summarizes the characteristics of healthcare facilities.

Table 1. Characteristics of healthcare clinics delivering TB treatment, including service volume, facility type, and staffing in 2022.

No	Facility Name	Year Start Operation	Distance From Tertiary Care Centre (km)	Total Outpatients in the year 2022	TB Outpatients in the year 2022	Average OPD Visits/Month	Health clinic Type	Number of Doctor
1	Klinik Kesihatan Taman Medan	1997	6.7	158,877	34	13,240	1	29
2	Klinik Kesihatan Kajang	2002	4.0	209,825	74	17,485	1-3	35
3	Klinik Kesihatan Ampangan	2008	10.0	87,867	10	7,322	1-3	24
4	Klinik Kesihatan Seremban	2000	0.8	256,128	12	21,344	1	45
5	Klinik Kesihatan Sungai Chua	2012	4.1	35,376	17	2,948	4-5	22

*Klinik Kesihatan – Healthcare Clinic

There was considerable variation in outpatient service volumes across facilities. Klinik Kesihatan Seremban in Negeri Sembilan state recorded the highest number of outpatient visits in 2022 (256,128 visits), whereas Klinik Kesihatan Sungai Chua in Selangor state recorded the lowest (35,376 visits). The annual number of tuberculosis outpatients also differed, ranging from 10 cases at Klinik Kesihatan Ampangan to 74 cases at Klinik Kesihatan Kajang, the latter likely reflecting a larger catchment population and more urbanized service coverage. The staffing profile similarly varied, with Klinik Kesihatan Seremban employing the largest medical workforce (45 doctors) compared to smaller clinics, such as Klinik Kesihatan Sungai Chua (22 doctors). Correspondingly, the average monthly outpatient load ranged from 2,948 to 21,344 visits, resulting in wide differences in the patient-to-doctor ratio. Klinik Kesihatan Kajang registered the highest patient load per doctor, 5,995 patients per doctor, whereas Klinik Kesihatan Sungai Chua reported the lowest, 1,608 patients per doctor, indicating substantial heterogeneity in workload distribution across facilities.

Collectively, these facilities represent diverse operational contexts in terms of capacity, caseload, staffing, and resources. This variation provides a representative basis for evaluating the feasibility, performance, and cost implications of GRVOTS implementation in routine public sector TB service delivery settings.

Participants characteristics and treatment adherence

A total of 142 patients were selected for this study. The characteristics of the patients in both the GRVOTS and DOT groups were summarized in Table 2.

Table 2. Characteristics and treatment outcomes of TB patients in the GRVOTS and DOT groups.

Variable	**GRVOTS Group (n=71)**		**DOT Group (n=71)**		**P value (Chi square)**
	n	**(%)**	**n**	**%**	
Age (years)					0.958
Median (Range)	38(19-65)		40 (17–83)		
<32	22	(31)	22	(30.6)	
32-41	22	(31)	16	(22.2)	
42-53	14	(19.7)	20	(27.8)	
>53	13	(18.3)	13	(18.1)	
Gender					0.596
Male	48	(64.9)	45	(62.5)	
Female	23	(31.1	26	(36.1)	
Nationality					0.111
Malaysian	66	(90.4)	60	(83.3)	
Non-Malaysian	5	(6.8)	11	(15.3)	
Occupational status					0.347
Employed	54	(76)	49	(69.4)	
Unemployed	17	(24)	22	(30.6)	
Treatment Outcome					0.313
Complete	64	(90.1)	60	(83.3)	
Not Complete	7	(9.9)	11	(15.3)	

There were 71 participants in the GRVOTS group and 71 in the DOT group. Patients in the DOT group were older, with a median age of 40 years compared to 38 years in the GRVOTS group. Most participants in both groups were aged below 41 years, representing economically active individuals who are typically at a higher risk of tuberculosis infection due to work-related exposures and mobility patterns. In terms of gender distribution, males predominated in both groups (64.9% in the GRVOTS group and 62.5% in the DOT group). Regarding nationality, most patients were Malaysian citizens, comprising 90.4 % of the GRVOTS group and 83.3 % of the standard of care group, while non-Malaysians represented a smaller proportion in both arms. Employment status also revealed notable socioeconomic vulnerability among participants whereby about 24 % in the GRVOTS group and 30.6 % of the DOT group were unemployed.

The participants' TB treatment completion status served as the basis for evaluating treatment adherence outcomes

In the GRVOTS group, 90.1% of the GRVOTS group completed their course of treatment and showed complete adherence. In comparison, only 83.3% of patients in the DOT group completed their therapy, meaning 15.3% did not. This discrepancy suggests that the adherence performance of GRVOTS users was significantly better than that of users under the traditional DOT system. However, the difference was not statistically significance ($p>0.05$).

DISCUSSION

Healthcare Facilities Characteristics for TB treatment services

In Selangor, the healthcare facilities providing TB treatment demonstrated distinct operational characteristics that shaped the delivery of DOT and GRVOTS. One of the clinics was a busy urban facility serving many working adults, where traditional DOT was logistically challenging due to patients' employment demands. In this setting, GRVOTS offered a more feasible alternative by enabling remote treatment supervision for a

predominantly tech-literate population. A second clinic was larger, well-staffed, and digitally advanced, with in-house laboratory and imaging services. Its high patient volume and strong infrastructure aligned with recommendations emphasizing the importance of robust primary care capacity in TB management(Coetzee et al., 2004; Kalonji & Mahomed, 2019). Here, GRVOTS provided added convenience for working patients, while standard DOT would have imposed unnecessary burden. In contrast, a smaller clinic with limited staffing and no Virtual Clinic system showed lower digital readiness. Although traditional DOT required substantial travel and time commitment, the use of basic smartphone-supported GRVOTS still had the potential to improve adherence among employed patients unable to attend daily visits. This clinic illustrated how facilities with modest resources may benefit from low-complexity digital adherence solutions.

In Negeri Sembilan, similar variations were observed. One clinic was mid-sized, whereas the other was among the busiest in the country. The combination of high patient load and strong infrastructure positioned the larger clinic to adopt mobile DOTS effectively. With sufficient resources and a digitally ready patient population, GRVOTS could be integrated with minimal disruption, offering an efficient alternative to labor-intensive traditional DOT in high-volume settings.

Tailoring digital TB interventions to clinic capacity and patient demographics is therefore essential. In busy urban clinics with many working adults, scaling up GRVOTS can reduce the logistical challenges of daily DOT visits while leveraging higher smartphone literacy. Large, well-staffed clinics with strong digital infrastructure can incorporate GRVOTS into routine workflows to enhance convenience and adherence. For smaller clinics with limited staffing or technology, introducing basic smartphone-based GRVOTS systems provides a scalable option to reduce travel burden and improve follow-up. Gradual improvements in digital readiness can be supported through targeted training, essential equipment provision, and phased expansion of mobile DOTS capabilities.

In high-load clinics with established e-health systems, institutionalizing mobile DOTS can optimize workforce efficiency and integrate seamlessly with existing electronic health records. Sustaining such initiatives will require ongoing technical support and periodic system upgrades. At the policy level, developing guidelines that endorse differentiated TB treatment supervision models based on clinic size, digital capacity, and patient characteristics would support consistent implementation across states(Cattamanchi et al., 2021; Getachew et al., 2022; Khachadourian et al., 2020). Strategic investment in digital infrastructure, particularly for smaller clinics, is crucial to ensure equitable access. Cross-clinic knowledge sharing and capacity building will further strengthen implementation. Ultimately, patient-centered approaches that consider employment constraints, mobility patterns, and digital literacy can enhance engagement and improve overall adherence to TB treatment.

Participants characteristics and treatment adherence

Most participants in both groups were aged less than 41 years old, reflecting an economically active population that is typically at higher risk of developing tuberculosis due to work-related exposures and frequent mobility. The predominance of male participants is consistent with national epidemiological patterns in Malaysia, where men bear a higher TB burden(Chikovore et al., 2020), influenced by occupational risks and behavioral factors, such as smoking, alcohol use, and wider social contact. Employment data also indicated socioeconomic vulnerability whereby about 24% of the GRVOTS group and 30.6% of the DOT group were unemployed, a pattern commonly observed among TB-affected populations and one that may influence treatment adherence and health-seeking behavior(Cantwell et al., 1998; Fuady et al., 2020). Overall, in present study, the two groups demonstrated comparable demographic characteristics, supporting the validity of subsequent comparisons of adherence, cost, and treatment effectiveness. Despite these similarities, adherence outcomes differed notably. The higher completion rate observed in the GRVOTS group suggests that mobile application–based monitoring provided more continuous engagement and reduced patient–provider miscommunication. Improved adherence may have been driven by structured reminders, remote observation, and reduced need for frequent clinic visits. These findings align with previous studies indicating that digital adherence technologies enhance treatment outcomes by increasing patient motivation and reducing loss to follow-up(Mohamed et al., 2024; Patel et al., 2020).

Digital adherence tools, such as GRVOTS, should be prioritized for economically active patients with tuberculosis (TB), particularly those in the working-age population who face heightened risks due to mobility

and occupational exposure. Implementing these tools widely can strengthen treatment adherence by enabling remote monitoring, structured reminders, and flexible scheduling that accommodates work commitments, while reducing the need for frequent clinic visits. Simultaneously, TB treatment programs must address the socioeconomic vulnerabilities of unemployed or low-income patients, who often encounter greater adherence challenges. This includes integrating counselling, social support, and referrals to financial or welfare services while ensuring that digital interventions remain accessible and equitable for all patient groups. Enhancing patient-provider communication through mobile platforms further improves treatment outcomes by clarifying instructions, preventing misunderstandings, and fostering continuous engagement through user-friendly and culturally appropriate interfaces. The incorporation of automated reminders and remote observation features promotes consistent medication intake and timely follow-up, while data analytics from these platforms enable the early identification of individuals at risk of non-adherence. Scaling digital TB treatment solutions should also be aligned with clinic capacity and patient demographics, ensuring that high-volume and technologically ready facilities fully benefit from comprehensive digital tools, while smaller or resource-limited clinics receive adaptable and low-cost digital options. To support sustainable implementation, policy-level integration is essential, including the establishment of national guidelines endorsing mobile adherence technology as part of standard TB care. Adequate funding for training, digital infrastructure, and ongoing technical support is necessary to maintain effective and equitable digital TB treatment programs over time.

STRENGTH AND LIMITATION

The findings of this study were limited by the use of secondary data extracted from the TBIS and an existing GRVOTS database. Any missing data, inconsistent documentation, or reporting errors can affect data completeness and quality. Furthermore, convenience sampling may have introduced selection bias. The patients included may not fully represent the broader TB population in the two states or in Malaysia.

Nevertheless, the data were collected from five healthcare clinics across Selangor and Negeri Sembilan, providing real-world insight into tuberculosis (TB) patient management in two states with different demographic and healthcare service contexts. This enhances the ecological validity of these findings. Data was extracted from the Tuberculosis Information System (TBIS), a standardized national registry, and from an existing GRVOTS study. This reduces the measurement error and enhances reliability.

CONCLUSION

GRVOTS users demonstrated better treatment completion than those receiving standard DOT, indicating that digital supervision can support stronger adherence to treatment. This pattern was observed across clinics with different levels of staffing, patient volume, and digital readiness, suggesting that GRVOTS can be effectively adopted in a range of operational environments. This highlights the potential of digital tools to enhance treatment continuity across diverse healthcare settings.

Ethical consideration

This study was approved by the Universiti Teknologi MARA (UiTM) Research Ethics Committee (REC) (reference number REC/01/2024 [PG/MR/41]) and the Medical Research and Ethics Committee (MREC) of the Ministry of Health Malaysia (MOH) (NMRR ID:23-03410-K8W[IIR]). This study also only analyzed de-identified and administrative data from the respective healthcare facilities for privacy and confidentiality. No direct data were collected from the patients.

Conflict of Interest

The authors declare no conflict of interest.

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