REVIEW

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Evaluating the Role of VELscope in Oral Cancer and Pre-Cancer Screening: A Scoping Review

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Abstract

Background: Oral cancer continues to be a major public health concern, particularly in low- and middle-income countries (LMICs), where late-stage diagnosis significantly contributes to high mortality. The Visually Enhanced Lesion Scope (VELscope), which uses tissue autofluorescence technology, aids in the identification of suspicious oral lesions. The objective of this scoping review is to systematically map the existing evidence on the effectiveness of VELscope in detecting pre-malignant and malignant oral lesions. **Methods:** This scoping review was carried out following the Arksey and O'Malley framework and JBI methodology and was reported per PRISMA-ScR guidelines. Four databases (PubMed, Embase, Scopus, and Cochrane Library) were searched between January 2010 – December 2024. A total of 27 studies involving 3,875 participants were included, assessing VELscope's diagnostic accuracy either alone or in combination with other tools. **Results:** VELscope demonstrated high sensitivity (>75%) in 20 studies, with values ranging from 30% to 100%. However, specificity varied more widely (15%–100%), with 16 studies reporting specificity of less than 75%. The diagnostic accuracy of VELscope was significantly influenced by clinicians' training and experience. While VELscope effectively enhanced lesion visualization and guided biopsy site selection, its low specificity often resulted in false positives and unnecessary referrals. Diagnostic accuracy also improved significantly when it was used in combination with conventional oral examination (COE), the toluidine blue test (TBT), or Raman spectroscopy. **Conclusion:** VELscope serves as a valuable adjunctive tool to COE, improving lesion detection in high-risk populations. However, its standalone diagnostic use is limited due to low specificity. Targeted clinician training and integration into multimodal screening protocols are essential to optimize its clinical utility. Further studies are warranted to assess its clinical effectiveness in community-based cancer screening among high-risk population with behavioural risk factors, as well as to conduct cost-effectiveness analyses.

Keywords: VELscope- oral cancer- potential malignant disorder- precancer screening- effectiveness- scoping review

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Introduction

Cancer is a leading cause of morbidity and premature mortality worldwide, responsible for one in six all-cause deaths (16.8%) and one in four deaths (22.8%) attributable to noncommunicable diseases (NCDs) [1]. Among the wide spectrum of malignancies, oral cancer represents a growing public health concern, particularly in low- and middle-income countries, where limited access to early diagnosis and appropriate treatment contributes to poor clinical outcomes [2].

According to GLOBOCAN 2022 oral cancer which is primarily associated with lips, tongue, and oral cavity malignancies ranks 16th in incidence and 15th in mortality among all cancers. There were an estimated 389,846 new cases and 188,438 deaths corresponding to an incidence and mortality rate of 4.0 and 1.9 cases per 100,000 people, respectively [3]. These figures reflect not only the widespread burden of oral cancer but also the stark gap between incidence and survival, particularly in resource-constrained settings where late-stage diagnosis and limited treatment options prevail.

LMICs carry a disproportionately high burden of cases and deaths. In the South and Southeast Asian countries like India, Bangladesh and Sri Lanka, oral cancer is among the top three cancers in both men and women [4]. The epidemiological distribution of oral cancer in these regions is strongly associated with modifiable lifestyle-related risk factors such as excessive tobacco and alcohol consumption, and the habitual use of areca nut or betel quid. It is often compounded by poor oral hygiene and inadequate access to preventive dental care [5]. The

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synergistic effect of these risk factors significantly elevates the risk of developing premalignant lesions followed by oral potentially malignant disorders (OPMDs), which may progress to invasive carcinoma if left undetected and treated timely [6].

Delayed diagnosis at an advanced stage of the disease can significantly reduce five-year survival rate, whereas early-stage diagnosis has been found associated with a better disease prognosis [7]. These emphases the critical need for effective, accessible, and scalable screening strategies. Conventional oral examination (COE), conducted through visual inspection and palpation, remains the most widely used standard mode of screening [8]. However, COE is subjective, heavily reliant on clinician expertise, and lacks sensitivity for detecting subtle or subclinical lesions, particularly those located in anatomically complex areas of the oral cavity [9].

To overcome these limitations, adjunctive diagnostic technologies have been developed to enhance the diagnostic accuracy of oral cancer screening. Among these, tissue autofluorescence-based devices such as the Visually Enhanced Lesion Scope (VELscope) have gained increasing attention. VELscope is a handheld, non-invasive device that uses blue light with a wavelength of 400–460 nm. It excites the endogenous fluorophores in the oral mucosa. In healthy tissue, fluorescence appears as a pale green glow, whereas dysplastic or neoplastic tissue shows loss of fluorescence or dark areas due to changes in metabolic activity and tissue architecture [10]. This visual contrast enables the identification of suspicious lesions that may not be readily apparent under conventional white light examination [9].

Many studies have evaluated the utility of VELscope as an adjunct to COE for the detection of OPMDs and early-stage oral cancers [11]. While some research suggests that VELscope may improve the visualization of premalignant changes and guide biopsy decisions, the clinical effectiveness of this tool remains debated [12, 13]. This scoping review aims to examine and elucidate the potential role of VELscope in oral cancer screening strategies. This review also seeks to inform clinical practice, policy decision-making, and future research in oral oncology and public health.

Materials and Methods

This scoping review was conducted using the methodological framework proposed by Arksey and O'Malley and subsequently refined by the Joanna Briggs Institute (JBI) for conducting scoping reviews [14, 15]. The reporting of this review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) (Supplementary File-1) guidelines to ensure methodological rigor and transparency [16]. The review protocol was prospectively registered on the Open Science Framework (OSF) with doi-10.17605/OSF.IO/36PZE.

Search strategy

Comprehensive database-specific search strategies were developed to identify relevant literature on the effectiveness of VELscope as a standalone as well as an adjunctive tool for the detection of oral premalignant and malignant lesions. Four major electronic databases-PubMed, Cochrane Library, Embase, and Scopus were searched for relevant articles published between January,2010- December,2024. The search strategy included a combination of MeSH/Mtree and relevant keywords such as "mouth neoplasms", "oral cancer", "VELscope", and "adjunct device", linked using Boolean operators "AND" and "OR" (Supplementary File-2).

In addition to database searches, grey literature was explored through manual searches of relevant conference proceedings and institutional repositories. Cross-referencing was also done to identify additional studies.

Study selection

All search results were imported into Rayyan, where duplicate records were identified and manually removed. The study selection process was carried out in two stages by two independent reviewers. In the first stage, titles and abstracts were screened for relevance based on predefined inclusion and exclusion criteria. Studies that appeared to meet eligibility criteria or required further assessment were selected for full-text review. In the second stage, the same two reviewers independently assessed the full texts to determine final inclusion. Disagreements at either stage were resolved in consensus with a third reviewer.

Eligibility Criteria

Inclusion Criteria

We included observational and experimental designs that assessed the diagnostic accuracy or clinical effectiveness of VELscope in oral cancer screening. Studies reported relevant diagnostic outcomes, including sensitivity, specificity, and/or predictive values involving adult populations, published in English in peer-reviewed journals between January 2010 to December 2024, were included. We also wanted to include studies assessing the cost-effectiveness or cost-utility of VELscope in oral cancer screening. However, we did not get any relevant study.

Exclusion criteria

Studies evaluating the effectiveness of adjunct oral cancer screening technologies other than VELscope were excluded. editorials, commentaries, letters to the editor, opinion pieces, or unpublished manuscripts; studies published in non-English language were also excluded.

Data extraction

A standardized data extraction form was developed using MS Excel. Information like author, publication year, country, study setting, study design, population characteristics, sample size, diagnostic tool comparison, lesion types examined, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), key findings were extracted by two authors.

Data synthesis

A narrative synthesis of the included studies was

performed, consistent with the goals of a scoping review. The primary focus was to map the extent and nature of the evidence on VELscope's diagnostic performance and explore its potential role in routine clinical screening for oral cancer and OPMDs. Studies were grouped based on key themes, including diagnostic accuracy, comparative effectiveness with conventional oral examination, and health economic outcomes. Findings were summarized qualitatively.

Barriers and facilitators influencing the clinical use of VELscope, as reported in the included studies, were also extracted and synthesized to provide contextual insights. These included factors such as clinician experience, device cost, ease of integration into clinical workflow, and interpretation challenges associated with false positives.

Results

A total of 355 relevant articles were identified through searches of the four selected databases. After removing 182 duplicate records, 173 articles remained for title and abstract screening. Of these, 141 were excluded based on the predefined inclusion and exclusion criteria. Full-text of the remaining 32 articles were assessed, following which 5 were excluded as three were review articles and another three had outcomes not related to the diagnostic accuracy of VELscope. Finally, 27 studies were included in this scoping review. The PRISMA flow chart (Figure 1) illustrates the study selection process.

Characteristics of included studies

Among 27 articles (Supplementary Table 1) included in this scoping review, six were conducted in India [12, 13, 17-20], followed by five in Germany [21-25], two in Australia [9, 26], two in China [27, 28], two in Italy [29, 30] and two in Taiwan [31, 32], one each from Belgium [33], Iraq [34], Iran [35], U. K [36], U.S.A [37], Romania [38], Sri Lanka [39], and Syria [40]. A total of 3875 participants visiting either the tertiary dental clinic or the Department of Oral and Craniomaxillofacial Surgery were included. Most of the participants were presented with oral premalignant and potentially malignant lesions. 24 studies have presented gender-segregated data and 54.2% of participants were male. The age of the participants ranged between 18-93 years.

Sensitivity: Of the 27 studies included in this review, 20 reported VELscope sensitivity greater than 75% in detecting true-positive cases of oral dysplasia or malignancy [12, 36, 38, 13, 37, 21, 31, 34, 32, 29, 30, 22, 40, 23-25, 18, 27, 19, 28, 20]. Sawan et al. [40] found that VELscope was effective not only in detecting premalignant and malignant lesions but also in guiding biopsy site selection and delineating lesion margins during surgery. Similarly, Scheer et al. [24] reported

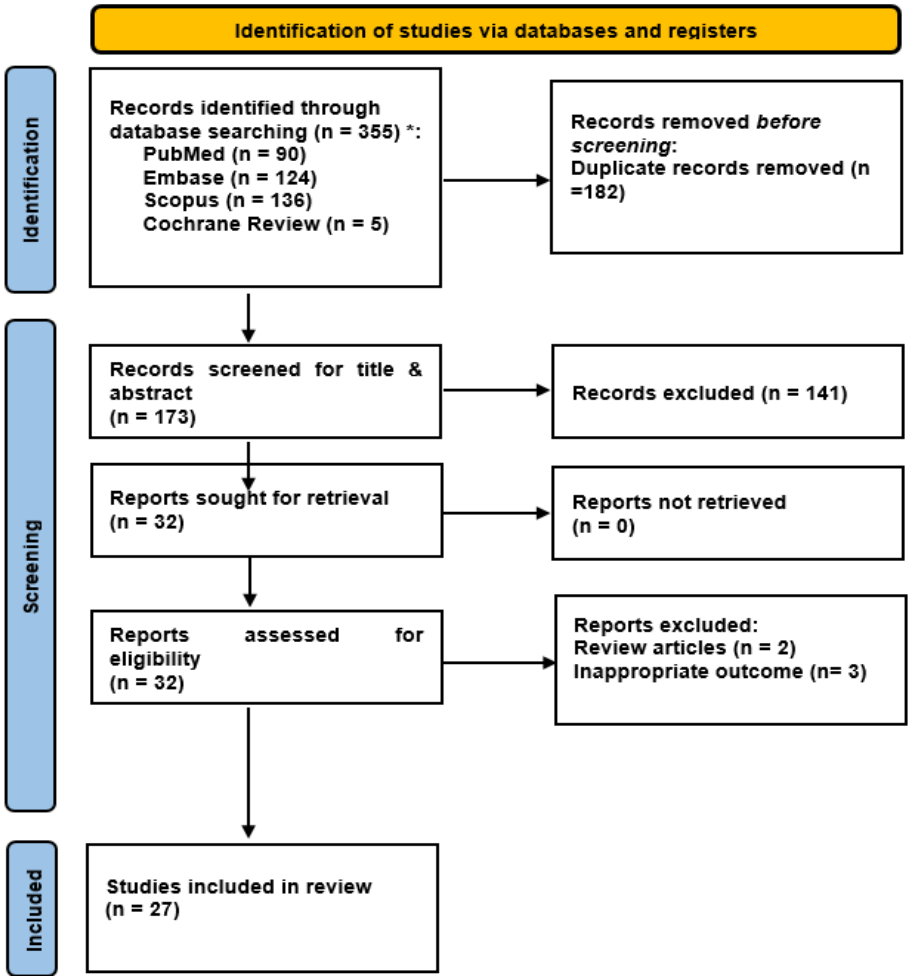

Figure 1. PRISMA Flow Chart

100% sensitivity in identifying malignant and potentially malignant disorders in high-risk populations; however, the device was ineffective in distinguishing benign from malignant lesions. Operator expertise appeared to be a key determinant of diagnostic performance, with significantly higher sensitivity observed when evaluations were conducted by oral and maxillofacial surgeons or trained personnel [29, 22, 24, 25]. In contrast, studies by Farah et al. [26] and Mehrotra et al. [17] reported lower sensitivities of 30% and 50%, respectively, when assessments were performed by clinicians or oral medicine specialists. These findings underscore VELscope's potential as a sensitive adjunct for the early detection of dysplastic and malignant lesions while highlighting its limitations in differentiating between malignant, dysplastic, inflammatory, and benign conditions, thus emphasizing the importance of clinician training to enhance diagnostic accuracy and reduce misclassification.

Specificity

The specificity of VELscope varied substantially across the studies, ranging from 15% to 100%. Sixteen studies reported specificity values below 75%, indicating a considerable rate of false-positive findings [35, 36, 9, 26, 13, 39, 21, 34, 17, 18, 27, 19, 20, 22, 40, 23]. Studies like Schorn et al. [25] and Canjau et al. [38] each reported 100% specificity, while Huang et al. [31] and Paderni et al. [30] reported specificities of 92.3% and 82.86%, respectively. The specificity of VELscope was found high when evaluation was done by oral and maxillofacial surgeons or by trained clinicians. The specificity was also improved when it was combined with clinical examination. However, several studies stated that VELscope alone cannot be used a screening or diagnostic tool [35, 26, 13, 17, 30, 27] and it can further increase burden on healthcare system by increasing the false positive cases [35].

VELscope as an adjunctive tool

Eleven studies (Table 1) have compared the effectiveness of VELscope with other diagnostic tools such as TBT, COE, Raman Spectroscopy, biomarkers [12, 35, 9, 26, 39, 37, 21, 32, 33, 18, 22]. A study by Kaur et al. [33] demonstrated that combining VELscope with salivary protoporphyrin IX levels improved both sensitivity and specificity, suggesting that multimodal screening approaches can enhance diagnostic yield. Similarly, Sharma et al., (2022) reported that while COE achieved 100% sensitivity, its specificity was extremely low at 10.40%, resulting in a high rate of false positives [18]. In contrast, VELscope in the same study showed a slightly lower sensitivity of 75% but a notably higher specificity of 61.39%, indicating improved accuracy in differentiating between benign and malignant lesions [18]. A study from India by also found that VELscope achieved a sensitivity of 90.47% and a specificity of 44.44%, supporting its value as a complementary diagnostic tool, particularly in high-risk populations [19]. Canjau et al. [38] also reported that VELscope, when used after COE, reached a sensitivity of 94.4% and a perfect specificity of 100%, highlighting its utility in detecting lesions not visible to the naked eye.

In comparison Veluswamy et al. (2024) found that VELscope had higher sensitivity (66.6%) but lower specificity (22.2%) than TBT, which showed 57.6% sensitivity and 50% specificity. When both methods were combined, the sensitivity improved to 78.8%, although specificity remained low at 22.2%, suggesting that combining diagnostic aids can enhance case detection but may also increase false-positive rates [39].

Discussion

The findings of this scoping review provide a comprehensive synthesis of 27 primary studies assessing the clinical effectiveness of the VELscope in the early detection of OPMDs. The evidence highlights that it offers enhanced mucosal visualization and demonstrates high sensitivity in identifying suspicious lesions, particularly when used by trained clinicians. However, considerable variability in specificity and operator dependency limits its utility as a standalone diagnostic tool.

Table 1. Diagnostic Accuracy of VELScope Versus Other Diagnostic Methods

Sr No.	Author_ Year	Diagnostic method	VELscope		Other methods		Combined	
			Sensitivity	Specificity	Sensitivity	Specificity	Sensitivity	Specificity
1.	Adil et al., 2020 [12]	VELscope VS TBT	85.36%	75%	83.13%	87.50%	85.60%	100.00%
2.	Amirchaghmaghi et al.,2018 [35]	VELscope VS COE	90%	15.00%	86.00%	85.00%	100.00%	12.00%
3.	Bhatia et al., 2014 [9]	VELscope VS COE	64%	54.30%	44.00%	99.00%	73.90%	97.90%
4.	Farah et al., 2011 [26]	VELscope VS COE	30.00%	63.00%	25.00%	82.00%	46.00%	68.00%
5.	Hani Z et al., 2012 [37]	VELscope VS COE	92.00%	77.00%	61.50%	87.50%	-	-
6.	Hanken et al., 2013 [21]	VELscope VS COE	97.90%	41.70%	75.90%	33.30%	-	-
7.	Sharma et al., 2022 [18]	VELscope VS COE	75.00%	61.40%	100.00%	10.40%	-	-
8.	Rana et al.,2011 [22]	VELscope VS COE	100%	74.00%	17.00%	97.00%	-	-
9.	Veluswamy et al., 2024 [39]	VELscope VS TBT	66.60%	22.20%	57.60%	50.00%	78.80%	22.20%
10.	Jeng et l., 2020 [32]	VELscope VS Raman Spectroscopy	100.00%	80.00%	80.00%	85.70%	100.00%	94.30%
11.	Kaur et al., 2024 [33]	VELscope VS Salivary Protoporphyrin	67.00%	62.00%	71.00%	70.00%	80.00%	79.00%

The results align with the outcomes of systematic view and meta-analysis by Chaitanya et al. [41], reported pooled sensitivity and specificity of 84.9% and 61.8%, respectively. These estimates are consistent with our findings, where 20 out of the 27 included studies reported sensitivity above 75%, and 16 studies reported specificity below 75%. The high sensitivity supports the utility of VELscope in ruling out disease, while the lower and inconsistent specificity suggests a risk of overdiagnosis and unnecessary biopsies, particularly in low-risk populations [42]. Similarly, Santos et al. [43], noted pooled sensitivity and specificity of 85% and 53% respectively. They concluded that VELscope is best used as adjuncts to conventional oral examination (COE) rather than as replacements for histopathological confirmation. This aligns with our review's conclusion, which emphasizes VELscope's adjunctive role in early detection strategies, particularly in high-risk populations.

Further, the diagnostic accuracy of VELscope was found to be influenced by several key factors, including the clinician's level of training and expertise, lesion characteristics, and anatomical site. Leuci et al. [29] showed that trained general dentists achieved markedly better diagnostic performance using VELscope (sensitivity: 86.7%, specificity: 90%) compared to untrained counterparts (sensitivity: 53.3%, specificity: 70%). To improve diagnostic reliability Bhatia et al. also proposed a decision-making protocol tailored to general dental practice, which significantly improved the interpretation of autofluorescence findings when compared to unstructured usage. Additionally, lesions on the tongue or floor of the mouth also complicates the interpretation [27, 28]. Further, presence of benign conditions such as oral lichen planus or inflammatory lesions and previous oral cancer treatment history can often result in fluorescence loss, mimicking dysplasia and causing false positives [23].

Moreover, anatomical location and lesion type significantly impact autofluorescence patterns. Shi et al. [27] and Wang et al. [28] found that lesions on the floor of the mouth and tongue exhibited ambiguous fluorescence changes due to anatomical and physiological variations. Benign inflammatory conditions such as oral lichen planus or hyperkeratosis often mimic dysplasia under autofluorescence imaging, leading to increased false-positive rates. These findings are corroborated by Epstein et al. [44], who emphasized the limitations of COE and adjunct tools in distinguishing between inflammatory and dysplastic changes.

From a public health perspective, the integration of VELscope into structured oral cancer screening protocols holds considerable promise. Evidence from a population-based cost-effectiveness study in India suggests that mass screening using light-based technologies over a three-year period could reduce the number of incident oral cancer cases by approximately 3,271.68 and avert an estimated 459.76 cancer-related deaths [45]. However, none of the studies included in this scoping review evaluated the cost-effectiveness of VELscope specifically, representing a critical gap in the current evidence base. Moreover, the majority of studies were conducted in tertiary care settings and led by specialists such as oral and maxillofacial surgeons, head and neck oncologists, or dentists. This specialist-driven context limits the generalizability of findings to primary care or community-based settings, where early detection efforts are most needed. Importantly, there is insufficient evidence regarding the usability, diagnostic performance, and acceptability of VELscope when operated by frontline healthcare workers such as auxiliary nurse midwives or community health officers. These gaps raise important questions about the scalability and feasibility of implementing VELscope-assisted screening in low-resource, high-burden regions. Future research should therefore prioritize evaluating the device's effectiveness in decentralized settings, including assessments of cost-efficiency, training needs, and real-world impact on cancer detection and outcomes.

In conclusion, VELscope as a valuable adjunct tool to conventional oral examination, particularly in enhancing mucosal visualization and assisting in the early identification of suspicious lesions. However, its diagnostic performance, especially its specificity, remains inconsistent, which limits its reliability as a standalone diagnostic tool. Evidence suggests that targeted training for general clinicians and dentists can significantly improve diagnostic accuracy. This emphasizes the need for comprehensive capacity-building initiatives. Future research should focus on developing standardized training protocols for general practitioners and frontline healthcare workers, as well as evaluating the feasibility of incorporating VELscope into structured community-based screening programs. In addition, well-designed studies assessing its impact on early detection, patient outcomes, and cost-effectiveness are essential to determine its role in large-scale oral cancer screening and control efforts, particularly in resource-constrained settings.

Author Contribution Statement

All authors contributed equally in this study.

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Declaration

Ethics Approval

Not applicable, as there were no human participants involved in this study.

Availability of data and material

All data generated or analyzed during this study are from published articles and additional information provided in supplementary files.

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Conflict of Interest

None.

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