International Journal of Dentistry

Teledentistry: a New Path in Modern Dentistry

Lead Guest Editor: Caren Bavaresco
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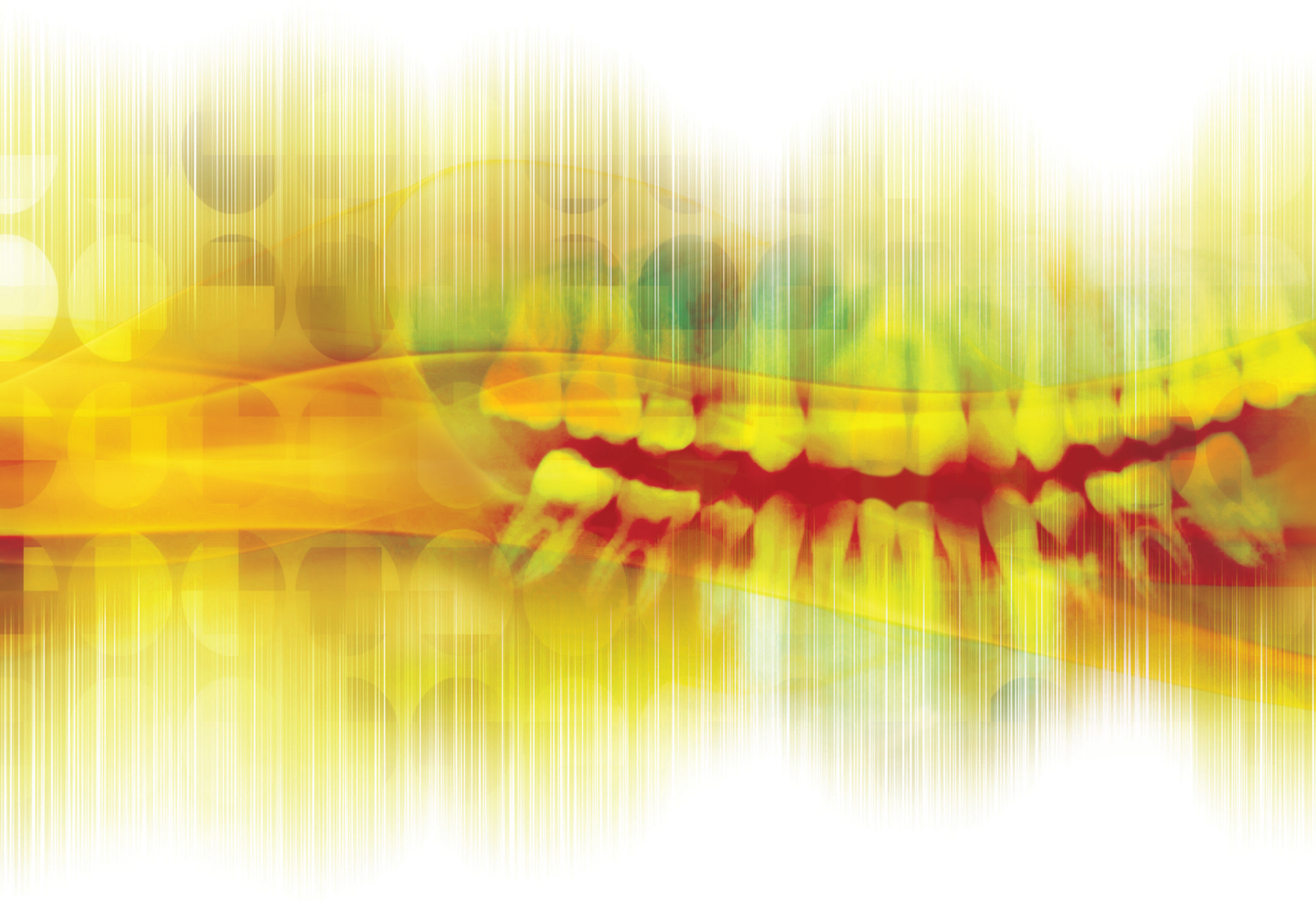

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Hindawi
International Journal of Dentistry
Volume 2021, Article ID 6814027, 9 pages
https://doi.org/10.1155/2021/6814027

Research Article

Validity and Reliability of Intraoral Camera with Fluorescent Aids for Oral Potentially Malignant Disorders Screening in Teledentistry

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Received 3 September 2021; Revised 8 October 2021; Accepted 15 October 2021; Published 29 October 2021

Academic Editor: Flávio Moura

There is limited documentation of using fluorescence images in oral potentially malignant disorders (OPMDs) and oral cancer screening through the field of teledentistry. This study aims to develop and evaluate the validity and reliability of the intraoral camera with the combination method of autofluorescence and LED white light used for OPMDs and oral cancer screening in teledentistry. The intraoral camera with fluorescent aids, which uses a combined method of both autofluorescence and LED white light, was developed before the device was evaluated for validity and reliability as a OPMDs screening tool for teledentistry. All lesions of thirty-four OPMD patients underwent biopsy for definitive diagnosis and were examined by an oral medicine specialist. Both images under autofluorescent and LED white light mode captured from the device were sent online and interpreted for the initial diagnosis and dysplastic features in addition to being compared to the direct clinical examination and histopathological findings. The combination method was also compared with autofluorescence method alone. The device provided good image quality, which was enough for initial diagnosis. Using the combination method, sensitivity, specificity, PPV, and NPV of the device via teledentistry were 87.5%, 84.6%, 63.6%, and 95.7%, respectively, which were higher than autofluorescence method alone in every parameter. The concordance of dysplastic lesion was 85.29% and 79.41% for category of lesion. The validity and reliability results of the combination method for the screening of dysplasia in OPMDs were higher than autofluorescent method alone. The intraoral camera with fluorescent aids for the OPMDs screening can be utilized for screening via teledentistry.

1. Introduction

Ninety percent of squamous cell carcinomas (SCC) are developed from oral potentially malignant disorders (OPMDs) [1]. OPMDs progress from hyperplasia to an increasing degree of dysplasia and finally into carcinoma in situ [2]. Autofluorescence is one of the diagnostic aids for screening detection of OPMDs and oral cancer. The principle is to illuminate the oral tissue with UV and blue excitation light [3–5]. The beams enter the tissue and are absorbed by "the fluorophores molecules"; then the fluorophores reemit the specific wavelength of fluorescence, which is a longer wavelength in the almost green, yellow, and red color spectrum [3, 4]. The various spectrums used as an excitation and emission wavelength are dependent on the equipment systems or the commercial product available in those studies [3–6]. For example, VELscope™ is a direct visualization tissue fluorescence device recognized by the

WHO in 2009 as a commercialized medical device that produces 400–460 nm of excitation spectrum [4, 6].

The dysplastic detection in OPMDs leads to timely referral and treatment [7, 8]. Teledentistry could improve access to oral healthcare while also having the benefit in early intervention, oral health education, and effectiveness of oral health services. The image tools widely used in teledentistry are digital cameras, smartphone cameras, and intraoral cameras, which are usually used in the field of general dentistry and pediatric dentistry as caries detection. Previous studies have shown that the validity and reliability of those devices used as teledentistry tools could be comparable to conventional direct examination for oral screening [9–11]. However, there is limited documentation and investigation on the validity and reliability of using fluorescence images from an autofluorescence method in teledentistry through the field of oral medicine for OPMDs and oral cancer screening as previous studies used only images under normal white light to evaluate via teledentistry [10, 11]; fluorescence images were not yet been included. The combination method between autofluorescence and white light from light-emitting diodes (LED) could be equivalent to a conventional oral examination and autofluorescence method may increase validity for detection of epithelial dysplasia.

The purposes of this study were to develop and evaluate the validity and reliability of the intraoral camera with fluorescent aids, which use a combination method of both autofluorescence and LED white light to screen OPMDs in teledentistry. The validity and reliability were also compared with autofluorescence method alone.

2. Materials and Methods

2.1. Devices. The intraoral camera with fluorescent aids for the screening of OPMD in teledentistry consists of 5 main components:

(1) UV-blue light source (Marubeni, USA): a light source utilizing 10 UV LEDs, which provides an excitation spectrum composed primarily of the 360–450 nm (UV-A) wavelength light.

(2) White light source (Inskam, China): conventional LED were used as white light source. Four of them were coupled around the camera on the tip of the handheld device. White light and UV-blue light could be alternated for use either in LED white light mode or in autofluorescent mode.

(3) Camera image sensor and lens (Inskam, China): CMOS image sensor came with the maximum camera resolution of 2594 × 1944P, 5 million pixels. The diameter of camera lens is 6 mm with IP68 waterproof grade with a lens system that provides autofocus of the focal length between 2 centimeters and infinity ($f = 2–\infty$).

(4) Light filter (Knight Optical, UK): a 480 nm long-pass filter was used as a fluorescent light filter, allowing the reemission of fluorescent wavelength from 480 nm and above spectrum to pass.

(5) Controller and processing units: these units were packed into a controller box that is responsible for controlling the intensity of the light and also syncing images or video received from camera to the smartphone via WiFi (built-in IPEX antenna with operating frequency of 2.4 GHz, IEEE 802.11 b/g/*n* network standard).

The device was used with a free application (Inskam, China) available on a smartphone or tablet for both iOS and android platforms. The images stored can be sent online via any application as electronic information for teledentistry. The camera image sensor and lens were mounted at the tip of the handle, arranged at 135-degree angulation to the handle axis base on "mouth mirror design." The handle is connected to the controller and processing units which can control the intensity of the light and sync images or video received from the camera to the smartphone via WiFi. The UV to blue spectrum light of the devices is safe to use because its spectrum is the same as those used in composite curing light. Additionally, the devices light intensity is much less than the intensity of curing light. The intraoral camera with fluorescent aids used in OPMDs and oral cancer screening can emit the maximum irradiance of blue excitation light at about 2000 Lux, also 7,500 Lux for LED white light at the focal length of 2.5 cm from the tissue.

The device mechanism is shown in Figure 1. The intraoral camera with fluorescent aids for the screening of OPMDs used in teledentistry is shown in Figure 2.

Under the autofluorescent mode, the principle is to illuminate oral tissue with an appropriate light source that is mostly in the UV to blue range of the spectrum. The excitation UV-blue light spectrum of 360–450 nm wavelength from 10 UV LEDs was used to stimulate fluorophores molecules in the epithelium and stroma. The fluorophores molecules then reemitted the fluorescence in several wavelengths. A 480 nm long-pass light filter was used to filter the reemission of fluorescent wavelength from 480 nm and above spectrum into the camera image sensor. Thus the camera can detect the green to red fluorescent light, while the blue excitation light is rejected. The light filter is removable from the front of the small camera, which allows switching between LED white light mode and autofluorescent mode. The device mechanism in autofluorescent mode is shown in Figure 3.

2.2. Patient Recruitment. An ethical approval was obtained from the Faculty of Dentistry Human Experimentation Committee (approval no. 80/2020), Chiang Mai University. Patients who had signed the informed consent documents were recruited from the Oral Biology and Oral Diagnosis Clinic, Faculty of Dentistry, Chiang Mai University, from December 2020 to March 2021.

Inclusion criteria were patients aged above 20 years old (1) who have lesions of OPMDs, (2) who have squamous cell carcinoma (SCC), (3) who permitted oral photography using the intraoral camera devices, and (4) who could have a tissue biopsy under local anesthesia.

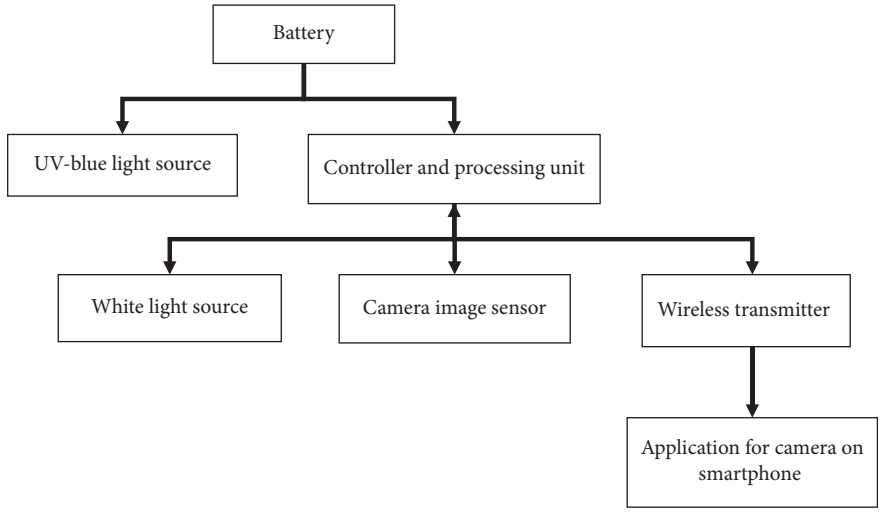


Figure 1: The overall device mechanism.

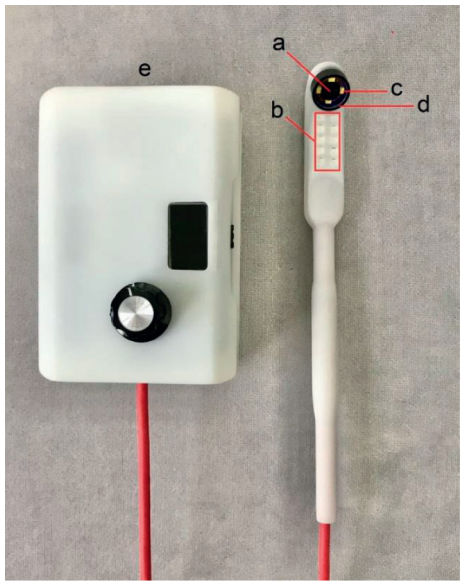


Figure 2: The intraoral camera with fluorescent aids for the screening of OPMDs used in teledentistry. This device consists of (a) camera image sensor and lens, (b) UV-blue light source, (c) white light source, (d) light filter, and (e) controller and processing units with rechargeable battery.

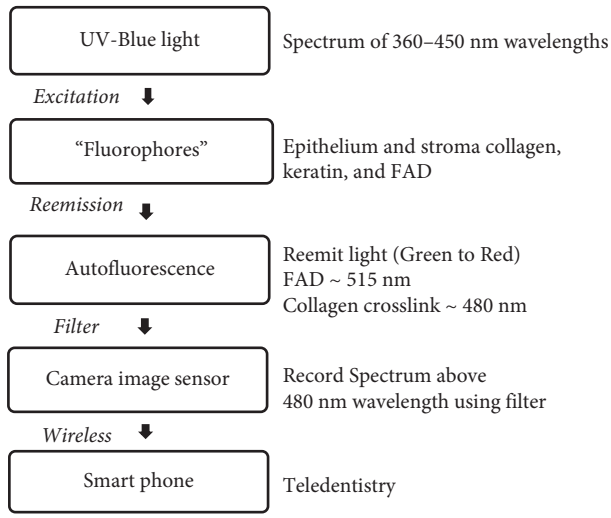
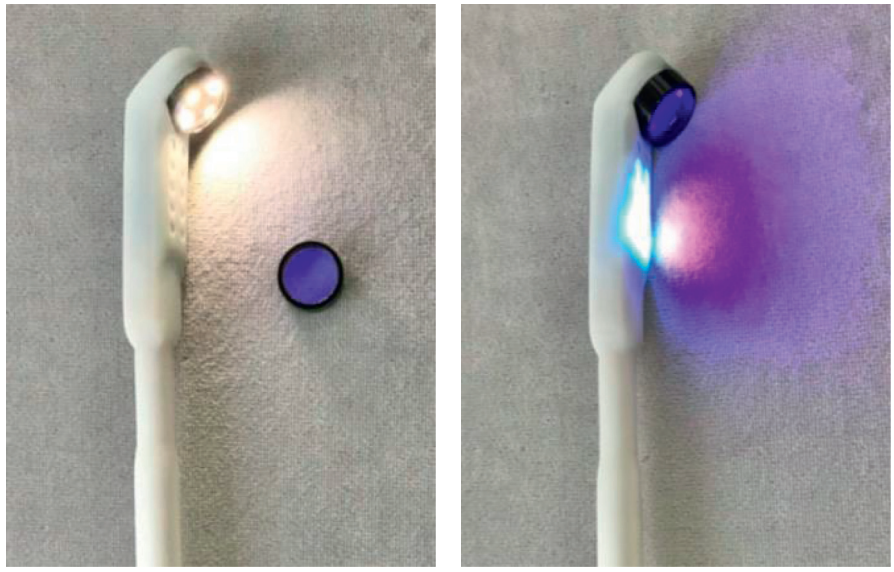


Figure 3: Devices mechanism for autofluorescent mode.

Exclusion criteria are patients with other inflammation lesions including traumatic or aphthous ulcer.

2.3. Sample Collection. The information of each patient including gender, age, hospital number, and subjective symptoms was required. Patients receiving an oral screening for OPMDs and oral cancer by an oral medicine specialist (OMS) were screened in seventeen locations of the oral cavity including (1) lips, (2) upper labial gingiva and vestibule, (3) upper left gingiva and vestibule, (4) upper right gingiva and vestibule, (5) lower labial gingiva and vestibule, (6) lower left gingiva and vestibule, (7) lower right gingiva and vestibule, (8) left buccal mucosa, (9) right buccal mucosa, (10) left retromolar area, (11) right retromolar area, (12) hard and soft palate, (13) dorsal tongue, (14) left lateral tongue, (15) right lateral tongue, (16) ventral tongue, and (17) floor of mouth. Each location of each patient was coded as a number. The patient information and initial diagnosis of the lesions were noted in the examination forms. In the same visit, a general dentist took an image of the most severe lesion of each patient using the intraoral camera in both LED white light mode and autofluorescent mode. Application of the intraoral camera with fluorescent aids for the screening of OPMDs in each mode was shown in Figure 4. All patients underwent tissue biopsy under a local anesthesia by the OMS or the oral surgeon. As it was known, some OPMDs have more than one histopathological feature in one lesion. The site of biopsy was chosen at the most severe features of the lesions to search for the worst diagnosis that the lesion could be. If the lesion has many curious characteristic features, the surgeon also took more than one site of each different feature. The most severe diagnosis is then analyzed in the research results. The resolution of the intraoral camera used



(a) (b)

Figure 4: Application of the devices in (a) LED white light mode and (b) autofluorescent mode.

to capture images was full HD (1920×1080 pixels). Each image code number was matched with the code in the screening form. After the washout time period, the OMS then was asked to do the diagnosis again from fluorescent image and the intraoral images under LED white light. Signs and symptoms and other information were also given. The reexamination data from the devices sent online through teledentistry was used to compare with the conventional direct examination and histological data from biopsy results. The study workflow is shown in Figure 5.

2.4. Examiner and Interpreter. All patients were examined in a prospective manner by an oral medicine specialist (OMS) who had acquired a Diploma of the Thai Board of Oral Diagnostic Sciences. The intracalibration was done to ensure that the analyzed result did not engage with the examiner error. To ensure that interpreter was reliable, OMS as the interpreter was asked to diagnose the set of OPMDs images twice, one week apart each time. Then the result of diagnosis which was done in the first time was compared with the second time and analyzed for concordance as a percent agreement. Showing 82.35% of percent agreement for the concordance, thus the interpreter was reliable since the statistic shows strong concordance.

2.5. Data Analysis. There were 3 parameters of the data to be analyzed including (1) category of lesion, (2) dysplasticity of lesion, and (3) image score.

The parameter of category of lesion was the initial diagnosis by the OMS according to patient's signs and symptoms and a clinical characteristic of the lesion. The category of lesion acquired from conventional direct examination was then compared with the reexamination data of reviewed images from the devices with the same code number. The percent agreement statistic was used for evaluation of diagnostic concordance as reliability. The parameter of dysplasticity of lesion was judged by fluorescence loss or low intensity of green fluorescence in the fluorescence images. OMS determined whether the lesion was dysplastic or not using combination method of both fluorescent images and images under LED white light and also fluorescence image from autofluorescence method alone. The parameter of dysplasticity of lesion was also compared with the histopathological results from biopsy. For the parameter of image score, OMS graded each image with score 0 to 2. The information of the three parameters is shown in Table 1.

3. Results and Discussion

3.1. Sample Characteristic. The demographic data of 34 patients enrolled in this study is provided in Table 2. Most of the patients were aged 50–59 years old. According to conventional direct examination, 19 lesions were diagnosed as oral lichen planus, which were the most common lesions found for the parameter of category of lesion. Nine lesions were clinically diagnosed as leukoplakia, 5 lesions were clinically diagnosed as discoid lupus erythematosus, and only one lesion was clinically diagnosed as a squamous cell carcinoma. All of the lesions underwent surgical biopsy, revealing 8 lesions as premalignant mild epithelial dysplasia for the parameter of dysplasticity of lesion, while the histopathological diagnosis shows the definitive diagnosis including 18 lesions of lichen planus, 5 lesions of discoid lupus erythematosus, 1 lesion of verruca vulgaris, 2 lesions of hyperkeratosis, and 8 lesions of premalignant mild epithelial dysplasia.

3.2. Validity and Reliability of the Devices. The parameter of dysplasticity of lesion was compared with the histopathological results from biopsy as a gold standard. Sensitivity,

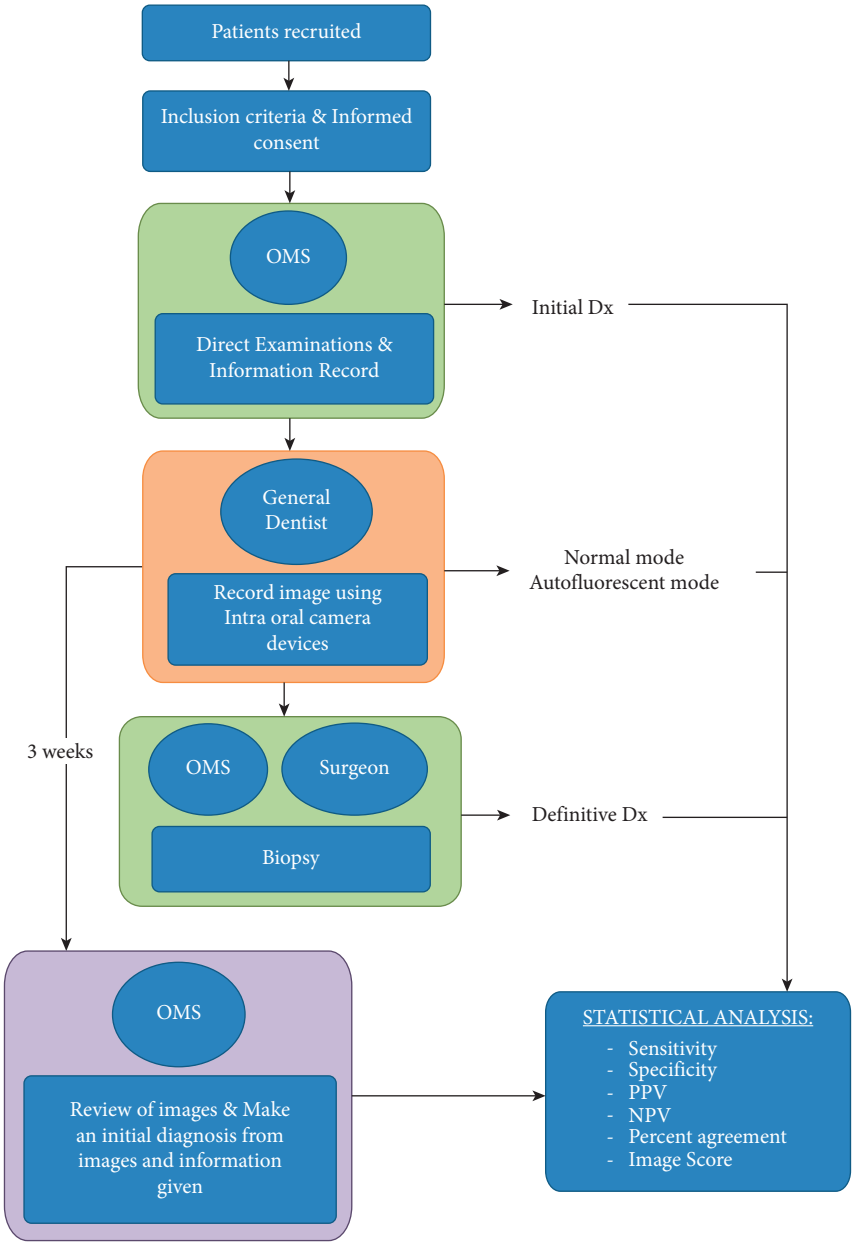


Figure 5: The study workflow.

Table 1: Parameters of the data.

Category of lesion	Dysplasticity of lesion	Image score
(i) Leukoplakia	(i) Dysplasia	0
(ii) Erythroplakia	(ii) No dysplasia	(i) Image quality is poor
(iii) Lichen planus (LP)	—	(ii) Not enough to get a diagnosis
(iv) Discoid lupus erythematosus (DLE)	—	1
(v) Palatal lesions in reverse smokers	—	(i) Image quality is fair
(vi) Oral submucous fibrosis (OSMF)	—	(ii) Enough to get a diagnosis
(vii) Actinic cheilitis	—	2
(viii) Squamous cell carcinoma (SCC)	—	(i) Image quality is good
—	—	(ii) Enough to get a diagnosis

specificity, PPV, and NPV of the device using combination method were 87.5%, 84.6%, 63.6%, and 95.7%, respectively, while the results were 50.0%, 80.8%, 44.4%, and 84.0%, respectively, for autofluorescence method alone (AF alone). Dysplasticity of lesion parameter acquired from combination method was 85.29% agreement while the concordance

Table 2: Demographic data of patients examined.

	n (%)
Gender	
Male	16 (47.06)
Female	18 (52.94)
Age	
20–29	1 (2.94)
30–39	1 (2.94)
40–49	3 (8.82)
50–59	13 (38.24)
60–69	9 (26.47)
70–79	7 (20.59)
Category of lesion (initial Dx by OMF)	
Leukoplakia	9 (26.47)
OLP	19 (55.88)
DLE	5 (14.71)
SCC	1 (2.94)
Histopathological diagnosis	
OLP	18 (52.94)
DLE	5 (14.71)
Verruca vulgaris	1 (2.94)
Hyperkeratosis	2 (5.88)
Mild epithelial dysplasia	8 (23.53)
Dysplasticity of lesion (histopathologic result)	
Dysplasia	8 (23.53)
No dysplasia	26 (76.47)
Dysplasticity of lesion (combination method)	
Dysplasia	11 (32.35)
No dysplasia	23 (67.65)
Dysplasticity of lesion (AF alone)	
Dysplasia	9 (26.47)
No dysplasia	25 (73.53)
Image score	
0	0 (0.00)
1	29 (85.29)
2	5 (14.71)

for AF alone was 73.53%. The concordance between clinical direct examination and images reviewing from the devices via teledentistry for determining the category of lesion on initial diagnosis was 79.41% agreement (Table 3).

3.3. Images Quality. OMS was accessed for all images by reviewing online via "Line Application" using the same smartphone (Apple Inc., USA), which would not alter the image resolution and image size. The median and mode value of image score were 1 (SD = 0.3937).

4. Discussion

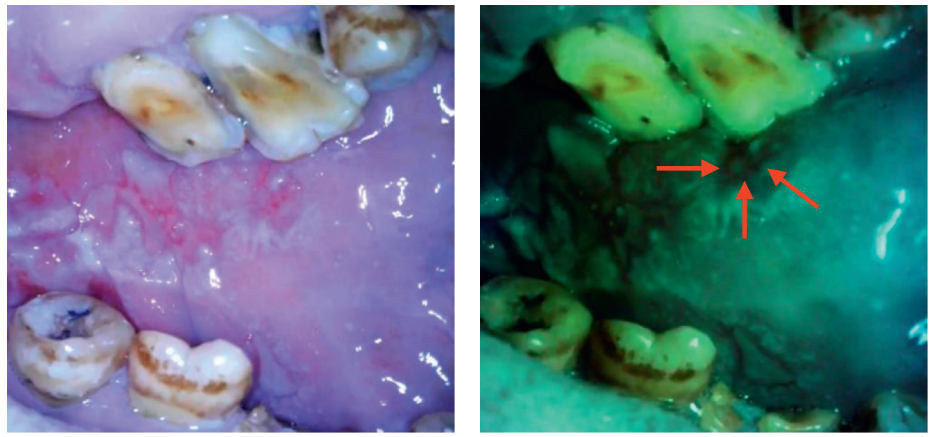
Since the dysplasticity of lesion could not be evaluated under LED white light image, autofluorescence is one of the diagnostic aids for screening detection of OPMDs and oral cancer. The validity and reliability of autofluorescence using in a direct fluorescence visualization device for the screening of epithelial dysplasia in OPMD and oral lesions have been assessed in previous studies [12, 13]. Several studies used only autofluorescence method alone while the others used a combination with a conventional oral examination [12, 14–17]. However those studies performed the examinations on site; teledentistry was not involved. The results are provided only in direct optical images and cannot be transferred as electronics information via teledentistry. The intraoral camera with fluorescent aids for OPMDs screening in teledentistry designed from this study could provide good image quality, which is enough to get the initial diagnosis. The image quality is important for making a decision for diagnosis, since previous study showed that the overall sensitivity and specificity of images used in teledentistry were dependent on image resolution to detect premalignant lesion and oral cancer [18]. Since the camera image sensor of the devices can produce high resolution images, up to 2K, the image resolution then depends on the resolution of the smartphone display when viewing images. Also, the application software for transferring the data through the Internet should not be the one that would reduce the image definition. Some images from the devices were shown in Figures 6 and 7. Another factor that could disturb the quality of the image is the light reflection, as light reflection could leave bright defects on the image, which could affect the interpretation of the lesions.

In this study, the device provides both LED white light mode and autofluorescent mode. This was equivalent to the same rationale used for the combination method, between conventional oral examination under LED white light and conventional direct fluorescence visualization device in autofluorescence method comparing to other studies. The systematic study showed that sensitivity and specificity of VELscope™, as an adjunctive tool to conventional oral examination for detection OPMD and/or SCC, were 73.9%–100% and 38%–97.9%, respectively [13]. Sensitivity, specificity, PPV, and NPV of the device using combination method were 87.5%, 84.6%, 63.6%, and 95.7%, which were higher than using autofluorescent method alone (50.0%, 80.8%, 44.4%, and 84.0%, respectively). From the results, low value of PPV on the parameter of dysplasticity of lesion might occur due to the low prevalence of dysplasia. There were only 23.53% (8 lesions) of all OPMDs samples that had mild dysplasia. The results showed that the value of percent agreement statistics for dysplasticity of lesion was 85.29%, which was strong and indicated that the device using combination method was a reliable tool in teledentistry. The results were consistent with other studies that revealed the combination method could improve the specificity [6, 12]. This might be because the images under LED white light mode can provide better clinical characteristics of the lesion than those in autofluorescence mode alone. These clinical characteristics could also help in diagnosis determination.

When interpreting fluorescence images acquired from the device, the loss of fluorescence, seen as dark areas from the device, was due to many factors. The alteration of abnormal dysplastic tissue is one of the situations that cause fluorescence loss. The presence of neoplasm, demonstrated by the different scattering and absorption properties of the light through the tissue, was dependent on the concentration of fluorophores that are found in the tissue matrix or in cells compositions such as flavin adenine dinucleotide (FAD), collagen, elastin, and keratin. Dysplastic tissue usually shows

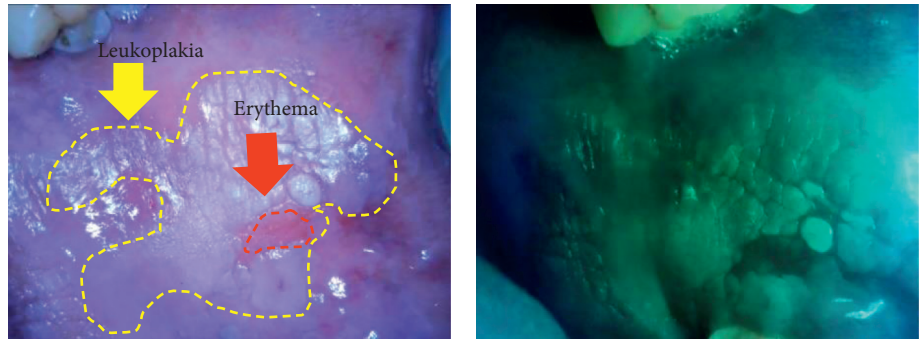
Table 3: Validity and reliability of the devices.

	AF alone	Combination method (AF + white LED)
Sensitivity	50.0% (15.3–84.7%)	87.5% (64.6–110.4%)
Specificity	80.8% (65.6–95.9%)	84.6% (70.7–98.5%)
PPV	44.4% (11.9–76.9%)	63.6% (35.2–92.1%)
NPV	84.0% (69.6–98.4%)	95.7% (87.3–103.9%)
Percent concordance (dysplasticity of lesion)	73.53%	85.29%
Percent agreement (category of lesions)	N/A	79.41%



(a) (b)

Figure 6: Intraoral images from the devices in (a) LED white light mode and (b) autofluorescent mode showing loss of fluorescence in suspicious dysplastic area.



(a) (b)

Figure 7: Images from the devices in (a) LED white light mode and (b) autofluorescent mode showing loss of fluorescence in erythema area. The image was in higher contrast, which could easily determine the outline of the lesion.

the loss of fluorescence, represented by a dark area under fluorescent light [3, 4]. The low intensity of fluorescence is the result of (1) the collagen breakdown following the invasion of dysplastic epithelial cells and (2) the increase in metabolic activities of dysplastic cells followed by the reduction of free FAD [3, 4]. Moreover, the increase in blood supply within the dysplastic lesion caused the accumulation of hemoglobin, which strongly absorbs blue and green light; thus the less reemission of fluorescence intensity was seen [3, 4].

The loss of fluorescence must be always considered with the clinical findings or signs and symptoms of the patient [3, 4]. Since the fluorescence image results do not yield a "yes or no answer," the device cannot be a replacement for definitive diagnosis. The device can be used as a clinical adjunct or screening tool rather than a diagnostic tool. It is more helpful to outline a determination before any biopsy for the histological evaluation since it can provide higher contrast between abnormal lesion and surrounding normal tissue. The interpretation of fluorescence loss could affect

Table 4: The intraoral camera with fluorescent aids for the screening of OPMDs properties.

Device properties	Conventional intraoral camera	Conventional direct fluorescence visualization device	Device developed from the study
Capturing and recording intraoral images/videos	✓	—	✓
Small size and angulation design based on "mouth mirror design"	—	—	✓
LED white light mode	✓	—	✓
Blue light mode	✓/—	✓	✓
Autofluorescent mode (i) Identifying oral potentially malignant disorders and oral cancer (ii) Identifying poor oral hygiene due to bacterial aggregation	—	✓	✓
Data sync via smartphone	✓/—	—	✓

Table 5: Characteristics of the intraoral camera with fluorescent aids for the screening of OPMDs.

Strengths	Limitations
1. Noninvasive	1. Image results should be interpreted by experienced clinicians
2. Portable and simple to use	2. Need a dark environment in autofluorescent mode
3. Provide both real-time and recorded images/videos	—
4. Cost-effective and no consumable reagents cost	—
5. Can be performed by wide range of operators after short training	—
6. Useful in teledentistry field	—

validity of the device, since darkness of the fluorescence loss in images is judged by human perceptual skill, which is very varying. On the other hand, artificial intelligence (Ai) could be the solution of these limitations, as they allow image acquisition, feature extraction, and mathematical analysis and demonstrate them as objective values [19–21]. Moreover, fluorescence images acquired from the device can be used for developing an artificial intelligence (Ai) diagnosis system as a measure for mass populations screening.

In practicality, the intraoral camera with fluorescent aids for the screening of OPMDs is portable and suitable for use as teledentistry tools in primary healthcare units in the community. In particular, the device is practical for dependent older adults, who have limitations in mouth opening. The intraoral part of the devices is small and can be performed in a dark environment due to its own light sources. Another advantage is that it is more ergonomic than the conventional direct fluorescence device, as dentists do not need to bend forward close to the patient mouth and star into the loupes. The intraoral image or fluorescence image is shown clearly on the display of smartphone in real time and can be transmitted as electronic information in teledentistry via the Internet. The device properties and characteristics are shown in Tables 4 and 5, respectively.

5. Conclusions

The intraoral camera with fluorescent aids, which has the combined advantages of both conventional intraoral camera and conventional direct fluorescence device, can be utilized as an adjunctive device for screening of dysplasia in OPMDs via teledentistry. According to the combination method between autofluorescence and an examination under LED white light, validity and reliability for the screening of dysplasia in OPMDs were higher than autofluorescence method alone. It is important that the results from device utilizing optical fluorescence imaging should be interpreted with the clinical findings or signs and symptoms of the patient. While the conventional intraoral camera cannot assess a parameter of dysplastic of the lesions, the intraoral camera with florescent aids can be a more useful tool in screening of dysplasia in OPMDs. The application on smartphone using with the intraoral camera in teledentistry should not alter the images quality.

Data Availability

The (pdf) data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

This study was supported by the Faculty of Dentistry, Chiang Mai University, and the Intercountry Centre for Oral Health, Department of Health, Ministry of Public Health, Thailand. The authors wish to thank Associate Professor Thawan Sucharitakul and Associate Professor Radom Pongvuthitham, academic staff, at the Faculty of Engineering, Chiang Mai University, for their assistance in developing the intraoral camera with fluorescent aids for OPMDs screening.

The authors also wish to thank Dr. Thanapat Sastraruji, researcher at the Faculty of Dentistry, Chiang Mai University, for his statistical advice.

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Hindawi
International Journal of Dentistry
Volume 2021, Article ID 9963329, 6 pages
https://doi.org/10.1155/2021/9963329

Review Article

The Exponential Rise of Teledentistry and Patient-Oriented Protective Measures in Southeast Asian Dental Clinics: Concerns, Benefits, and Challenges

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Received 12 March 2021; Accepted 24 September 2021; Published 6 October 2021

Academic Editor: Flávio Moura

In the Southeast Asian region, various policies have been advocated by health regulatory bodies that entail protective measures such as face masks, gloves, maintaining distance in public areas, and more. These protective measures are aimed at helping reverse the growth rate of the coronavirus. Dentists in this region have incorporated several changes to their practices to help minimize risks of person-to-person transmission inside dental offices. This narrative review aimed to provide an in-depth overview of the current situation in the Southeast Asian region regarding the use of teledentistry during the pandemic. Teledentistry involves the transfer of patient information across remote distances for online consultation and treatment planning. A few years back, it used to be a lesser-known entity but has seen an exponential rise in its incorporation into dental practices all around the Association of Southeast Nations (ASEAN) region. Many clinics in the Southeast Asian region have started using online consultations to ensure that patients can be diagnosed or followed up during their treatment. Teledentistry is the clear answer in the coming months as it will help reduce the risk of virus transmission and help patients get access to oral healthcare and dentists to see their patients. This article reviews the current pandemic situation in the ASEAN region, the recent evidence, and the scope of teledentistry. It also provides recommendations for the future and sheds light on the different types of teledentistry and how it can be incorporated into practices by regulatory authorities in this region.

1. Introduction

At the time of preparing this review, the entire world has been affected by the COVID-19 pandemic. While the Southeast Asian region has seen a lesser incidence of COVID-19 than the developing countries, many countries have gone into lockdown again in the past few months because of rising new cases [1]. Several measures have been implemented in this region to aid in the containment of the virus, including lockdowns, travel restrictions across borders, and the advocacy of different safety protocols depending on the geographical location. In the Southeast Asian region, various policies have been advocated by health regulatory bodies that entail measures such as the use of protective face masks and gloves and maintaining distance in public areas, all of which are aimed at helping to reverse the growth rate of the virus [2]. Among these measures, the use of virtual dentistry, or teledentistry as we call it, has been rising during this period. The Southeast Asian region, as we know, includes three groups of countries: the lower-middle-income, upper-middle-income, and the high-income group of countries. The lower-middle-income group is formed by

Indonesia, Cambodia, Sri Lanka, the Philippines, and Vietnam. The upper-middle-income group comprises Malaysia and Thailand, while Singapore has been placed in the high-income group of countries (Tables 1 and 2) [3, 4].

One of the principal problems in this region is oral health, and there have been no cross-national studies conducted to evaluate the oral health status. National oral healthcare plans have not been organized and implemented in many countries in this region due to budgetary restrictions. There are very less public oral health services because of which dental problems are widely prevalent here. It has been shown in previous studies conducted in the Association of Southeast Nations (ASEAN) region that people who received treatment for severe dental problems were forced to reduce expenses on necessities because of the additional costs incurred [5–12]. Teledentistry is a cost-effective way to deliver primary as well as specialty care [13, 14]. The problem is that, before the pandemic, teledentistry was considered an optional form of oral healthcare delivery rather than a mainstream one [15]. There have been several challenges in implementing virtual dentistry in Southeast Asia and globally, such as technical issues, expenditure, Internet speed, political clearances, and health infrastructure [16–18].

Teledentistry has been defined as the virtual delivery of dental services by various means such as video, audio, or multimedia [19, 20]. These dental services can include gathering records for diagnosis, consultations, and treatment follow-up using a systematic collection of records [21]. The primary benefit of this technology is that it can benefit patients based in remote areas to get access to healthcare without physically covering the distance to see their dentist [22]. Many clinics in the Southeast Asian region have started using this virtual modality to ensure that patients can be diagnosed or followed up during their treatment.

2. Brief Review of the Literature

Over the past few years, Teledentistry has been proven to be highly effective in disseminating access and advantageous in terms of a profound reduction in the treatment time and costs [23]. Previous studies have analyzed the cost-benefit ratio across patients located in rural areas and found teledentistry to be a financially cost-effective option. Virtual dentistry has also been demonstrated to be helpful when it comes to remote screening for oral lesions, oral health education programs, and virtual consultations in remote rural areas [24]. In Latin America, Information and Communication Technologies (ICT) is considered a part of dental health provision and has been highly efficient in educational programs and research [25, 26]. The major problem faced by developing countries in using teledentistry has been attributed to many factors such as shortage of infrastructure, insufficient resources, materials, and even the conservative thought process of the governing bodies [27]. During the past year, many concerns have arisen regarding the risk of cross infection from patients visiting dental clinics for treatment. Governing bodies have set down various guidelines to prevent the spread of the SARS-CoV-2 virus [28–30]. Some of the recommendations include patient screening at the clinic entrance, telephonic screening before the patient visit, recording the patient's recent travel history to infection hotspots, and even the use of virtual consultations to alleviate patient concerns [31].

Table 1: Association of Southeast Nations (ASEAN) grouped according to the World Bank (Asian human capital index) [3].

Lower middle income	Upper middle income	High income
Indonesia	Thailand	Singapore
Myanmar	Malaysia	Brunei
Philippines		
Cambodia		
Vietnam		
Lao PDR		

3. Patient-Oriented Changes Incorporated by Dental Clinics in the ASEAN Region

Dentists in this region have incorporated several changes to their practices to help minimize risks of person-to-person transmission inside dental offices [32]. Staff-oriented measures such as thermal screening at the clinic entry, hand hygiene utilizing handwashes and alcohol before wearing gloves, and the diligent use of personal protective equipment have been implemented [33]. Patients have been asked to complete additional travel and medical history forms concerning the viral infection and its symptoms. At-risk patients are identified at the entry and requested to postpone any elective treatments for 14 days, while asymptomatic patients who clear screening are allowed inside with their masks on at all points of time except when receiving treatment [34]. Respirators such as N95 and four-layered masks have been used in conjunction with clear face shields to reduce transmission risk during treatment. After treatment, the clinical area is cleaned, sterilized, and subject to UV lamp disinfection for half an hour. While dentists have been as worried as the public about the infection risks, their experience and added safety approaches have brought about an air of confidence towards infection control.

4. Incorporation of Teledentistry

While this modality has been developing slowly in the more developed regions of the world, it has taken time to find its use in the developing areas [35]. It has various benefits to offer such as

(1) Improving the oral healthcare delivery to remote areas

(2) Making dental care accessible to everyone

(3) Bringing down the costs by enabling every person to get regular checkups

(4) Helping gather data for research that can be applied to the betterment of oral health

(5) Reducing the risk of virus transmission by bringing down physical visits to clinics until the vaccination process is complete

Table 2: Key economic characteristics of ASEAN countries [4].

Country	Population (in millions)	Per capita gross domestic product (GDP)	Gross domestic product (GDP)
Indonesia	227.75	1.897,57	432,18
Myanmar	57.64	350,14	20,18
Philippines	88.71	1.683,68	149,36
Cambodia	14.32	603,13	8,63
Vietnam	85.15	835,09	71,11
Lao PDR	6.09	693,64	4,22
Thailand	63.03	3.917,89	246,97
Malaysia	27.18	6.872,50	186,83
Singapore	4.83	36.694,53	177,58
Brunei	0.39	31.404,31	12,24

In the Southeast Asian region, many countries such as Thailand and Malaysia have reimposed lockdowns at the time of preparing this review. While this may be effective in reducing the SARS-CoV-2 virus transmission, it is detrimental to oral health as people cannot get access to oral healthcare in certain regions. This situation is where teledentistry has been found to be most effective, as dental practitioners can continue to see their patients virtually. While dentists may not be able to provide most treatment services online, the use of teledentistry has ensured that preventive services such as virtual oral consultations and counseling can be carried out.

4.1. Regulations on Teledentistry. As medical regulatory bodies, dental councils of countries in this region have not laid down any specific guidelines for the training, practice, and implementation of teledentistry into daily practice. Teledentistry has been expensive for acquiring the required equipment, and previous studies have reported no revenue for practitioners [36]. Since there is a deficit of established guidelines, there is a marked difference in patient information confidentiality, privacy, liability, and consent regarding its implementation across the Southeast Asian region. There is a distinct lack of measures to maintain control over the safety and efficiency of teledentistry as many users do not have the required training. The Royal College of Dental Surgeons of Ontario is one of the few regulatory authorities that have established guidelines that can be particularly useful for the practice of teledentistry [37]. Salient features of these guidelines include

(i) The use of audio-video technology for data collection before any medicines are prescribed

(ii) Patient data confidentiality following the guidelines laid down in the Personal Health Information Protection Act, 2004

(iii) Patient data must be accessible only to the dentists and the concerned patients

(iv) Privacy must be maintained during virtual consultations

(v) Regular monitoring and evaluation of virtual sessions to ensure uniformity in the practice of teledentistry

4.2. Types of Teledentistry. The American Dental Association has defined teledentistry as the use of telehealth systems and methodologies in dentistry [38]. This modality of providing the patient remote access to healthcare services includes the use of a broad group of technologies, which are categorized as follows:

(1) Store and forward: using this medium, a patient's oral health records such as radiographs and photographs can be electronically transferred to a dental practitioner for evaluation. The dentist then analyzes the records and provides a diagnosis via a nonlive medium.

(2) Remote patient monitoring: this modality is used for patient data collection from a remote site and then transferring to a dental practitioner in another location. The dental practitioner is then able to provide an evaluation to help treat the patient.

(3) Live video: this involves the use of a live interaction between the patient and the dentist utilizing audiovisual communication for diagnosis.

(4) Mobile health: it makes use of mobile communication devices such as phones and tablets to provide virtual oral healthcare services or even for educational programs (Figure 1).

The Southeast Asian region during the last decade has undergone a lot of changes with regard to industrialization. Trade and services have seen liberalization that has brought in investments and lifted the economy [4]. Previous studies conducted across the ASEAN (Association of Southeast Asian Nations) region have estimated more than 150 billion dollars of revenue from digital economy-related activities of which connectivity and online services form the two major contributors [39, 40]. This region has also been shown to have among the highest rates of Internet usage globally with Thailand and Indonesia demonstrating double the daily usage compared to the public in the United States [39]. The daily consumption of online media content is also exceedingly high in this region as Vietnam and Thailand have been placed among the top 10 countries for the highest media viewership [39]. The high Internet and online media usage can be utilized for various beneficial purposes, such as the setting up teledentistry centers that could provide oral healthcare access and information to the less-privileged areas.

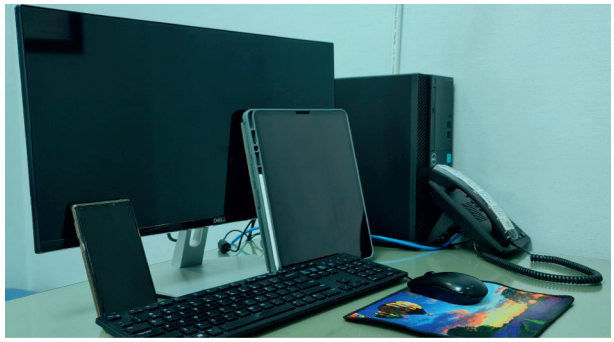

Figure 1: Different screen-based devices used for teledentistry consultations in the ASEAN region.

4.3. Challenges. During this period, the main areas of concern have been the availability of personal protective equipment (PPE), transmission risks, and the financial matters arising from reduced patient inflow and the enhanced costs associated with the newer patient screening and sterilization measures [41]. While most dentists in the Southeast Asian region have managed to incorporate most of the guidelines into their daily practice, there is a lingering sense of worry arising from not knowing when the situation would go back to normal. The COVID-19 outbreak has not only brought into focus the occupational hazards associated with the field of dentistry but also has forced us to change and adapt to the new normal [42].

Regarding the implementation of teledentistry and teleorthodontics, there have been various challenges in this region. One of the problems that have been faced in this region is the quality of images required for proper evaluation. Patients can consult virtually, but the quality of diagnosis is severely limited by a lack of appropriate intraoral records such as periapical radiographs [37, 43]. Another crucial element that affects the quality of the virtual session is the time consumed versus the financial returns for the participating dentist. No regulated service provider offers these services in this region to ensure compensation for the dentists for these virtual services [44].

5. Future Perspectives

With teledentistry and telemedicine proving to be particularly useful during the pandemic, the World Health Organization (WHO) must set down guidelines that regional regulatory authorities can adopt [45, 46]. Establishing guidelines would aid in solving legal, scientific, and ethical issues occurring with the implementation of transregional programs [47–49]. Guidelines also need to be established regarding human resource training and minimum credentials required to register participating hospitals and clinics. Dentists must be encouraged to join such training as an option and an added standard for dental care.

6. Final Considerations

The risk of transmission through dental procedures must be kept to a minimum through precise actions and protocols. Dentists must keep themselves updated with the characteristics of SARS-CoV-2 and the latest infection control measures. As the number of COVID-19 cases continues to increase, dentists must ensure that they participate in advanced infection control programs to strengthen their knowledge [50, 51]. Teledentistry is the clear answer in the coming months as it will help reduce the risk of virus transmission and help patients get access to oral healthcare and dentists to see their patients. This modality needs to be considered by governing and regulatory bodies to ensure a proper structure is followed for best results.

Data Availability

All data related to the study have been included in the article.

Conflicts of Interest

The authors declare no conflicts of interest.

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