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Original Article

A comparison between clinical and digital images with various resolutions to evaluate glass ionomer cement restoration on primary teeth

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ABSTRACT

Introduction: Dental photography has increasingly been used in practice. One of the purposes of dental photography is for treatment evaluation. Notably, photo resolution affects a picture's quality. Glass ionomer cement (GIC) restorations are frequently used on pediatric teeth and must be evaluated periodically. In this digital era, digital photos can be used to evaluate restorations. The evaluation of restorations using FDI criteria is typically effective in clinical uses.
Objective: This study aims to compare differences in digital photo resolution and clinical results to evaluate GIC restoration in primary teeth.
Materials and methods: Forty mandibular primary first molars from 31 pediatric patients aged 4 to 9 years from Universitas Indonesia dental hospital were included in this study. All teeth were examined and clinically evaluated, and photos were taken using a DSLR camera with low resolution (8 MP), medium resolution (15 MP), and high resolution (32 MP). The photos were then evaluated. Clinical GIC restorations and digital photographs were evaluated using FDI criteria. All of the collected data were analyzed using a Pearson's chi-square categorical comparative test with a significance level of $p < 0.05$.
Result: Based on the comparative test, there were no statistically significant differences in the clinical groups with low resolution, medium resolution, and high resolution for evaluating GIC restorations in primary teeth.
Conclusion: Digital photography can be used to support the evaluation of restoration status. Digital photos can indicate the clinical state of GIC restorations. This study recommends using digital photos between low and medium resolution (8–15.3 MP) as media in dental practices to evaluate GIC restorations in primary teeth, comparable to smartphone cameras or pocket cameras.

1. Introduction

Digital photography is useful in various applications, such as treatment planning, oral health education, formal documentation, communication with dental laboratories, and treatment evaluation (Werle et al., 2015). The use of digital photography in dentistry has proliferated following the development of digital cameras and electronic devices. Previous research found that nearly half of the dentists (48 %) in The United Kingdom use digital photography in their clinical practice (Morse et al., 2010). The growing use of this modality necessitates a standardized documentation method to increase the clinical relevance of digital photography in dentistry (Table 1).

In addition to clinical and radiological evaluations, digital photography provides an easy and convenient means to evaluate dental treatments. However, several standards must be met to ensure the representativeness of digital images with respect to the corresponding clinical conditions. The resolution of digital photos is important to ensure excellent output. There are several factors that affect the resolution of digital photos, including pixels, sensors, colors, file size, and the media on which the photos are displayed (Kalpana et al., 2018; Sharland, 2013). These factors can affect the quality of digital photos, thus affecting the interpretability of the photos.

Several methods are currently used to evaluate restorations, typically based on several clinical assessment criteria. One of them is the method advised by the World Federation of Dentistry (FDI) (Hickel et al., 2010). This method has been studied previously and has proven effective in the

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Table 1
Population characteristic.

Population	Frequency (Percentage)
Sex	
Boy	12 (38.7 %)
Girl	19 (61.3 %)
Age	
4–5 years	7 (22.6 %)
6–7 years	9 (29 %)
8–9 years	15 (48.4 %)
Total	31 (100 %)
Evaluated Tooth	
74	23 (57.5 %)
84	17 (42.5 %)
Total	40 (100 %)

clinical evaluation of restorations. Previous studies have been conducted to evaluate composite resin restorations on permanent dentition using digital photography (Kim et al., 2017; Signori et al., 2018). Other studies have also conducted clinical evaluations of composite resin restorations in pediatric teeth (Cavalheiro et al., 2020). However, no studies have compared pictures with different resolutions to evaluate glass ionomer cement (GIC) restorations in children. In this study, we aimed to compare the differences between the evaluations based on clinical and digital photographs with different resolutions for GIC restorations in primary teeth.

2. Materials and methods

2.1. Ethi***cal statement

This research protocol has been reviewed and ethically approved by the dental research ethics committee (KEPKG) in the Faculty of Dentistry, Universitas Indonesia, under registration number 117/Ethical Approval /FKGUI/XI/2022.

2.2. Participants

The study was conducted at the Pediatric Dentistry Clinic at Universitas Indonesia dental hospital; it included boys and girls aged 4 to 9 years who had received approval from their parents/guardians to participate in the study and who had signed an informed consent sheet. The participants had undergone GIC restorations on 74 and/or 84 in the occlusal area to treat damage caused by caries. Uncooperative and/or special needs patients, malpositioned teeth, and mobile teeth were excluded from the study. Based on a sample size calculation with an alpha value of 0.05, 31 patients were required to achieve 80 % statistical power.

2.3. Digital photography standardization and evaluation methods

One digital camera (Canon EOS 90D, Canon, Japan) with a 100 mm macro lens (Canon EF 100 mm, Canon, Japan) was used to take clinical pictures. A ring light (Amaran AHL-HC100, Aputure, China) mounted on the camera body was used as a continuous light source for all of the photographs. The camera was programmed with a manual mode, ISO 250, f2.8, speed 1/100, and color space RGB. The display grid on the screen was enabled, the lens was calibrated in the autofocus (AF) setting, and a camera remote was connected to take the pictures.

The patient was seated on the dental unit with the backrest tilted at 45° (Fig. 1). A clinical evaluation was performed using intraoral mirrors and a cheek retractor, and additional lighting was obtained from a standard LED lamp in the room and dental unit. Prior to the evaluation, oral prophylaxis was performed with an emphasis on the evaluated site. The researcher clinically analyzed the restorations for 3 min and

Fig. 1. Patients' and camera position during clinical evaluation and photography.

recorded the evaluation results on the FDI evaluation form. Clinical photos were then taken using a camera three times, with the following three resolutions, by changing the settings menu on the camera: a low resolution of 3472 x 2320 pixels (8 MP), a medium resolution of 4800 x 3200 pixels (15.3 MP), and a high resolution of 6960 x 4640 pixels (32 MP).

The collected photo files were stored on a hard disk and were transferred using a laptop. The administrator coded and randomized the photos before the photos were further analyzed. The evaluation of the restorations from digital photos was conducted in a dark room, where the photos were displayed on a smart TV screen. The photos were displayed in actual size and in full screen mode and were distanced 2.7 m from the investigators (Fig. 2). A photo evaluation assessment was carried out on each sample using the FDI restoration evaluation criteria.

GIC restorations were assessed using the FDI criteria for the evaluation of direct and indirect restorations (Supp 1), namely surface luster, staining, color match and translucency, aesthetic anatomical shape, material fracture, marginal adaptation, occlusal conformation and wear, and caries recurrence. Scores were determined on a scale from 1 to 5, with the following interpretations corresponding to each number: clinically excellent (1); clinically good (2); moderately satisfactory or clinically adequate (3); clinically unsatisfactory (4); and clinically poor (5). Treatment conclusions/decisions were simplified to the following: retained (1–3); improvement needed (4); replacement needed (5). The collected clinical and photo evaluation data were entered into a table and analyzed statistically.

3. Results

This study was conducted on GIC restorations in 40 teeth (74 and/or 84) from 31 pediatric patients aged 4 to 9 years at our dental hospital. Among the participants, there were 12 boys and 19 girls. Seven children were aged 4 to 5 years old; nine were aged 6 to 7 years old; and 15 children were aged 8 to 9 years old. The GIC restorations evaluated amounted to 23 restorations on tooth 74 and 17 restorations on tooth 84. An evaluation of two sample cases is presented in Fig. 3.

The picture displays an evaluation of two sample cases. K = control, F1 = high resolution, F2 = moderate resolution, F3 = low resolution.

This study evaluated GIC restorations based on eight selected criteria, out of 16 in the FDI restoration evaluation protocol. The eight selected criteria were surface luster; staining; color match and translucency; anatomical shape aesthetics; material fracture and retention; marginal adaptation; occlusal contour and secondary caries; erosion and abfraction. Table 2 indicates the data distribution regarding the number of retained, repaired, and replaced restorations based on the assessment criteria and comparisons of the clinical evaluations and low-, medium-, and high-resolution photographs.

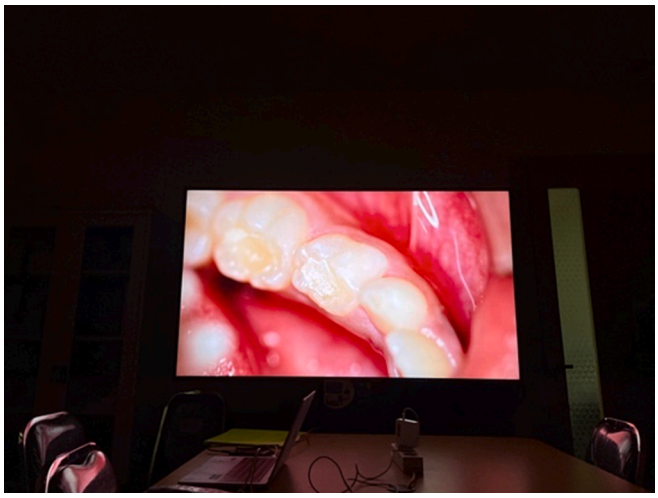

Fig. 2. Evaluation condition for digital photographs.

In the luster evaluation, more restorations were retained on the low-resolution digital photographs. On the other hand, for the evaluation criteria of staining, color match, material fracture, marginal adaptation, occlusal contour, and caries recurrence, more restorations were retained in the clinical evaluations. Meanwhile, for the anatomical shape criteria, low- and medium-resolution photos had the same number of retained restorations. Across all criteria, the number of restorations requiring a replacement was higher for the high-resolution photos than for the clinical and low- and medium-resolution groups.

The FDI assessment criteria are based on five levels of scoring, which can be classified into three groups of scores: restorations with scores of 1 to 3 are acceptable and maintained; scores of 4 are improved; and scores of 5 are unacceptable and replaced. All clinically and digitally evaluated restorations with low, medium, and high resolutions were categorized based on the worst presenting score among the eight criteria. Based on the FDI assessment, 52.5 % of the restorations in the clinical assessment were considered to be preserved, compared to the digital photograph-based assessment, with 60 % of the restorations considered to be preserved at low resolution, 55 % at medium resolution, and 47.5 % at high resolution (Fig. 4).

Two researchers conducted the clinical evaluation and digital photo evaluation. To measure the consistency of the measurements, an inter-rater agreement Cohen's Kappa test was conducted. In the clinical evaluation reliability test, the agreement value was moderate (0.467). On the other hand, a very strong agreement (0.81–1.00) was observed in the digital photo evaluation.

4. Discussion

Digital photography in dentistry primarily aims to record and document the clinical state of a patient's oral cavity. Digital clinical pictures can serve as documentation of examinations mid-treatment and post-treatment. In practice, dental photography is expected to assist dentists in improving the quality of delivered care (Morse et al., 2010; Werle et al., 2015). The use of digital photography for treatment evaluation has been continuously developed in various studies.

This study aims to compare the differences in evaluations between clinical and digital photographs with different resolutions for GIC restorations in primary teeth. This study was conducted at the pediatric dental clinic at our dental hospital by sampling clinical examinations and digital photographs with various resolutions and analyzing the restorations according to the FDI criteria through each media.

The FDI criteria delineate 16 metrics for evaluating restorations. The list includes aesthetic, biological, and functional properties that can be assessed to determine the quality of the restorations. Each of the criteria is scored based on a 1–5 scale scoring system: (1) clinically very good, (2) clinically good, (3) clinically sufficient, (4) clinically unsatisfactory, and (5) clinically poor (Hickel et al., 2010). The scoring indicates the need for the repair or replacement of the restorations based on the overall scoring. In this study, we selected eight out of 16 FDI criteria that facilitate visual assessment, namely surface luster, staining, color match and translucency, aesthetic anatomical shape, material fracture and retention, marginal adaptation, occlusal contour and wear, and secondary caries, to assess GIC restorations based on images with different resolutions.

The FDI criteria for the evaluation of restorations are increasingly being used by researchers in clinical studies. Furthermore, studies have used these criteria to evaluate composite resin restorations clinically and via digital photography, demonstrating its potential to be used in two-dimensional media (Cavalheiro et al., 2020; Kim et al., 2017; Signori et al., 2018). Previous studies have evaluated composite resin restorations in adults and pediatric patients (Cavalheiro et al., 2020; de Almeida et al., 2021). Despite some potential findings, these studies have found that clinical assessments can still detect more restoration

FDI Criteria	K	F1	F2	F3
Surface Luster	3	3	4	4
Staining	2	2	3	4
Color Match and Translucency	3	3	3	4
Anatomical Form and Esthetics	4	4	4	4
Material Fracture and Retention	2	2	2	2
Marginal Adaptation	2	3	3	5
Occlusal Contour and Wear	2	4	4	4
Caries Recurrence	1	1	2	2
Conclusion	4	4	4	5

FDI Criteria	K	F1	F2	F3
Surface Luster	5	5	5	5
Staining	5	5	5	5
Color Match and Translucency	5	5	5	5
Anatomical Form and Esthetics	5	5	5	5
Material Fracture and Retention	5	5	5	5
Marginal Adaptation	5	5	5	5
Occlusal Contour and Wear	4	5	5	5
Caries Recurrence	5	5	5	5
Conclusion	**5**	**5**	**5**	**5**

Fig. 3. Evaluation results of 2 cases.

repair and replacement needs (de Almeida et al., 2021; Signori et al., 2018). Therefore, further research must be conducted to consider additional variables, including image resolutions.

GIC restorations are often used in pediatric dentistry due to their fluoride-releasing properties, making them appropriate for children with a high caries risk. However, GIC restorations are sensitive to moisture, drying, and discoloration. This sensitivity to moisture and drying is clinically evident, as when the restoration is dry, the margins, texture, and luster of the restoration are more apparent. Moreover, other clinical steps may also affect the final restoration. During the cavity preparation, if the carious tissue is not fully removed, leakages may occur, and secondary caries may result. Furthermore, during the placement of the GIC into the cavities, proficient skills are required to achieve proper anatomy and marginal adaptation.

Dental photography involving intraoral images is usually classified as a branch of macrophotography (Bengel, 2006). Specialized photographic equipment is used to execute macrophotography techniques, including DSLR cameras, macro lenses, and additional flashes attached to the camera. In this study, a DSLR camera was used due to its superior specifications that can be manually standardized to support this research. The lens used in the study was a macro lens with a 100 mm focal length to achieve an adequate field of view, as is commonly recommended in dental photography (Ong et al., 2022). For lighting, an additional ring-light flash was used in this study to achieve optimal intraoral lighting. These settings are endorsed by Golkari et al., who argue that cameras with macro lenses and ring-lights are highly effective for detecting changes in enamel color, transparency, and thickness in primary teeth. Furthermore, in this study, all photos were taken with the same settings, namely, ISO 250, f-2.8, and speed 1/100, to optimize the field of view and focus.

In this study, all digital photo data were saved on an external hard disk using a laptop after photos of the research subjects were taken. The file sizes of the photos varied depending on the resolution; low resolution had a file size of about 1.6–1.9 MB, medium resolution had a file size of 3–3.4 MB, and high resolution had a file size of 7–7.8 MB. In digital images, the number of pixels is proportional to the file size, due to the increased information stored digitally (Ahmad, 2019). Furthermore, the photos were analyzed in a dark room using a smart TV screen from a distance of 2.7 m. The medium used to display digital photos also affects the quality of the photos (Ahmad, 2019). The number of pixels on the display determines the original size of the image, but a larger number of pixels can confer an advantage when the image is enlarged or cropped (Ahmad, 2009, 2019). In this study, the photos were displayed at actual size; thus, the high-resolution photos appeared larger than the medium- and low-resolution ones. This allows certain details to be captured more clearly at higher resolutions.

A statistical analysis indicated statistically insignificant differences ($p > 0.05$) in the restoration evaluation between the clinical analysis and the analysis of images with low, medium, and high resolutions. Furthermore, a medium interrater reliability (0.467) was observed when comparing the evaluation results between investigators. This implies that digital photos can represent the clinical conditions of GIC restorations, regardless of the image resolutions.

The low-resolution digital photos in this study were 3472 × 2320

Table 2
Evaluation of quality of GIC restorations (FDI criteria).

FDI Criteria	Clinical	Low Resolution	Moderate Resolution	High Resolution
Surface Luster				
Maintained	30 (75 %)	31 (77.5 %)	29 (72.5 %)	27 (67.5 %)
Improved	6 (15 %)	6 (15 %)	9 (22.5 %)	8 (20 %)
Replaced	4 (10 %)	3 (7.5 %)	2 (5 %)	5 (12.5 %)
Staining				
Maintained	37 (92.5 %)	32 (80 %)	34 (85 %)	27 (67.5 %)
Improved	2 (5 %)	6 (15 %)	4 (10 %)	10 (25 %)
Replaced	1 (2.5 %)	2 (5 %)	2 (5 %)	3 (7.5 %)
Color Match and Translucency				
Maintained	34 (85 %)	29 (72.5 %)	30 (75 %)	28 (70 %)
Improved	4 (10 %)	9 (22.5 %)	8 (20 %)	8 (20 %)
Replaced	2 (5 %)	2 (5 %)	2 (5 %)	4 (10 %)
Anatomical Form and Esthetics				
Maintained	23 (57.5 %)	25 (62.5 %)	25 (62.5 %)	21 (52.5 %)
Improved	13 (32.5 %)	11 (27.5 %)	10 (25 %)	12 (30 %)
Replaced	4 (10 %)	4 (10 %)	5 (12.5 %)	7 (17.5 %)
Material Fracture and Retention				
Maintained	33 (82.5 %)	33 (82.5 %)	29 (72.5 %)	32 (80 %)
Improved	4 (10 %)	3 (7.5 %)	7 (17.5 %)	3 (7.5 %)
Replaced	3 (7.5 %)	4 (10 %)	4 (10 %)	5 (12.5 %)
Marginal Adaptation				
Maintained	33 (82.5 %)	28 (70 %)	24 (60 %)	23 (57.5 %)
Improved	4 (10 %)	5 (12.5 %)	11 (27.5 %)	9 (22.5 %)
Replaced	3 (7.5 %)	7 (17.5 %)	5 (12.5 %)	8 (20 %)
Occlusal Contour and Wear				
Maintained	28 (70 %)	27 (67.5 %)	26 (65 %)	24 (60 %)
Improved	10 (25 %)	10 (25 %)	9 (22.5 %)	9 (22.5 %)
Replaced	2 (5 %)	3 (7.5 %)	5 (12.5 %)	7 (17.5 %)
Caries Recurrence				
Maintained	34 (85 %)	31 (77.5 %)	34 (85 %)	31 (77.5 %)
Improved	2 (5 %)	3 (7.5 %)	0 (0 %)	2 (5 %)
Replaced	4 (10 %)	6 (15 %)	6 (15 %)	7 (17.5 %)
Total	40 (100 %)	40 (100 %)	40 (100 %)	40 (100 %)

pixels (8 megapixels), representing digital photos commonly found on digital media, such as email, messenger apps, or photo editing tools. These low-resolution images were shown to have the closest counts to the clinical conclusions in five of the eight criteria, implying that these images adequately captured the details of the restoration to be assessed in this study. These criteria include surface luster, anatomical shape and aesthetics, fracture material and retention, marginal adaptation, and occlusal contour and wear. It can therefore be concluded that all five criteria are effective for assessments using low-resolution digital photographs.

Medium-resolution digital photos, which were 4800 × 3200 pixels (15.3 MP) in this study, represent digital photos from electronic devices such as smartphones and compact digital cameras. In medium-resolution photos, three of the eight criteria correspond to the number closest to the number of clinical conclusions. These criteria are staining, color match and translucency, and caries recurrence.

Furthermore, high-resolution digital photos have the same resolution that DSLR cameras generally have. In these high-resolution photos, the visible details are clearer, and the sharpness is higher. Across all FDI assessment criteria, the number of restorations to be replaced in the high-resolution image evaluation was higher than in the clinical assessment. High-resolution images appear larger (zoomed) when displayed at their actual size. Zooming increases the number of restorations rated as unsatisfactory compared to the clinical evaluation results (Ahmad, 2019). Therefore, high-resolution photos may lead to over-treatment decisions for dental treatment needs, such as when evaluating restorations (Moncada et al., 2014). One common misconception regarding photography involves equating the number of pixels with image quality, even though the pixels determine the size of the original image as opposed to the image quality (Ahmad, 2019; Bengel, 2006). However, the large number of pixels may be significant if the image is enlarged or cropped (Ahmad, 2019).

This study yielded a wide range of results regarding the surface luster and color match criteria. Restorative materials may have varying opacity, as they reflect and absorb different amounts of light. Moreover, the depth of the cavities and the thickness of the material also affect the radiopacity of the restorative material. Clinically, this may be evident in the appearance of clinical color and translucency, as well as in the surface luster of the GIC restorations. Hence, the difference in the surface luster in this study could be due to the different thickness and depth of the cavities in the study sample. The standardization of this criterion should therefore be ensured in future studies.

Digital photography can be a useful tool for assessing restoration status. One of the advantages of evaluating restorations with photography is that it can be done over a longer period in stable conditions. This may not always be possible during clinical examinations, especially in uncooperative children (Moncada et al., 2014). The statistically significant difference between clinical and digital photography means that digital photography can represent the clinical appearance of GIC restorations in primary teeth. Based on the percentage of the number of GIC restoration evaluations, the results from the low- and medium-resolution photos were similar to the clinical group. This finding implies that low- and medium-resolution digital images can represent clinical conditions as seen by the human eye. The resolution of the human eye varies from 324 megapixels to 576 megapixels (Ahmad, 2019). However, the human visual system is limited to about 15 megapixels per eye (Deering, 1998). This resolution is similar to the resolution of digital photos at medium resolution.

Despite a lack of statistical differences, some differences were observed between each group. It is worth noting that photographs are two-dimensional images representing three-dimensional objects; therefore, digital photography should only be used as an indirect evaluation method or complementary form of examination (Moncada et al., 2014). In terms of its utilization in dental practices, this study recommends using digital photographs between low and medium resolution (8–15.3 MP) as a medium for evaluating GIC restorations in primary teeth. Dentists can use electronic devices such as smartphones or pocket cameras to take photos of patients, which is certainly easier and more practical while achieving satisfactory quality in evaluating restorations.

5. Conclusions

Digital photography can be a useful tool for assessing the GIC restoration status of primary teeth. A statistical analysis showed that there were no statistically significant differences in the FDI evaluation scores between the clinical evaluations and low-, medium-, and high-resolution digital photographs. Therefore, digital photos may represent the clinical states of GIC restorations. Regarding further applications in dental practices, this study recommends using digital photographs between low and medium resolution (8–15.3 MP) as a medium for evaluating GIC restorations in primary teeth. Low- and medium-resolution digital images may capture the clinical conditions as seen by the human eye. A higher resolution may result in over-treatment because a large image size may make details more visible.

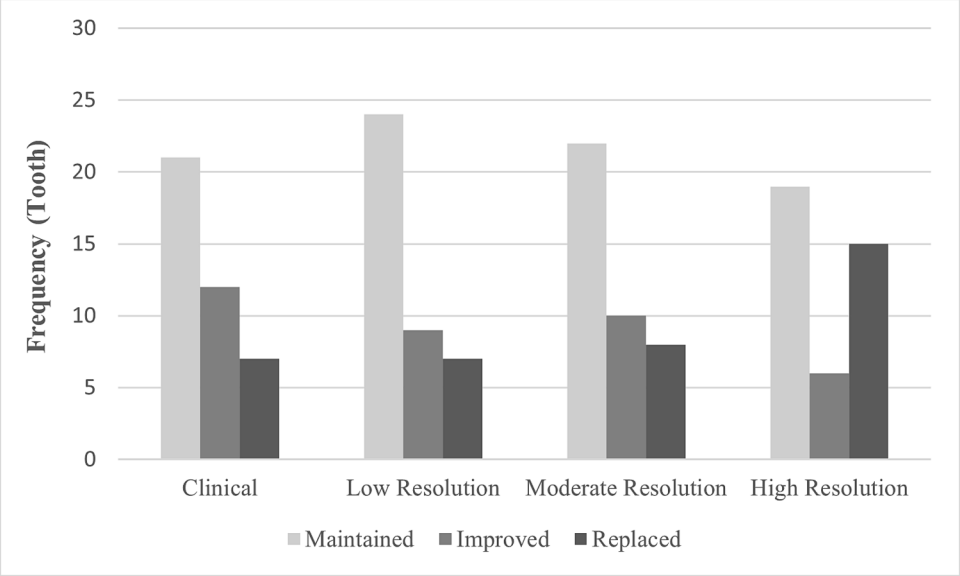

Fig. 4. Maintained, improved, and replaced restorations based on assessment.

CRediT authorship contribution statement

Irdra Lastyautari: Conceptualization, Writing, Formal analysis. **Mochamad Fahlevi Rizal:** Methodology, Supervision. **Eva Fauziah:** Methodology, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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