Galician medical journal 2024
Vol. 31, Issue 1, e-GMJ2024-A06
DOI: 10.21802/e-GMJ2024-A06

Research Article | Dentistry

Analysis of Artifacts and Errors on Intraoral Phosphor Plate Radiographs: A Retrospective Study

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Abstract

Introduction. The advantages of phosphor plates (PPs), including their flexibility, thinness, and wireless connectivity, have contributed to their widespread use in dentistry alongside the advancement of digital radiography techniques. Continuous use of PPs and certain errors may lead to artifacts on the images. This retrospective study aimed to determine the frequency and types of intraoral PP artifacts.

Methods. This study was conducted on 814 intraoral PP radiographs, including periapical and bitewing images. The errors and artifacts were classified into 4 main categories: technical errors, plate-related artifacts, scanner-induced artifacts, and ambient light artifacts.

Results. A total of 656 periapical and 158 bitewing radiographs were examined. The most observed artifacts on the radiographs were plate-related artifacts, followed by technical errors (n=542, n=461, respectively). Within the category of plate-related artifacts, the most common artifacts were cracks or scratches (n=418, 77.1%), while within the category of technical errors, these were cone-cut errors (n=188, 40.7%). Parallel or zigzag radiopaque lines were the most common scanner-induced artifacts (n=313, 98.7%) and fading was the most common ambient light artefact (n=93, 49.2%). On more than half of the PPs, more than one artifact group was observed.

Conclusions. Cone-cut, cracks/scratches, parallel zigzag radiopaque lines, and fading were common PP artifacts and errors in this study. The analysis revealed that over half of the PPs exhibited appearance of more than one artifact group. The high frequency of artifacts poses a risk of incorrect and incomplete diagnoses in radiographs, emphasizing the crucial importance of understanding the causes and developing effective prevention strategies for artifacts to enhance the reliability of diagnostic imaging and ensure the accuracy of patient assessments.

Keywords
Artifacts; Bitewing; Dentistry; Digital Dental Radiography

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Introduction

Digital radiography has begun to replace conventional film radiography in the field of dentistry worldwide. Digital imaging offers numerous advantages over conventional radiography such as real-time imaging, eliminating the need for conventional radiographs, image processing, easier archiving and transmission, improved contrast resolution, and reduced radiation exposure for both patients and operators [1, 2]. In conventional X-rays, the image is formed directly on the film. This imaging system uses chemical solutions, more time and effort, and higher radiation doses. The signal detected by sensors is digitized, and the image comprises these obtained values in the digital imaging systems [2, 3].

Digital radiographic images are obtained directly, using a charge-coupled device (CCD) or complementary metal-oxide semiconductor (CMOS), or indirectly, using phosphor plates (PPs), on a monitor. Compared to CCD or CMOS sensors, PPs are believed to be more acceptable to patients due to features of cordless, flexible, and slim design resembling conventional films [4–6]. Despite these advantages, PPs, which can be used repeatedly, are vulnerable to scratching and bending during handling. The need

Publication history:
Received: December 4, 2023
Revisions Requested: January 6, 2024
Revision Received: January 18, 2024
Accepted: February 9, 2024
Published Online: March 1, 2024

for a scanner to obtain images on PPs can extend the imaging process time. Additionally, depending on the ambient light and scanner, artifacts may occur on the plates, which may lead to loss of image analysis. Even with careful use, a loss in image quality has been reported when using PPs [6–8].

Proper radiographic technique and obtaining optimal radiographs are crucial in dental clinical practice. The accuracy of information provided by a well-exposed and developed radiograph can impact all phases of diagnosing and planning treatment for dental structures. A good-quality radiograph can be defined as one that exhibits proper contrast and brightness, adequately captures the area of interest, and is appropriately developed. Artifacts and errors are situations that can lead to incorrect and incomplete diagnosis on radiographs [3, 9]. Under the circumstances, dentists, students, and X-ray technicians need to be aware of the types of artifacts, understand their causes, recognize their impact on the diagnostic ability of the images, and know how to prevent these artifacts [10, 11].

Therefore, this study **aimed** to analyze and determine the distribution of PP errors and artifacts. Specifically, the causes of PP artifacts and errors were thoroughly discussed within the framework of artifact distribution analysis.

Materials and Methods

Study Design

This retrospective study was conducted on periapical and bitewing PP images obtained between January 2020 and December 2020 at the Oral and Maxillofacial Radiology Clinic of the Kutahya Health Sciences University, Faculty of Dentistry, Kutahya, Turkey.

Study Sample

For the study, 2,154 PPs taken between January 2020 and December 2020 were examined. A total of 814 PPs with artifacts and errors were included in the study. Radiographic intraoral areas were examined in 3 groups: maxillary, mandibular, and bitewing. Artifacts and errors were evaluated under 4 headings, based on a study by Çalışkan & Sumer [10]. These were categorized as technical errors, plate-related artifacts, scanner-induced artifacts, and ambient light artifacts.

Technical errors – angulation errors (vertical-horizontal), incorrect placement of the plate, underexposed-overexposed, elongation/shortening, distortion, motion artifact, plate bending, cone-cut, reversed image (Fig. 1).

Plate-related artifacts – cracks/scratches, bite marks, peeling of the plate, plate contamination (dust, glove powder, fingerprint), crescent-shaped bending (Fig. 2).

Scanner-induced artifacts – parallel zigzag radiopaque

Figure 1. Technical errors: A) angulation errors (vertical); B) incorrect placement of the plate; C) underexposed image; D) elongation; E) distortion; F) motion artifact; G) cone-cut; H) reversed image.

Figure 2. Plate-related artifacts: A) crack; B) scratches; C) peeling of the plate; D) plate contamination; F) crescent-shaped bending.

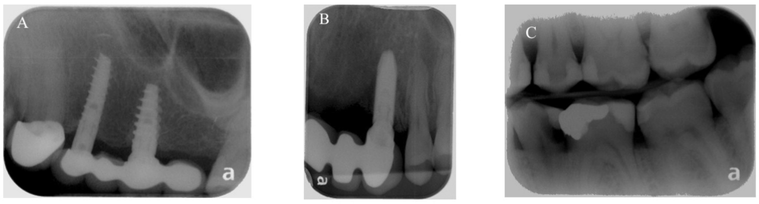

Figure 3. Scanner-induced artifacts: A) parallel zigzag radiopaque lines; B) radiolucent lines; C) peeling of the conveyor belt.

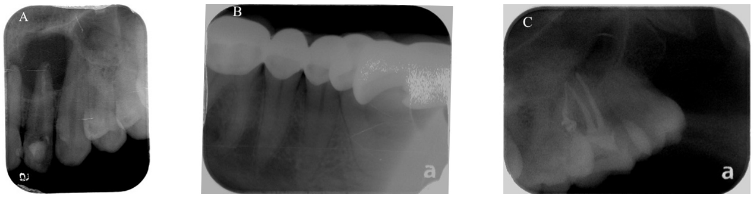

Figure 4. Ambient light artifacts: A) fading; B) shinning; C) noisy image.

lines, erasure artifact, radiolucent lines, peeling of the conveyor belt (Fig. 3).

Ambient light artifacts – fading, shinning, non-uniform image density, and noisy image (Fig. 4).

Image Evaluation

In the study, all radiographs were obtained by using the bisecting angle technique with 8 mA, 60-70 kVp on a NewTom RxDc periapical device (Newtom CEFLA Imola, Italy). The images were scanned on a Scan X Duo (Air Techniques IDX, NY USA) intraoral PP scanner. An oral and maxillofacial radiologist (M.Y.) with 9 years of experience examined artifacts on a 23.8-inch LEN-V3V5-C-A computer screen (Lenovo, Pekin, China) with a resolution of 1920x1080, in the semi-dark lighting room.

Statistical Analysis

Statistical analyses were conducted using IBM SPSS Statistics v. 23 (IBM Corp., New York, NY; formerly SPSS Inc., Chicago, IL, USA), and the frequency and percentage of artifacts were determined. The Pearson chi-square test was used to test the relationship between categorical variables, depending on the sample size. A significance level of $p < 0.05$ was accepted.

Results

A total of 814 PPs out of 2,154 PPs (37.8%), including 656 periapical and 158 bitewing radiographs, were included in the study. The maxillary right molar and right bitewing radiographs were the most frequently evaluated. The most observed artifacts were plate-related artifacts, followed by technical errors (n=542 and n=461, respectively). Within the category of plate-realted errors, cracks and scratches on the plates were found as the most frequently detected errors (n=418, 77.1%). Within the category of technical errors, the two most identified errors were cone-cut and angulation errors (n=188 and n=125, 40.7% and 27.1%, respectively) (Table 1). Parallel zigzag radiopaque lines were the most commonly observed scanner-induced artifacts (n=313, 98.7%), while fading was the most frequently identified ambient light error (n=93, 49.2%). No plate folding or erasure artifacts were found on the evaluated radiographs. The most frequently identified technical error on the mandibular and bitewing radiographs was cone-cut, and on the maxillary radiograph, it was angulation error ($p < 0.001$) (Table 2). The most prevalent plate-related artifacts on the periapical and bitewing radiographs were cracks and scratches on the plate ($p < 0.001$) (Table 3). The relationship between PP image areas and scanner-induced and ambient light artifacts was summarized in

Table 1. Distribution and percentage values of technical errors and plate-related artifacts.

	Type	n	%
Technical errors	Angulation error	125	27.1
	Incorrect placement of the plate	59	12.8
	Underexposed/overexposed	44	9.5
	Elongation/shortening	9	2.0
	Distortion	13	2.8
	Motion artifact	5	1.1
	Bending of plate	0	0
	Cone-cut	188	40.7
	Reversed image	18	4.0
	Total	461	100
Plate-related artifacts	Cracks/scratches	418	77.1
	Bite marks	26	4.8
	Peeling of the plate	69	12.7
	Contamination	22	4.1
	Crescent-shaped bending	7	1.3
	Total	542	100
Scanner-induced artifacts	Parallel zigzag radiopaque lines	313	98.7
	Erasure artifact	0	0
	Radiolucent lines	1	0.3
	Peeling of the conveyor belt	3	1.0
	Total	317	100
Ambient light artifacts	Fading	93	49.2
	Shinning	68	36.0
	Non-uniform image density	14	7.4
	Noisy image	14	7.4
	Total	189	100

Table 2. Frequency distribution relationship between phosphor plate image areas and technical errors.

	Maxilla	Mandibula	Bitewing	Total	p
Angulation error	69	46	10	125	
Incorrect placement of the plate	14	31	14	59	
Underexposed/overexposed	33	6	5	44	
Elongation/shortening	7	2	0	9	
Distortion	3	10	0	13	<0.001*
Motion artifact	1	4	0	5	
Bending of plate	0	0	0	0	
Cone-cut	50	87	51	188	
Reversed image	4	14	0	18	
None	213	128	87	428	

Notes: multiple different artifacts may coexist in a single PP. *-Chi-square test.

Table 3. Frequency distribution relationship between phosphor plate image areas and plate artifacts.

	Maxilla	Mandibula	Bitewing	Total	p
Cracks/scratches	177	122	119	418	
Bite marks	10	5	11	26	
Peeling of the plate	31	32	6	69	<0.001*
Contamination	11	9	2	22	
Crescent-shaped bending	3	3	1	7	
None	162	131	30	323	

Notes: multiple different artifacts may coexist in a single PP. *-Chi-square test.

Table 4. Frequency distribution relationship between phosphor plate image areas and scanner-induced artifacts.

	Maxilla	Mandibula	Bitewing	Total	p
Parallel zigzag radiopaque lines	143	112	58	313	
Erasure artifact	0	0	0	0	
Radiolucent lines	1	0	0	1	0.80
Peeling of the conveyor belt	2	0	1	3	
None	231	170	98	499	

Notes: multiple different artifacts may coexist in a single PP. *-Chi-square test.

Table 5. Frequency distribution relationship between phosphor plate image areas and ambient light artifacts.

	Maxilla	Mandibula	Bitewing	Total	p
Fading	42	36	15	93	
Shinning	20	31	17	68	
Non-uniform image density	7	6	1	14	0.12
Noisy	9	3	2	14	
None	298	206	122	626	

Notes: multiple different artifacts may coexist in a single PP. *-Chi-square test.

Tables 4 and 5. On more than half of the PPs (52.95%), more than one artifact group was observed (Fig. 5). Plate-related artifacts were most observed as single PP artifact (Table 6). Similarly, plate-related artifacts were most found in conjunction with technical errors or scanner-induced artifacts. However, it is important to highlight that those technical errors exhibited the highest diversity in associations with other types of artifacts, leading to a range of combinations. A total of 14 PPs showed artifacts from all four groups (Table 6, Fig. 6).

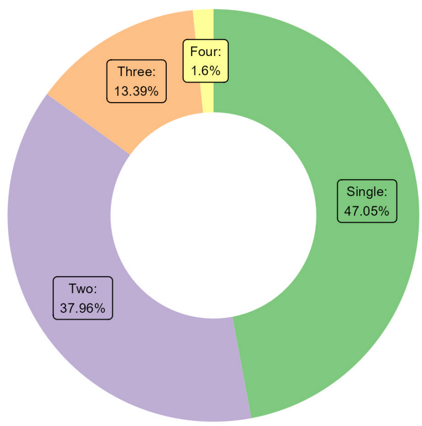

Figure 5. Distribution of the number of detected artifacts on the phosphor plates.

Table 6. Distribution of artifact groups and combination of their appearance on the phosphor plates.

Single Artifact		Two Artifacts		Three Artifacts		Four Artifacts	
Type	n	Type	n	Type	n	Type	n
Technical errors	103	Technical errors & scanner-iduced artifacts	62	Technical errors & plate-related & scanner-induced artifacts	56	Technical errors & plate-related & scanner-induced & ambient light artifacts	14
Plate-related artifacts	169	Technical errors & plate-related artifacts	134	Technical errors & scanner-induced & Ambient light artifacts	12		
Scanner-induced artifacts	76	Technical errors & ambient light artifacts	42	Technical errors & plate-related & ambient light artifacts	22		
Ambient light artifacts	35	Plate-related & scanner-induced artifacts	86	Scanner induced & plate related & ambient light artifacts	17		
		Scanner-induced & ambient light artifacts	16				
		Plate-related & ambient light artifacts	37				

Note: different instances of the same artifact group coexisting on a single radiograph were treated as a single artifact during classification.

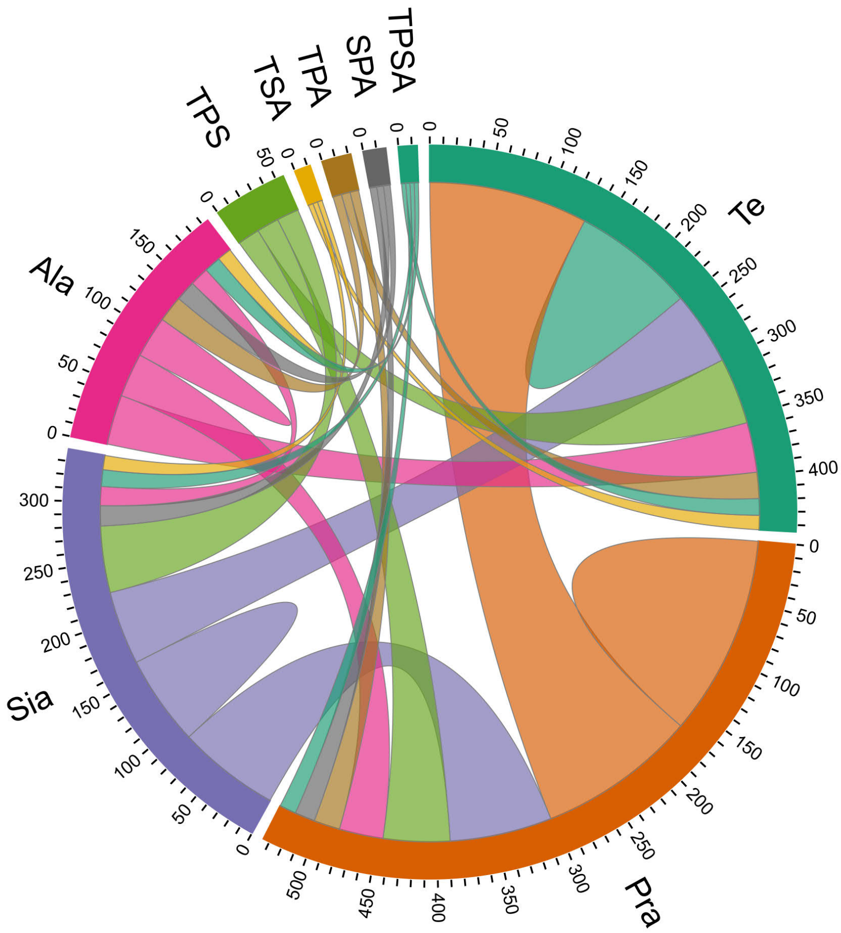

Figure 6. An overview of artifact occurrence and their conjunctions on the phosphor plates.
Abbreviations: Te – technical errors; Pra – plate-related artifacts; Sia – scanner-induced artifacts; Ala - ambient light artifacts; TPS – technical errors & plate-related & ambient light artifacts; TSA – technical errors & plate-related & scanner-induced artifacts; TPA – technical errors & scanner-induced & ambient light artifacts; SPA – scanner-induced & plate-related & ambient light artifacts; TPSA – technical errors & plate-related & scanner-induced & ambient light artifacts.

Discussion

Radiographs are one of the fundamental dental imaging methods playing a crucial role in assessing the teeth and jaws. The radiographic examination has become an indispensable component of diagnostic imaging as it provides valuable information for evaluating the jaws, teeth, and pathologies, and planning dental treatment. One of the frequently used techniques in dentistry is digital periapical radiography [3, 11].

An artifact is an undesirable image observed on a radiograph due to certain errors that have no relevance to the anatomical region being examined. Artifacts can mislead the dentist in evaluating the radiographs. It becomes inevitable for dentists, patients, personnel, and the environment to be exposed to unnecessary radiation where radiographs need to be retaken due to artifacts. Additionally, retaken radiographs lead to a waste of time and money [2, 9, 10].

In radiology, there is no widely accepted standard classification in the literature. However, various researchers have proposed different types of classifications. Chiu *et al.* [12] divided artifacts into three groups: operator errors, scanning errors, and PP defects. Deniz & Kaya [13] classified artifacts into six groups based on artifacts causes: operator errors, superimposition, ambient light errors, plate errors (physical deformations and contamination), scanner, and software errors. Hasan *et al.* [9] divided artifacts into 2 groups: technical and image processing errors. Çalışkan & Sumer [10] examined artifacts under 4 headings: operator and patient-related errors, ambient light-related errors, plate-related errors, and scanned-induced artifacts. In this study, PP artifacts were categorized into 4 groups based on a study by Çalışkan & Sumer [10] due to its ease of use and comprehensibility: operator and patient-related errors were classified as technical errors; artifacts from the scanner were categorized as scanned-induced artifacts; physical deformations and contamination errors on the plates were classified as plate artifacts; artifacts arising from ambient light were included in the ambient light artifact group.

During imaging, improper vertical and horizontal angulation can lead to image distortion, resulting in the teeth appearing abnormally longer or shorter than their actual size. Due to incorrect positioning of the periapical device, the entire area of the PP does not receive radiation. Cone-cut refers to the radiopaque areas in regions where no X-ray exposure was intended on the periapical image [6]. Numerous studies on artifacts [12, 14, 15] identified cone-cut as the most common artifact of operator or technical errors. In this study, among technical errors, the most common artifact was cone-cut (40.7%), followed by angulation errors (27.1%) and incorrect placement of the plate (12.8%).

Reusing the plates inevitably damages them. Rough handling, excessive bending, patient biting, and forcefully inserting them into the scanner can damage the PPs. These damages can result in diagnostic loss or misdiagnosis, manifesting as cracks, white lines, or scratches that resemble root canal fillings on the image [5, 10]. Additionally, friction and continuous use can lead the protective and light-stimulating phosphor layer to peel off at the edges of the plates. The appearance of contamination, such as glove powder or fingerprints, on the plate surface may indicate a lack of proper cleanliness during plate usage [5, 7, 9]. According to Çalışkan & Sumer [10], the most common plate artifact was peeling. They observed peeling on more than half of the plates (53.4%). Elkhateeb *et al.* [14] mentioned that bite marks were the most common plate artifacts (40.3%). In this study, plate-related artifacts were the second most common group of artifacts, and cracks and scratches were the most frequent plate artifacts (n=418, 48.3%) (Fig. 2A, B). The reason for different results in the studies may be attributed to discrepancies in artifact classification, variations in phosphor plate counts across studies, and variances in the experience levels of individuals utilizing the PPs (interns, experienced radiology technicians, etc.).

Short-term variations in laser scanning intensity can cause horizontal white lines to appear on the image. These lines can appear in different regions of scanned plate. Additionally, due to dust particles and dirt along the path of the laser light in the scanner, parallel radiopaque lines (Fig. 3A) can be observed in the scanning direction. These lines consistently appear in the same location on every scanned image. Dust particles and dirt that become trapped in the scanner during the scanning process can produce straight radiopaque lines on the image and the slight movement of these particles can result in the formation of zigzag-shaped radiopaque lines (Fig. 3A) on the image [6, 10]. The radiolucent line (Fig. 3B) observed on the scanned PP has been suggested to be a consequence of electromagnetic interference artifacts. These artifacts can arise from any factors that disrupt, interrupt, decrease, or limit the performance of the scanner. To prevent this artifact, it is necessary to implement appropriate electromagnetic shielding, use the correct voltage source, ensure an uninterrupted power supply, and regularly maintain the scanner [10, 13]. In a study conducted at two different institutes, Tashiro *et al.* [8] determined a browser error rate of 52% in one institute. Additionally, Çalışkan & Sumer [10] stated that approximately 53% of PP artifacts were induced by the scanner. The most frequently detected scanner-induced PP artifacts in their study were straight lines [9]. Furthermore, Elkhateeb *et al.* [14] stated that delayed non-uniform density or bright images were the most common scanning errors (39.9%). Chiu *et al.* [12] detected scanning machine errors in 4.5% of PPs, with horizontal white lines being predominant. In this study, parallel zigzag radiopaque lines were the most common scanner-induced artifacts (98.7%). The variation in devices and artifact classifications across studies may have contributed to the differences in results. It should also be kept in mind that scanner-induced artifacts can generally be resolved by rescanning, whereas most other artifacts required retaking the radiograph.

PP artifacts may occur due to exposure to ambient light. Due to prolonged exposure to ambient light when the plate is unsheathed and awaiting scanning, fading may occur along the edges of the scanned plate. Additionally, shining may appear in the center of radiopaque structures or at the edges of the scanned plate due to a complete loss of the acquired signal in those areas due to excessive spontaneous releasing. Partial exposure of the plate to ambient light typically occurs when plates overlap while unsheathed, resulting in fading in the exposed area. If ambient light has partially affected the plate, a decrease in image density appears in the areas exposed to ambient light. The area protected from ambient light appears with normal density. In this scenario, the image may depict two or more radiographic areas with differing densities for the same structures [6, 10, 15]. According to Çalışkan & Sumer [10], the most common ambient light artifact was fading, accounting for approximately 44.1% of plates. Elkhateeb *et al.* [14] reported delayed scanning artifacts at an approximate rate of 40%. In this study, fading artifacts were detected on half of the plates, followed by shining artifacts (49.3% and 35.9%, respectively). To prevent the formation of artifacts, PPs should be scanned within a maximum of 10 min after exposure in a semi dark room. If scanning cannot be performed immediately, the plates should be stored at room temperature in a light-free environment [16]. Research indicates that the diagnostic quality of the image decreases proportionally with increasing light intensity and exposure time [17].

Limitations

The study has several limitations, including its single-center design and the use of only PPs. Additionally, the influence of healthcare workers' background experience was not accounted for. Future studies with a greater number of digital intraoral receptors will provide further insights into the topic and enhance the existing literature.

Conclusions

In this study, the distribution of PP errors and artifacts were analyzed and determined. Cone-cut, cracks/scratches, parallel zigzag radiopaque lines, and fading were common PP artifacts and errors in this study. On more than half of PPs, more than one artifact group was observed. However, while plate-related artifacts were most prevalent in terms of frequency, technical errors exhibited greater diversity in their association with other artifacts. The relatively high occurrence of artifacts and errors (37.8%) significantly increases the risk of misdiagnoses and the need for image retakes, underscoring the importance of understanding their causes to prevent unnecessary X-ray exposures and minimize excessive radiation doses for patients, practitioners, and the environment.

Ethical Statement & Informed Consent

The study received approval from the University Non-Interventional Ethics Committee (Decision No. 2023/11-19). Informed Consent: not applicable.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of Interest

The author declares that no conflicts exist.

Financial Disclosure

This research did not receive any specific grant from funding agencies in the public, commercial, or non-for-profit sectors.

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