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IMPROVING BITEWING RADIOGRAPHY: EVALUATING THE EFFECT OF A DENTAL X-RAY POSITIONER ON IMAGE QUALITY IN DENTAL EXAMINATIONS

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Abstract

Bitewing radiography is a valuable tool in detecting and monitoring dental decay and other oral health problems and is typically performed as part of a routine dental examination. It has certain limitations that should be considered. Some of these limitations may cause discomfort or pain to the patient if not positioned correctly. Some patients may find biting down on the film holder difficult or have a strong gag reflex, making the procedure uncomfortable or even impossible. Bitewing radiography can be costly, especially if it needs to be performed regularly, which may limit access to this diagnostic tool for some patients. This study aimed to evaluate the effect of a dental X-ray positioner with a silicone layer on the quality of radiographic images in posterior bitewing dental examinations. Using this positioner was expected to improve the precision of radiographic interpretation and subsequent patient treatment. The study used a multivariate general linear model to analyze the data obtained from radiographic images using the X-ray positioner with the silicone layer and the conventional X-ray positioner. The results showed no significant difference in image quality between the two positioners, indicating that adding the silicone layer did not significantly improve image quality. However, using any X-ray positioner is still beneficial in ensuring accurate radiographic interpretation and subsequent patient treatment.

Keywords: *X-ray Dental Positioner; Silicon Coating; Intraoral Bitewing; Radiographic Image Quality*

1. Introduction

Premolar teeth, which belong to the posterior group of teeth in the back of the oral cavity (von Arx & Lozanoff, 2016), can experience pain due to various conditions or diseases. Consequently, in specific circumstances, it becomes necessary to provide treatment for these affected premolar teeth. The first premolar tooth is the tooth that most frequently requires treatment. The first premolars are the teeth that are most commonly performed (de Sousa Dardengo, Fernandes, & Júnior, 2016). Most of the time, a dental radiography test is needed to help with treatment.

A dental radiography examination is a medical procedure utilized to diagnose conditions such as trauma, inflammation, abscess, fractures, or tooth injuries in a specific area of the tooth, with the assistance of X-ray (Whitley et al., 2015). Two commonly employed techniques for film placement in dental radiography examinations are employed:

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extra-oral radiography, which involves positioning the film outside the oral cavity, and intra-oral radiography, which entails placing the film within the oral cavity (Iannucci & Howerton, 2016).

Intra-oral radiography examination is a diagnostic procedure used to examine teeth and adjacent structures within the oral cavity, which is a fundamental examination in dental radiography. It requires a receptor tool such as film, Imaging Plate (IP), or a detector. The receptor used in intra-oral radiography examination is placed inside the oral cavity to obtain images of teeth and supporting tissue structures. In intra-oral radiography, a dental examination is performed separately for different parts, including incisors, canines, premolars, or molars (Whaites & Nicholas Drage, 2021). There are several types of intra-oral radiography examination, such as occlusal, periapical, and bitewing.

Bitewing radiography is an examination technique that requires the patient to bite on a small wing-like part attached to the intra-oral film. Currently, bitewing examination has been using more modern designs by using a holder that has replaced the need for wing-like details (now called tabs). This technique also uses digital image receptors (solid-state or phosphor plates) that can be used as a substitute for film, but the terminology and clinical indications remain the same. This examination is designed to show the crowns of premolar and molar teeth on one side of the jaw (Whaites & Nicholas Drage, 2021).

The advantage of the bitewing examination is that it is relatively more uncomplicated and straightforward. The image receptor can be firmly positioned and cannot be displaced by the tongue. The aiming device determines the X-ray tube head's position, which helps the operator ensure that the X-rays are always at the correct angle to the image receptor. This technique can also avoid cut-off or cone cutting on the anterior part of the image receptor. Additionally, the holder can be sterilized or used as a disposable holder. However, the bitewing examination has several drawbacks (Whaites & Nicholas Drage, 2021).

The drawbacks of bitewing examination are that the holder's position in the mouth depends on the operator performing the analysis, so the image cannot be reproduced 100%, making it not ideal for monitoring the progression of caries. The most likely drawback that directly affects the patient is the holder used. Generally, the holder used is unsuitable for pediatric patients, and positioning the film and image receptor holder may be uncomfortable, especially when using solid-state digital sensors.

In order to address the discomfort associated with the existing drawbacks, the author implemented innovative changes to the holder utilized in the intra-oral bitewing examination. The holder has been modified to incorporate a synthetic rubber or silicone coating, which comes into direct contact with the patient. Silicone, known for its non-toxicity to the human body and the environment, is generally well-tolerated and deemed safe for medical applications (Mojsiewicz-Pienkowska, Jamrógiewicz, Szymkowska, & Krenczkowska, 2016). By incorporating a soft-textured silicone material on the holder's surface, the aim is to enhance patient comfort during its use.

2. Method

This study employed a quasi-experimental quantitative approach, specifically using a post-test-only research design. Data collection took place at the Dental and Oral Hospital of Muhammadiyah University Semarang between June and October 2021.

The research design used in this study is a post-test-only group design. The effectiveness of the dental x-ray positioner innovation was evaluated by conducting radiographic imaging on cadaveric skulls. The focus of this investigation was on the bitewing radiography examination holder, which was designed to include a silicone rubber protector on the image receptor support and bite block. The subsequent section illustrates the design of the Dental X-ray Holder utilized in this study:

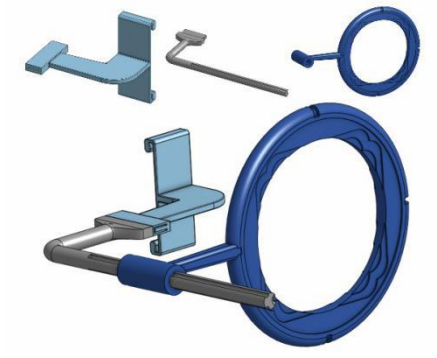

Figure 1. *Dental X-ray Holder*

This study was conducted by exposing cadaveric skull teeth to X-ray using a dental unit with the assistance of a dental holder. The data collection and processing steps include

designing the dental holder and testing its efficiency and radiographic image results. The research instrument used was a questionnaire. The data obtained from the Likert scale responses, which ranged from 1 to 4 and included the criteria of 1. Strongly Disagree, 2. Disagree, 3. Agree, and 4. Strongly Agree, were analyzed using the General Linear Model.

3. Result and Discussion

The development of the holder's three-dimensional design in this study involved multiple steps. These steps encompassed initial two and three-dimensional sketches, specification of size and thickness, analysis of the three-dimensional geometry, and virtual simulation of each component in three dimensions. The majority of the three-dimensional design work was conducted using the OnShape application. The final outcome of the innovation was a document or file in STEP (Standard for the Exchange of Product Data) and STL (Stereo-lithography) format.

Basic Sketches

This study's basic sketch of the dental holder for bitewing X-rays was done on paper media. Several existing models of dental bitewing holders were used as references or considerations to produce the basic sketch of the holder in this study, namely the Rinn FPS 3000 dental holder model.

Figure 2. *Reference design of dental holder model Rinn FPS 3000*

Spesification of Size and Thickness

The size and thickness of the holder are determined by adopting various sizes and thicknesses from the Rinn brand dental model holder. The resulting size is based on an approach that considers patient comfort and general applicability, aiming for the holder to be used for all types and shapes of adult oral cavities. A 1 mm silicone layer covers the portion that will come into direct contact with the patient's teeth, with a total bite thickness of 4 mm.

Analysis of the three-dimensional geometry

The three-dimensional shape employed is based on an assessment of both patient comfort and the quality of the produced radiographic images. To ensure patient comfort, the bite block of the dental holder is designed to have a silicone rubber coating on the portion that directly touches the patient's teeth.

Figure 3. *Design of the bite block on the bitewing holder, the red-colored part is the area covered with silicone material*

Virtual Simulation

Virtual assembly was performed on each previously designed part. This simulation was done using the OnShape three-dimensional graphic design application. The purpose of this was to check the dental holder design before printing. The most important aspect of this process was to ensure that the ring aligns the rays parallel or perpendicular to the IP, whether the ring is close or far from the IP.

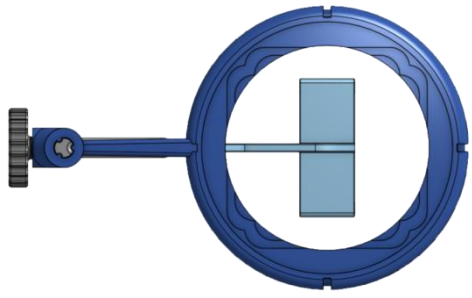

Figure 4. *Holder in front view*

Making a Holder

In this research, dental trays were produced utilizing a 3D printer and the corresponding printing procedure. The printing process

involved utilizing an STL file type document for printing. PLA (Polylactic Acid) material was selected for the printing, and specifically, food-grade PLA material was used, ensuring its safety for use in the oral cavity. Subsequently, the printing of the dental holder using PLA material was performed for two sets, followed by the assembly and refinement of the printed outcomes. Figure 5 displays the printed dental holder achieved through the 3D printing process.

Figure 5. *The result of printing the holder using a 3D printer*

Making Silicone Layer

Once the 3D printed dental holder is obtained, the subsequent step involves the application of a protective silicone layer on the bite block. The creation of this silicone layer involves various stages, including molding and casting. During the molding stage, a mold is created using food-grade silicone material, utilizing the PLA material that was designed and printed with a 3D printer. Figure 6 illustrates the design utilized for molding and casting the silicone layer.

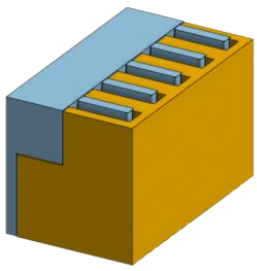

Figure 6. *Molding design*

Next, the molded outcome is used to cast the food-grade silicone material, filling it into the prepared mold. Subsequently, the printed result is refined and affixed to the previously fabricated dental holder. Figure 7 illustrates the effect of the silicone material print along with one set of dental holders, which have been enhanced with a silicone layer on their bite blocks.

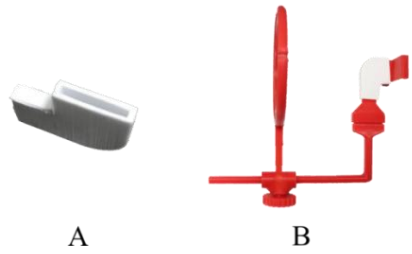

Figure 7. *(A) The result of silicon layer printing, (B) One set of bitewing dental holder equipped with a silicon layer on its bite block part*

Testing

The testing was conducted to determine the efficiency of the made holder when used, especially based on the radiographic images displayed. The testing was performed using a cadaver skull bone as shown in figure 8.

Figure 8. *The position of the holder testing against the cadaveric skull*

The experiment involved the exposure of the right first and second molar teeth of a skull cadaver. Each treatment group underwent 16 repeated exposures. The two treatment groups in the study were the innovation group and the control group.

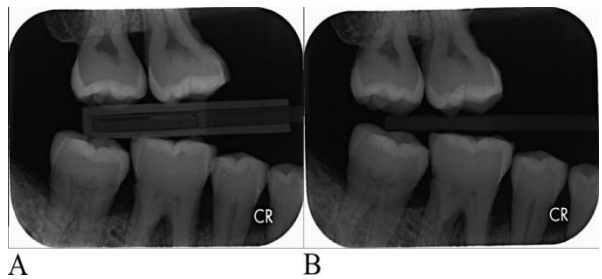

Figure 9. *The radiographic images produced using (A) the innovative dental holder and (B) the Rinn FPS 3000 dental holder commonly used in the Department of Radiology, Dental and Oral Hospital Muhammadiyah University of Semarang are shown in the following Figure.*

The innovation group consisted of images obtained using the newly created dental holder, while the control group consisted of images obtained using the Rinn FPS 3000 dental holder commonly used in the Department of Radiology, Dental and Oral Hospital Muhammadiyah University of Semarang. The resulting radiographic images from the exposures are depicted in Figure 9.

The radiographic images obtained were subjected to evaluation using a questionnaire method, involving both a radiographer and a dental radiology specialist. The radiographer's evaluation aimed to determine the efficiency of the newly developed dental holder, while the specialist's evaluation focused on assessing the quality of the resulting radiographic images. Additionally, an evaluation was conducted on the commonly used Rinn FPS 3000 dental holder at the Department of Radiology, Dental and Oral Hospital Muhammadiyah University of Semarang. The statistical description of the evaluation results using the questionnaire method is presented in Table 1.

Table 1. The statistical description of questionnaire data results.

Variable	Group	Mean	Deviation Standard	N
Work Efficiency	Inovation	3.2	0.08	16
	Control	2.8	0.08	16
	Total	3	0.2	32
Radiographic Image	Inovation	3.5	0.09	16
	Control	3.6	0.16	16
	Total	3.6	0.13	32

Table 1 presents the statistical analysis of the questionnaire data, comparing the work efficiency and radiographic image quality between the innovation and control groups. Each group consisted of 16 participants. The average work efficiency was found to be 3 ± 0.2, while the average radiographic image rating was 3.6 ± 0.13. In terms of work efficiency, the innovation group had an average rating of 3.2 ± 0.08, which was higher than the control group's average rating of 2.8 ± 0.08, indicating that the made dental holder is more efficient than the control group.

For the assessment of radiographic image quality, the average ratings in the innovation and control groups were 3.5 ± 0.09 and 3.6 ± 0.16, respectively. The average rating in the innovation group was slightly lower than that in the control group. Further testing is required to determine the exact influence and contribution of the made dental holder on work efficiency and radiographic image quality.

To analyze the data and determine the percentage of influence and contribution, a Multivariate General Linear Model test was conducted. The results of this test on the questionnaire data are presented in Table 2.

Table 2. The result of Multivariate General Linear Model Test on Work Efficiency.

Testing	B	Std. Error	Sig.	95% CI	Partial Eta Squared
Dental Holder Innovation Control Group (Rinn FPS 3000)	0.375	0.30	0	0.314 – 0.436	84%

Table 2 displays the efficiency measurements of cadaveric skull bones when exposed with the innovative dental X-ray holder made of silicone material. The efficiency value is determined to be 0.375, indicating higher efficiency compared to the conventional holder utilized at the Department of Radiology, Dental and Oral Hospital Muhammadiyah University of Semarang. The improvement in efficiency is statistically significant (p-value < 0.001). The utilization of the innovative dental X-ray holder made of silicone material has the potential to impact radiographers' efficiency values by up to 84%.

Table 3. The result of the Multivariate General Linear Model Test on the Quality of Radiographic Images.

Testing	B	Std. Error	Sig.	95% CI	Partial Eta Squared
Holder Dental Innovation Control Group (Rinn FPS 3000)	-0.087	0.47	0.72	-0.813 – 0.008	10.4%

Table 3 shows that the cadaveric skull exposed using a conventional holder used in the Department of Radiology, Dental and Oral Hospital Muhammadiyah University of Semarang produces a radiographic image quality value of 0.087, better than that of the dental x-ray holder innovation made from silicone material. However, there is no significant difference in the

radiographic image quality between the two holder types (p-value > 0.001). Using the dental x-ray holder innovation made from silicone material can only provide a low effect on radiographic image quality of 10.4%.

Dental X-ray holders are designed to be safe, efficient, and produce good-quality images. However, some dental holders have several drawbacks, such as being difficult to use and uncomfortable for patients during examination (Thomson & Johnson, 2018). Department of Radiology, Dental and Oral Hospital Muhammadiyah University of Semarang has a type of dental holder with the Rinn FPS 3000 brand, which has a telescopic feature on the ring part to align the beam with the film position and the beam parallel to each other. Still, it is difficult to use and tends to cause patient discomfort. During an examination, if the patient feels pain, they will likely make unnecessary movements, resulting in motion artifacts. Motion artifacts occur due to movements that produce a blurred image in which the level of detail and sharpness of the image decreases, and the idea is not good enough for use in diagnosis (Bwanga, 2021; Yeung & Wong, 2021).

If the resulting image does not meet the standard in radiology examination services, the radiology staff will take another picture. It has an impact on several aspects. First, it increases the examination time. Long examination times affect waiting time and response time in the related unit. According to Mulisa et al. (2017), she states that lengthy examination waiting times will affect patient satisfaction. Second, repeating the image also increases the dose received by the patient (Yesim & Seher, 2019). Based on the results of JK & JM (2014), in bitewing examinations, the dose received by patients is around 0.0058 μ Gy – 0.036 μ Gy in the thyroid gland, 0.1374 μGy – 0.2113 μGy in the oral cavity, dan 0.068 μ Gy – 0.0984 μ Gy in the salivary glands. The more repetitions performed, the higher the radiation dose received by the patient. The accumulation of doses in patients can cause unwanted biological effects.

Based on Chauhan & Wilkins (2019) research, intraoral dental examinations may cause local cytotoxicity in the mouth area exposed to radiation. Therefore, to anticipate movement that causes artifacts during bitewing examinations, the author innovated the dental holder by adding a layer of silicone to the bite-block that comes into direct contact with the patient's teeth.

The silicone material is a flexible elastomer material (Thomas & Maria, 2017). Certain types of silicone are also safe for medical use. Applying a silicone layer to the bite-block of the dental holder bitewing is hoped to reduce the discomfort that patients may feel during the examination. The holder is made using materials that are safe for medical use and environmentally friendly. The holder part is made from 100% PLA food-grade material made from corn and bagasse. In addition, the silicone material used is also food-grade silicone that is safe for use.

Based on the statistical test results, the dental X-ray holder with a layer of silicon rubber has an average value of 3 ± 0.2. Radiographers agree that the dental holder made is efficient when used. By using this dental holder, radiographers can minimize the possibility of discomfort patients feel when biting the holder. It minimally allows radiology staff to reposition or intervene in film and X-ray tube settings. There are several advantages to be gained by minimizing interventions during bitewing examinations.

Firstly, Cowan et al. (2013) states that radiographers can complete examinations more efficiently, leading to a reduction in their workload and an increase in the number of studies that can be conducted, which is advantageous for hospitals as it generates more revenue. Secondly, Ilhan et al. (2020) explained using the innovative dental holder minimizes the need for excessive intervention in the patient's oral cavity, reducing the risk of disease transmission and making patients feel more comfortable and at ease. This relatively inexpensive and well-tolerated dental holder, made from environmentally friendly and safe materials, ensures that patients do not experience pain during the examination.

Statistical test results indicate that the dental holder contributes to a work efficiency value of 0.375. This suggests that the innovative dental holder, incorporating silicone layers, significantly enhances the overall work efficiency of radiographers compared to the conventional holder used at the Department of Radiology, Dental and Oral Hospital Muhammadiyah University of Semarang, with a notable influence value of 84%.

Moreover, based on the statistical test results, the dental X-ray holder with a layer of silicone rubber has an average rating of 3.5 ± 0.09, indicating that radiology specialists agree that the dental holder produces high-quality

radiographic images. The assessment considered the clarity of the alveolar crest, tooth crowns, pulp, and the sharpness and shape of the resulting anatomy. The study's findings demonstrate that the radiographic images captured using the developed dental holder accurately display dental anatomy, exhibiting good sensitivity and no distortion or elongation. This benefits radiology specialists in interpreting the results and aids referring doctors and patients in making informed decisions (Aps et al., 2020).

Improved radiographic image quality facilitates easier interpretation for radiology specialists and reduces diagnostic errors (Aps et al., 2020). It also has a positive impact on referring doctors and patients, as referring doctors can quickly review the interpretation results based on the high-quality radiographic images. These results guide the appropriate course of action, particularly for patients requiring precise treatment. When the radiographic images are of good quality, the likelihood of interpretation errors decreases, ensuring that referring doctors take suitable actions to address patients' issues. Consequently, patients receive appropriate treatment, leading to successful resolution of their problems. Conversely, poor radiographic image quality may result in sub optimal treatment, which is detrimental to the patient.

The statistical test results reveal no significant difference (p-value = 0.72) between the newly developed dental holder and the commonly used dental holder at the Department of Radiology, Dental and Oral Hospital Muhammadiyah University of Semarang. This suggests that the changes and innovations made in the dental holder have only a minor impact (10.4%) on the quality of the radiographic images produced. Consequently, the new dental holder does not produce inferior results compared to the conventional holder used in the department.

4. Conclusion and Suggestion

In conclusion, the research results suggest that the use of a dental X-ray holder with a layer of silicone rubber can address some of the limitations associated with conventional dental holders. The innovation aims to improve patient comfort during the examination, reduce the need for repositioning or intervention, and enhance the efficiency of radiographers. The dental holder made from safe and environmentally friendly materials is designed to minimize discomfort for patients and reduce the risk of disease transmission.

The study demonstrates that the dental holder with a silicone layer contributes to work efficiency and is preferred by radiology specialists compared to the conventional holder. The innovation significantly reduces examination time, potentially increasing the number of studies conducted and benefiting the hospital financially. Furthermore, minimizing interventions in the patient's oral cavity reduces the possibility of disease transmission and enhances patient comfort.

The research findings also indicate that the radiographic images produced using the dental holder with a silicone layer exhibit good quality, displaying clear dental anatomy without distortion or elongation. This quality improves the interpretability of the images for radiology specialists, leading to more accurate diagnoses and appropriate treatment decisions. The referring doctors and patients also benefit from the improved image quality as it facilitates faster and more reliable interpretation and subsequent treatment planning.

Overall, the dental holder with a silicone layer shows promise in addressing the drawbacks of conventional holders, providing a relatively inexpensive and acceptable solution that enhances patient comfort, work efficiency, and radiographic image quality. Further studies and evaluations may be warranted to validate these findings and explore potential modifications or enhancements to the dental holder design.

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