Three Intraoral Radiographic Receptor-Positioning Systems: A Comparative Study

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ABSTRACT

QUN TANG: Three Intraoral Radiographic Receptor-Positioning Systems:
A Comparative Study
(Under the direction of Dr. Sally M. Mauriello)

This study compared the number and types of radiographic technique errors when photostimulable phosphor sensors were used with XCP® (Standard), XCP-ORA™ (Modified), and XCP®/JADRAD™ (Standard/Shield) devices. A randomized block design was used to assign senior dental hygiene students (n=29) into groups with alternating sequences of systems used. A clinical survey regarding use of each system and a post study survey comparing the systems were administrated upon each full mouth series exposure and completion of all tested systems respectively. Images were assessed by a calibrated evaluator (ICC=0.87) for technique errors based on standard guidelines. Quantitative data were analyzed using ANOVA. The mean percent (sd) of any technique error for the Standard, Modified, and Standard/Shield system was 18.4(8.1), 17.5(7.2), and 15.4(6.6) respectively (p=0.43). No statistical difference in technique errors was found among the systems. Error types varied per device. Half of the subjects who used all three systems preferred the XCP-ORA™.

DEDICATION

I’d like to dedicate this thesis to my grandmother, **Ziling Zhou,** for her unconditional love and care.

ACKNOWLEDGMENTS

I would like to thank: Dr. Sally Mauriello for her encouragement, consistent guidance and support through the entire thesis process; Dr. John Ludlow for his impressive research knowledge and editorial insights; Dr. Enrique Platin for his expert advice and sense of humor. Also, special thanks to Dr. Ceib Philips for her expert suggestions on statistical tests used.

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LIST OF TERMS and ABBREVIATIONS

Any Error Horizontal, Vertical, Packet placement, Conecut and Retake

BW Bitewing radiograph

CSQ Clinical Study Questionnaire

DH Dental Hygiene

EPR Electronic Patient Record

FMX Full Mouth Series

Major Error Error that results in diagnostically unacceptable radiographic images (Retake).

Minor Error Error that is not significant and does not cause diagnostically unacceptable radiographs (Horizontal, Vertical, Packet placement, Conecut)

N Number of students (subjects)

n Number of Full Mouth Series

PA Periapical Radiograph

PSQ Post Study Questionnaire

RPS Receptor Positioning System

Rinn XCP® Extension Cone Paralleling

Rinn XCP® /JADRAD™ XCP® used with /JADRAD™ Dental X –Ray Shield

Rinn XCP-ORA™ Extension Cone Paralleling- One Ring & Arm

SD (sd) Standard Deviation

SOD School of Dentistry

UNC University of North Carolina at Chapel Hill

1. INTRODUCTION

Background

For decades dental radiographs have been one of the most valuable tools to aid in the diagnosis of dental disease and subsequent clinical evaluation on treatment results. Collecting information from radiographic images has also become an essential component of current comprehensive dental care. The reason for radiographs being considered an important adjunct to the clinical examination is because the status of the bony tissues covered by the gingiva or that within the hard tissues cannot be detected by clinical inspection alone. Thus, a diagnosis of dental disease is greatly facilitated with use of dental radiography. Dating back to the discovery of X-rays over one hundred years ago, radiographic imaging has evolved and today computer-based image acquisition and processing techniques have supplanted film in many practices. However, good radiographs seldom happen by chance and image quality is not guaranteed by digital technology. In order to assure the diagnostic quality of radiographic images, radiographs should meet certain requirements of standardization and reproducibility. Since intraoral radiographic image formation is based on the principle of projecting a three-dimensional object onto a two-dimensional image plane, information is lacking about the third dimension. The orientation of the x-ray source beam toward the object is an important factor that could affect the resulting x-ray view. Different orientations of the projection results in a different image, which in turn may affect the interpretation and diagnosis based on that radiograph. For that reason, standardization and reproducibility are

regarded as essential requirements for the reliability of radiographic images. Many theoretical technique principles have been suggested to help guide image-exposures in clinical practice. Among them, the paralleling technique has been widely recommended as it can help to visualize the object while minimizing image distortion. Closely related to the application of the paralleling technique is the use of a receptor-positioning system (RPS). RPS can help accurately align the x- ray beam to the receptor area while geometrically holding the receptor in place within the mouth. The use of receptor-positioning devices and the paralleling technique has been strongly recommended for high quality images. The ultimate goal of intraoral radiography is to produce high quality diagnostic images using the best RPS while keeping a radiation dose to patients as low as reasonably achievable (ALARA). In light of this principle, this study was designed to compare the performance of three intraoral radiographic RPSs that either have been widely accepted for decades (Rinn XCP®) or recently introduced to dental practice (Rinn XCP-ORA™ and Rinn XCP®/JADRAD™).

Aims and Hypotheses

The specific aims of the study are:

1. Compare the number and types of technical errors among the three systems: XCP®, XCP-ORA™ and XCP®/JADRAD™. Technical errors were defined as packet placement, horizontal angulation, vertical angulation and cone centering or conecut.

2. To compare the number and types of diagnostically unacceptable projections among the three systems: XCP®, XCP-ORA™ and XCP®/JADRAD™.

3. To determine the preference of radiographers when using the three RPSs on patients.

The above specific aims were addressed by testing the following hypotheses:

1. There is no significant difference between XCP®, XCP-ORA™ and XCP®/JADRAD™ on the number and type of technique errors.
2. There is no significant difference between XCP®, XCP-ORA™ and XCP®/JADRAD™ on the number and type of diagnostically unacceptable projections.
3. There is no difference between XCP®,XCP-ORA™ and XCP®/JADRAD™ on radiographers' preference of the systems.

The purpose of this study was to help identify an intra-oral RPS with the best diagnostic performance, thus reducing radiation dose on patients through reduction of image retakes and producing high quality diagnostic images with few technical errors.

This study had potential difficulties and limitations: participation of the student population may limit the findings and conclusions for general population of radiographers. There was a risk of not being able to achieve the desired number of full mouth series (FMX) in the radiology clinic, depending on patient diagnostic needs and other factors uncontrolled by the study during the clinical sessions. Both limitations may pose threats to the internal and external validity of the study.

2. REVIEW OF LITERATURE

According to Dixon and Hildebolt, “dental radiography has undergone a slow but steady advancement since the early 1900’s” and “eliminating exposures to fingers (of patients’ or operators’ who helped to hold the film device in place) was the first of many improvements” [1]. Beginning in 1916, a film holder was used to control projection geometry. Twenty years after its preliminary invention by Kells in 1896[1], a metal-plate type receptor positioning system (metal plate helped absorb scattered radiation) was invented to hold the film with an extraoral rod to align the X ray tube. It was as early as in 1920, a film holder with a handle and finger grip already existed [1,5]. The paralleling technique introduced in this time period to overcome the shortcomings of the bisecting angle technique set up a solid foundation and guideline for subsequent receptor positioning devices design and modifications. The paralleling principle, as a golden rule, is widely advocated when exposing most intra-oral radiographic projections with use of RPS. The bitewing film packet we use today is largely unchanged from its original design in the 1920s [1].

A major development in RPS occurred in 1950s when the x-ray cone and film holder was semi-rigidly coupled (merely resting against each other) [1]. A wire extension localizer attached to a pointed cone took the original form of an aiming ring when used with the Snap-A-Ray instrument. Between 1950 and 1979, the RPS had undergone several phases ranging from x- ray cone semi-rigidly coupled with film holder to x-ray cone rigidly coupled or attached to film holder. The major goal of the “coupled” design was to improve the reproducibility and geometric accuracy of the images. Theoretically, the rigid coupled design

should provide ideal images of the dentition, but in reality, this type of device was extremely challenging when used in a patient's mouth. Thus, due to the discomfort brought to patients and difficult manipulation by operators, the rigid coupled system did not gain wide acceptance. Nevertheless, it was during this period, the Snap-a-Ray (Rinn Manufacturing Company, Elgin, IL, 1951) and the Precision X-Ray (Issac Masel, Philadelphia, PA, 1962) were introduced [1]. The Precision X-Ray device was made of stainless steel which absorbed unneeded direct as well as scattered radiation of x-ray beam. The rectangular opening in the middle of collimator of the device is slightly larger than the size of a film. The receptor-holding component is physically connected to the collimator portion of the precision device for facilitating accurate geometric projections. Two handles are provided on sides of the collimator for a patient to assist in holding. Compared to Precision instruments, Snap-A-Ray is a receptor holding device made of hard plastic and it doesn't have an x-ray aligning component. Both Snap-a-Ray and Precision X-Ray systems developed for use with the paralleling technique are still used today in some private and public dental practices. Both are often taught in many dental schools as supplementary aids in radiology clinics. However, there are no reports available about their accuracy and reliability [1].

Finally, in 1967 and 1968, Rinn Instruments (Rinn Manufacturing Company, Elgin, IL) became available for use with the bisecting angle technique and the paralleling technique, individually [3]. Again, "all references found were descriptive in nature and no report on accuracy /reliability were found" [1]. It was suggested that intraoral receptor-holding devices performed well or even better when compared to paper bitewing tab or cephalostat-based systems [4,5-11]. As indicated by Dixon and Hildebolt, image acquisition and manipulation

have been the focus of many studies during the past two decades in dental radiology and a perfect receptor holder has yet to be developed [1].

Common RPSs used in dental practice today are the XCP® and more recently on the market, XCP-ORA™. Despite its original invention over fifty years ago, XCP® still remains popular and no other intraoral RPS has been adopted so widely as it has been in general routine practices [1]. In 2009, Dentsply International (company) which advertised XCP-ORA™ for reduction of office clutter and ease in device assembling also claimed a "better diagnosis"[12] due to certain improved features of the device. Although there was an article about assembly and clinical use of the XCP-ORA™ [13], no research data has been provided by either the Dentsply or any comparative study so far. Another device branded as JADRAD ™ Dental X-Ray Shield designed to replace the positioning plastic ring of XCP® has been newly introduced to the commercial market. It was designed to be used with other components of the XCP®. JADRAD™ was claimed to minimize the number of conecuts, eliminate distortion errors, and have fewer retakes [14]. Therefore, this study was purposely designed to compare the number and types of technique errors as well as the diagnostic quality of radiographic images among the XCP®, XCP-ORA™ and JADRAD™ Dental X – Ray shield used with XCP® components.

3. MATERIALS AND METHODS

Study Devices

To increase precision of radiographic images and decrease radiation doses for patients, receptor-positioning device that align the receptor precisely with a collimated beam are recommended for periapical and bitewing radiographs [15]. This is especially important when a paralleling technique is applied. To help reduce the incidence of collimator cut off (conecut), most RPS have an external guide ring component that aids the operator to align the aiming cylinder of the x-ray tube head with the image receptor area in both horizontal and vertical planes. XCP®, XCP-ORA™, XCP®/JADRAD™ are three examples of the RPSs.

XCP® (Extension Cone Paralleling), an example of Standard RPS, is the product of Dentsply International RINN Division. It has been on the market for over fifty years. XCP® was developed in an attempt to simplify paralleling procedures and minimize dimensional distortion. The system is composed of three parts: plastic bite-block, plastic aiming ring and metal indicator rod (Figure 1). The device must be assembled prior to use and have separate components which are color coded for anterior, posterior and bitewing positioning. To reduce the area of radiation on patients, a snap-on rectangular collimator is usually added to the positioning indicating device (PID) of X-ray tube head to restrict the size of the radiation beam. The whole device can be autoclaved.

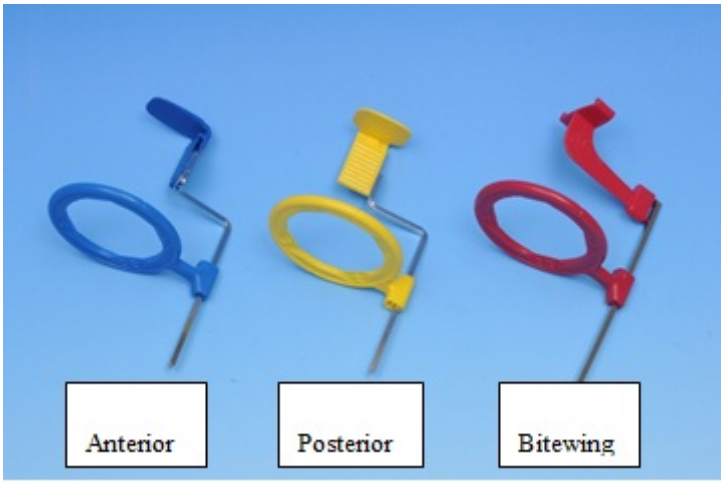

Figure 1 Example of Standard Receptor Positioning System

XCP-ORA™ (Dentsply International RINN Division), an example of Modified RPS, is the receptor holding device upgraded on the basis of the XCP® for "better diagnosis" and easiness of positioning with fewer parts [12]. The Anterior /Posterior segment can function as a finger grip for a bitewing projection (Figure 2). In its new design, the collimator guide (ring) was modified to include deeper indentions for better accommodation with the rectangular collimator when compared to XCP®. The color coded components still need to be assembled prior to anterior, posterior and bitewing projection use. XCP-ORA™ combines three aiming rings and three positioning bars into one ring and one bar for easier use and less bulky sterilization.

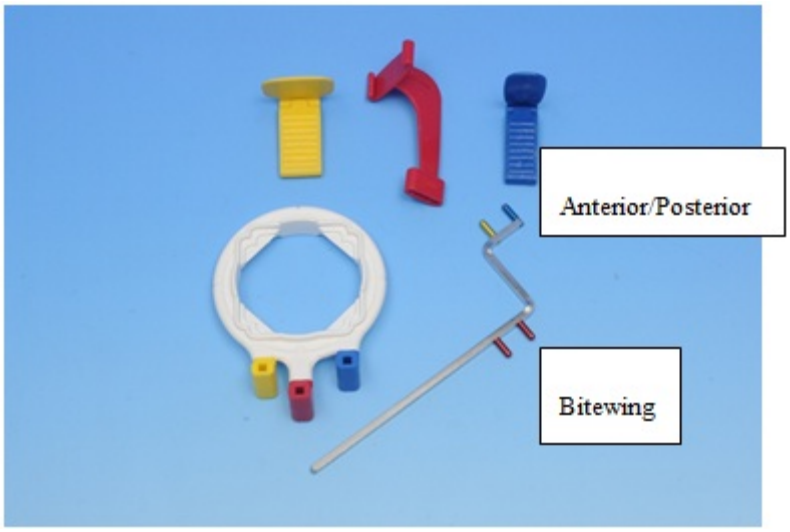

Figure 2 Example of Modified Receptor Positioning System

XCP®/JADRAD™ uses the JADRAD™ Dental X-ray Shield with the XCP® bite blocks and XCP® metal indicating rods. The shield is made of 0.070 inches 302 stainless steel with rectangular collimation (Figure 3). It replaces all three plastic aiming rings of XCP®. Due to the collimating plate, this RPS requires no additional rectangular collimation from the PID. JADRAD™ shield has been designed to improve receptor positioning to eliminate distortion errors and retakes for "better detection and diagnosis" [14]. Same as XCP® and XCP-ORA™, all components require assembly for anterior, posterior and bitewing projection use. JADRAD™ shield itself is not color coded, but letters embedded on the shield plate indicate which arm to be used for anterior/bitewing and posterior projections.

Figure 3 Example of Standard/ Shield Receptor Positioning System

Study Design

The senior Dental Hygiene Class of 2011 at the UNC School of Dentistry (SOD) participated in the study during their intraoral radiology clinical rotation. A randomized block study design (Figure 4) was used to randomly assign the students to six study groups. Each study group was associated with an alternating sequence to use the three study RPSs for three different patients (each patient only received one RPS use). Patients' FMX prescriptions were previously ordered by their dentists based on individual cases and were not specifically related to this research. The FMX in the study was composed of 10 to 18 periapical (PA) or periapical and bitewing (BW) images. All radiographic images were exposed during the student intraoral radiology school clinical rotation in the spring semester, 2011.

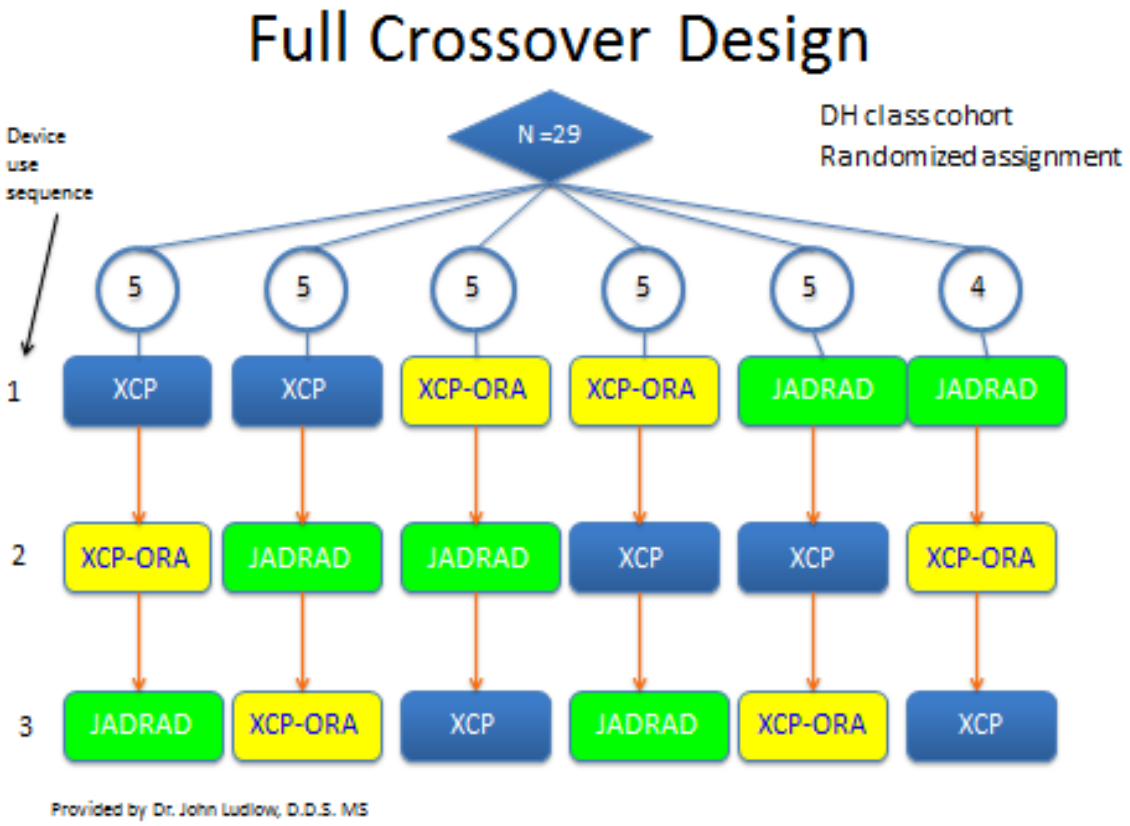

Figure 4 Randomized Block Full Crossover Design

Study Population

Interested participants of this study (subjects) consisted of 29 senior dental hygiene students enrolled at UNC SOD. Characteristics of the study population are presented in Table 1. Approximately 25% of the study population was over the age of 30 years. Twenty four percent of the subjects had previous dental experience prior to entering the dental hygiene program. Eligibility for the study included current enrollment in the dental hygiene program, two semesters of experience of exposing radiographs on patients and fulfillment of radiology competency requirement in radiology curriculum. Radiology competency requirement

demands the student to successfully expose six FMXs in a row or its equivalent with a grade of 86% or higher. Prior to the study, the subjects already had experience with use of XCP® for one semester and XCP-ORA™ for another semester.

Students' Demographic Characteristics		N	Percent
Sex	Female	29	100
	Male		
Age (years)	22-30	22	76
	31-40	4	14
	41-44	3	10
Previous dental work experiences	Yes	7	24
	No	22	76
Race	Caucasian	18	62
	African American	7	24
	Asian	2	7
	Hispanic	2	7
Language	English as second language	2	7

Table 1 Demographic Characteristics of Senior Dental Hygiene Students

Study Procedures

Upon the approval of IRB application for the study, a consent form was signed by each student prior to study implementation. Stratification was applied to allocate the subjects who had previous dental experience evenly among the six study groups. After the rest of subjects being randomly assigned to the study groups, during intraoral radiology clinical rotation, each subject was expected to expose three FMXs for three patients using a different test system on each patient. The order of using three RPSs depended on the group number

that the student was assigned to. Radiographic image information was collected and stored in UNC SOD Electronic Patient Record (EPR) system. The resulting images were assessed for the number and type of technical errors and image diagnostic quality when the entire data collection procedure completed. No student grade was given to subjects by this research. The image data collection of the study occurred between January 10, 2011 and April 30, 2011.

Study Surveys

Clinical Study Questionnaire (Appendix A)

In order to collect feedback on device use from the operators, subjects were asked to fill a six-item Clinical Study Questionnaire (CSQ) (Appendix A) at the completion of each FMX. CSQ was a quantitative survey. The questionnaires solicited information regarding the system types that were used, the difficulty of using the system, and patient management issues with use of the system.

Post Study Questionnaire **(**Appendix B)

A Post Study Questionnaire (PSQ) (Appendix B) was completed by subjects at the completion of 3 FMXs designated in the study. PSQ was a qualitative survey that focused on collecting information about subjects' perception when comparing use of the three RPSs. A pizza lunch was provided to subjects at the end of the survey.

Therefore, CSQ and PSQ were two different surveys with different goals. All responses were anonymous. Upon completion, CSQ and PSQ questionnaire forms were collected and returned to the research principal investigator.

Study Evaluator and Data Collection

The FMX image assessment was conducted by an experienced examiner with an intra-class correlation rater reliability of 87% throughout the length of the study. The examiner was blinded to the type of RPS used for each FMX and had no grading responsibilities for the subjects. The performance of each RPS was determined by the number and type of technique errors (horizontal, vertical, packet placement and conecut) and the number and reason for any diagnostically unacceptable projections. The radiographic images were retrieved from patient EPR and evaluated on a 22" desktop monitor with 1024 X768 pixels resolution in a dimly lit room. No software enhancement features were used to alter the display of the image. No identification of the radiographers or patients was visible to the evaluator. All images from technique performance of RPSs were assessed based on prescribed criteria (Appendix C). The evaluation results were documented on an Evaluation Results Analysis Form (Appendix D). Direct data entry by a recorder was used to record findings. Upon completion of radiographic image assessment, the examiner revaluated one third of FMXs randomly taken out of the total FMXs. The reevaluation results were compared to their corresponding initial assessment to compute the examiner's rating reliability.

Data Analysis Method

Minor technique errors in this study were categorized into RP-Receptor Placement, V-vertical error, H-Horizontal error, C-cone centering error. An image with minor errors was diagnostically acceptable. Major errors were defined as an error necessitating a retake due to diagnostically unacceptable quality. "Any errors" said in this study contains both minor and

major errors. Intra-rater reliability data was determined with Intra Class Correlation. The data from the performance of the three RPSs were analyzed to compare the mean percent of technique errors by using one-way ANOVA. Statistical frequency was used to report results of the CSQ and PSQ surveys.

4. RESULTS

Twenty nine subjects consented to participate in the study. One student later on decided to withdraw from the study. Three subjects meet the inclusion criteria regarding required technique competency late prior to beginning of the study. Thus, the study population was composed of 25 subjects (86.2% of the class). All subjects completed at least one FMX using assigned RPS. Fifteen subjects completed three FMX with use of all RPSs. The distributions of the FMXs (n=60) associated with study device use are shown in Figure 5 below.

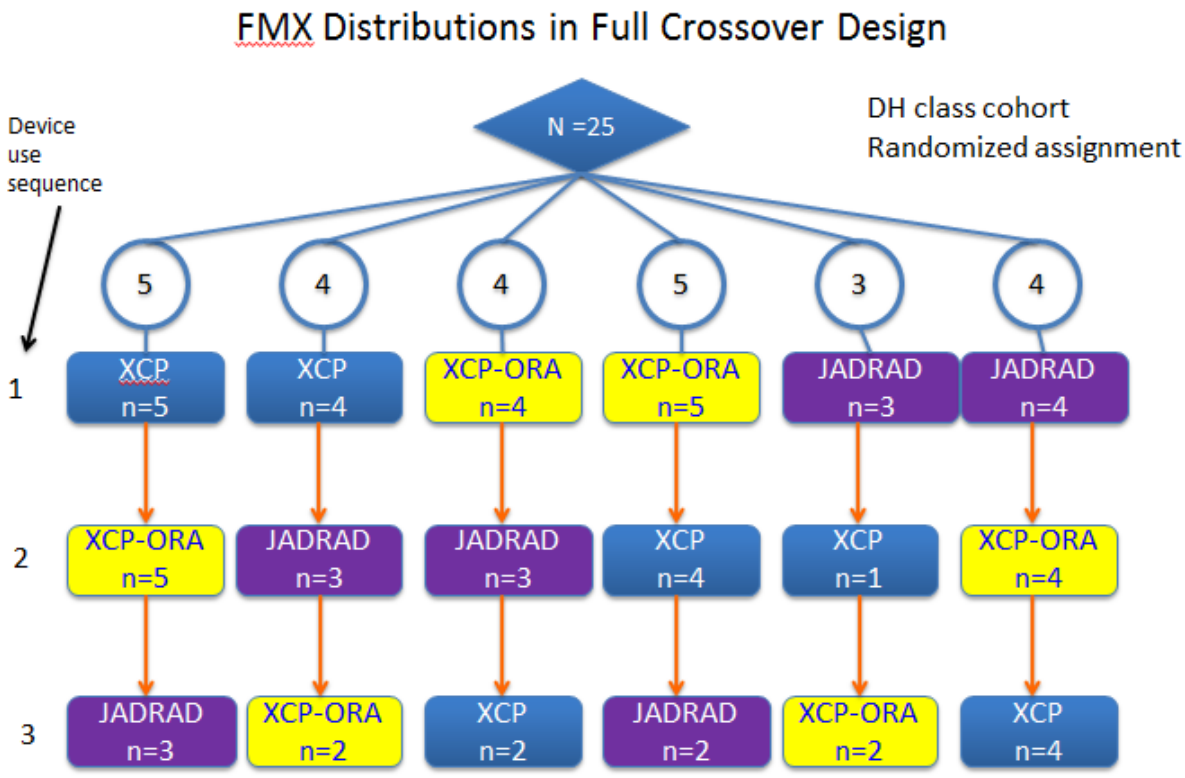

Figure 5 Distributions of Full Mouth Series with Use of the Study Devices

A total of sixty one FMXs were exposed by the 25 subjects who completed up to three FMXs. One FMX was excluded from the data analysis due to inability to retrieve images with a missing EPR chart number. All sixty one clinical surveys from the sixty one FMXs were included in the quantitative survey data analysis. The fifteen subjects who completed FMXs using all three RPSs participated in the post-study survey. The mean percentage of any technical errors and minor technical errors over FMXs were normally distributed except for that of major errors which skewed due to small number size.

Technique Quality

All FMX images taken by the subjects were evaluated for the technique errors from the assigned RPSs used. Based on prescribed guidelines (Appendix C), the technique errors were categorized into minor errors and major errors. When minor errors are exhibited, radiographs are still diagnostically acceptable. With major errors are presented, a retake is required due to diagnostically unacceptable image quality.

Figure 6 displays the average percentage of technique errors among the three RPSs including minor errors, major errors and any errors. Any error of a device is the combination of minor error and major error. The mean (sd) percentage of any technique error of Standard, Modified, Standard/Shield was 18.4(8.1), 17.5(7.2), and 15.4(6.6) respectively. Given $p=0.43$, there were no statistically significant differences among the average mean percent of any technique errors for the three devices. The mean percent minor errors share the same trend as any errors. For major errors, mean percentages were similar across three RPSs.

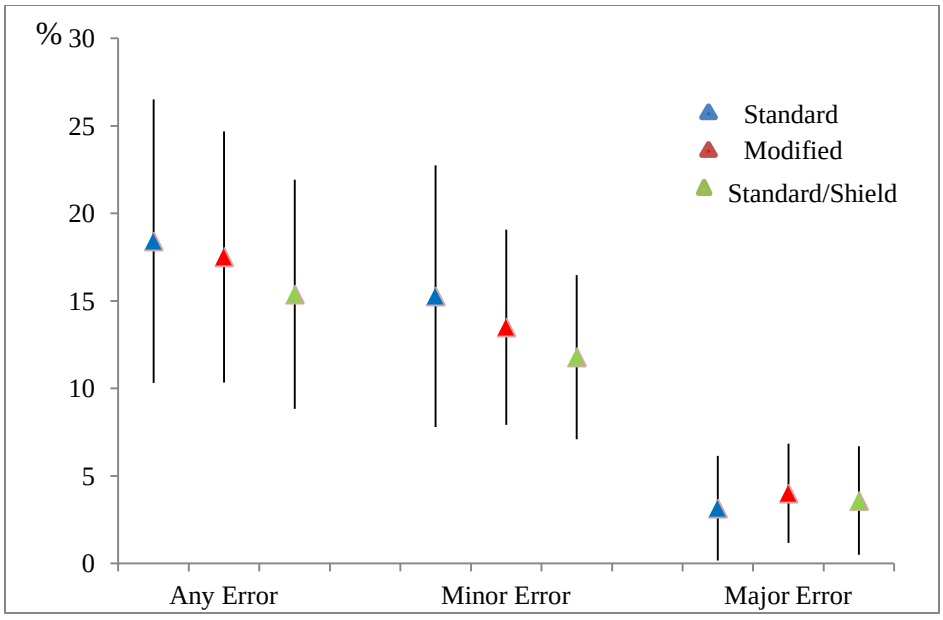

Figure 6 Mean Percentages of Technique Errors among Devices

Figure 7 shows the average percentage of any technique errors by error type among three RPSs. Mean percentages for error types varied per each device. The average percentage of receptor placement errors was similar among the systems. The lowest mean percent 15.8(8.4) of cone centering errors were seen with the Standard/Shield compared to the highest 25.1(4.0) of the Modified system. The mean percentage horizontal errors ranged from 5.9(4.4) with the Standard/Shield system to the highest 11.2(5.2) with the Modified device. However, the Modified system had the lowest percentage mean of vertical errors 4.2(4.2) compared to the highest 8.7(6.5) with the Standard/Shield. Across the three RPSs, the Modified system demonstrated the least variance in performance that resulted in Receptor Placement errors and Conecuts.

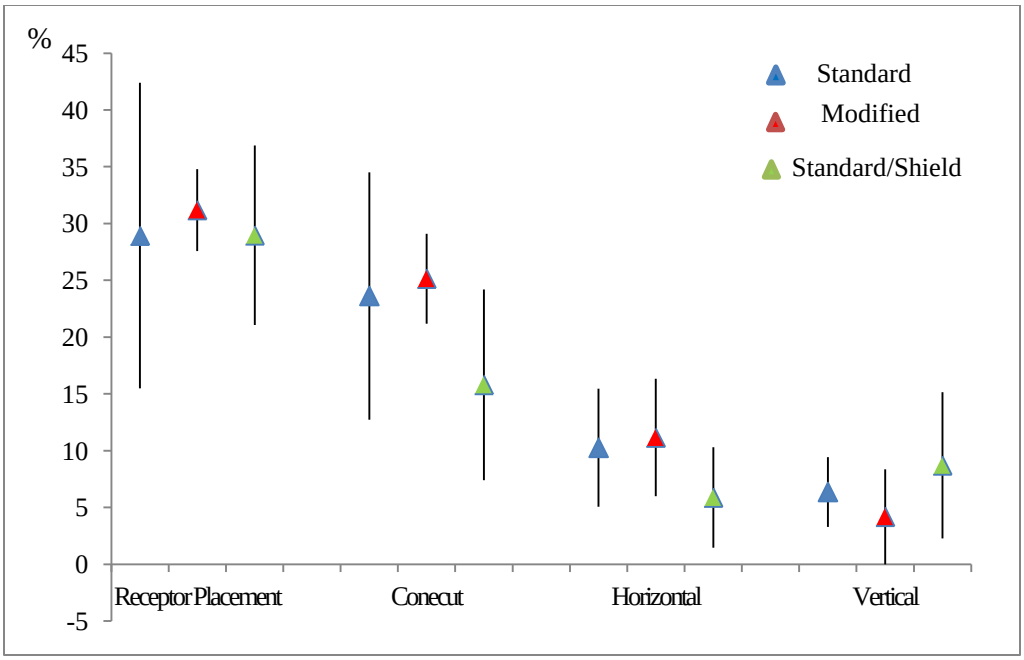

Figure 7 Mean Percentage of Technique Error Types by Device

Figure 8 displays the mean percentages of any technique errors that occurred by projection location among the three RPSs. Average percentages of any errors in anterior projections were ranging 8.1 (7.1) with the Standard/Shield to 12.8 (10.5) with the Standard. For posterior projections, the mean percentage of any technique errors was 21.9 (9.9) for the Standard system, 20.6 (7.8) for the Modified and 20.0 (10.5) for the Standard/ Shield PRSs.

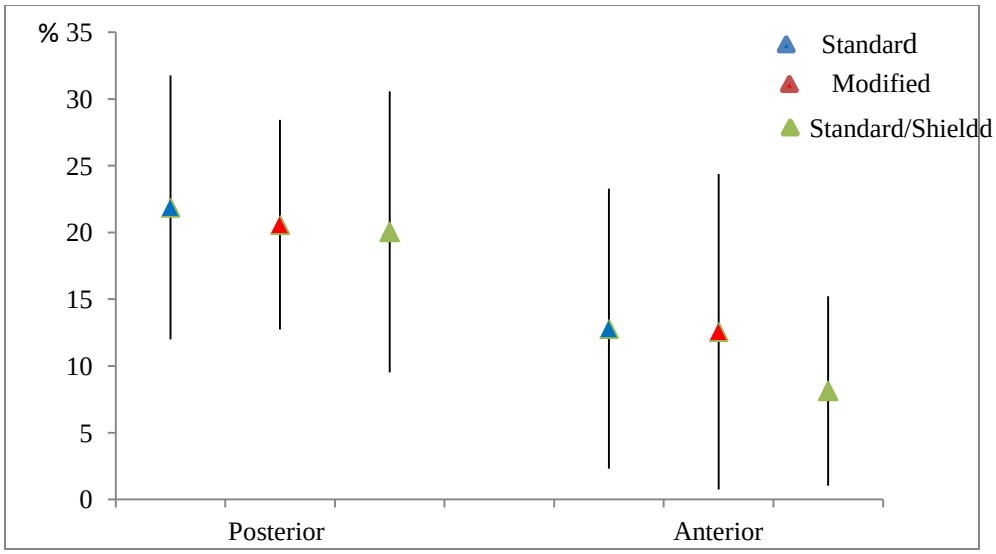

Figure 8 Mean Percentages of Any Technique Errors by Location

Students' Feedback on Comfortable Levels of Using Devices

Table 2 exhibits comfortable level from various perspectives in the process of using devices by the subjects in the Clinical Quantitative Survey. While nearly 50% of the subjects who used the Standard /Shield system expressed difficulty with device assembly, the majority indicated that they felt comfortable using all three RPS devices. When the subjects were asked if they had any difficulty positioning the device into patient's mouth, at least one fourth of the subjects reported difficulty with the Standard and the Standard/ Shield devices correspondingly. A little less than one fifth of the study population reported difficulty with the Modified device.

	Standard	Modified	Standard/Shield
Number of FMXs exposed with the device	20	22	19
% of students with difficulty in device assembly	15%	4.5%	52.6%
% of students with difficulty positioning the device	25%	18%	31.5%
% of students comfortable using the device	85%	91%	89.5%

Table 2 Clinical Quantitative Survey Report

Students' Feedback on Strengths and Weakness Associated with Devices

Table 3 displays the themes of strengths and weakness associated with each RPS based on subjects' opinions after using all three systems. Each subject was able to provide multiple responses to strengths and weakness in the Post-Study Qualitative Survey**.** For the standard system, color coding of accessible parts was favored by subjects. Improved indentation of the aiming ring and fewer device components in the modified system were highlighted in strength of the device. Easy alignment the X ray PID to the metal shield of the Standard/Shield system was claimed by subjects with a feeling of decreased cone cone-cuts. Meanwhile, the heaviness of the shield became an issue when using for edentulous patients or patients who couldn't help to hand hold the device.

Feedback on Device	Strengths	Weaknesses
Standard	• Easy to use (once learned how to use) • Color coded • Helpful for accurate angulations	• Longer assembly time (multiple rings and bars) • PID doesn't stay in line with rectangular collimator
Modified	• Nice indentation of aiming ring • Easier for beam-alignment • Fewer pieces for assembly • Light weight	• Still easy to get cone-cut error • Not as convenient as Standard/Shield system • Wear and tear of rings made it slide easily on the positioning bar
Standard/Shield	• Patient can hold it for comfort and control • Easier to align with x-ray tube head (to decrease cone-cut) • Helps gagging patients	• Heavy weight (hard to place/position, difficult for edentulous patients) • Not user friendly at the beginning • Must rely more on patient's compliance • Difficult for patient with unsteady hand to hold the device • Feel awkward asking patient for help in holding device

Table 3 Post-Study Qualitative Survey Report (N=15)

Students' Preference of Devices

Table 4 shows a device preference in percentage of the subjects (N=15) who completed study radiographs when using all three RPSs in the PSQ survey. Half of the students preferred the Modified device, who expressed its' ease to use and patient acceptability. There was about one fifth of the study population who preferred both the Modified and the Standard /Shield RPSs.

Device Preference	% of Subjects	Emic Expressions
Modified	50	• "Collimator fits into the ring better" • "Easy and comfortable to use" • Light weight • Patients were comfortable with it • Less time to assemble
Both Modified and Standard/Shield	21.4	• "Like the quality of my radiographs exposed" • "Same reason listed under the device's strength"
Standard/Shield	21.4	• Fewer parts to put together • "Allows more room for patient movement" • "Fewer cone cuts" • "Simple to use"
Standard	7.1	• "The easiest one to work with"

Table 4 Device Preference and Emic Expressions

Major Themes Identified about Characteristics of Devices

Table 5 reveals three major themes that emerged from the analysis of the qualitative data of the PSQ survey. Several characteristics important and desired to the subjects regarding the best choice of radiographic device were instrument design, patient comfort/compliance, image quality and device RPS preference. Major points were listed under each theme. Instrument design and image quality focus on the areas that were more important to the device using and the quality of resultant images. Opinions from subjects about patient comfort and compliance indicated concerns of patient acceptability from the radiographers' perspective.

Themes	Major Points
Instrument Design	• Light weight • Few pieces for assembly and use • Color-coded • Adapt easily to rectangular collimator • Durable material
Patient Comfort/Compliance	• Allow device placement without patient having to stabilize device • Light weight to adapt to clinical conditions/situations • Comfortable for patients
Image Quality	• Designed to minimize cone cuts • Allow accurate representation of object
Device Preference	• 50% of subjects preferred the modified device

Table 5 Major Qualitative Themes

5. DISCUSSIONS AND CONCLUSION

About Clinical Results

This study found no statistically significant difference in regards to image quality among XCP®, XCP-ORA™ and XCP®/JADRAD™ receptor-positioning systems. One explanation for this finding may be attributed to the same paralleling projecting principle and the beam alignment design used by the three RPSs tested. For instance, XCP-ORA™, the modified system combined three aiming rings used for periapical (PA) and bitewing (BW) projections of XCP® into one aiming ring and three metal rods into one positioning rod. The XCP®/JADRAD™, a Standard/ Shield system, attempted to decrease conecuts by replacing the plastic positioning rings with a stainless metal shield as a way of eliminating the use of the rectangular collimator. Although the device designs of three systems were varied to a certain degree, the paralleling principle and associated exposure techniques are fundamentally the same with no change. It is worth noting that a similar finding was documented by a study conducted at Howard University of Dentistry (Washington, DC) in 1990's. Choksi and Rao found no significant difference in the total number of errors when comparing XCP-I (a Standard RPS) to XCP-II (a Modified system with a metal shield attached to aiming ring) [16].

On the other hand, if we look closer at the number and type of "any" technique errors distributed among three systems, the data showed a trend (although not statistically significant) of decreased conecuts and horizontal errors with the use of the Standard/ Shield

system. The contributing factors could be no use of rectangular collimator by the system due to the metal shield functioned as a collimator and guiding ring at the same time. The round opening of the PID can be relatively easier to align against the collimator plate when compared to the other two systems. With either the Standard or the Modified system, the snap–in rectangular collimator is expected to fit snuggly into the rectangular rim of the device aiming ring. Therefore, a reduction in conecut and horizontal errors with use of the Standard/ Shield is possible unless the PID drifted from the target area. However, if the PID didn't align perfectly or parallel to the shield by leaving a certain vertical line angle of discrepancy, a vertical error would readily occur. This may also more or less help to explain why the Modified system displayed a trend of having a lower mean percentage of vertical error. The newly revised deepened rim design in the Modified system helps the PID stay in position better than the Standard and the Standard/ Shield systems.

About Survey Results

As indicated in PSQ survey, we found nearly half students preferred the Modified system due to deepened rim design on the aiming ring and fewer components for assembly. We also noticed that the Standard/ Shield system was also preferred by some student operators for an easy alignment of PID and reduced conecut produced. Assembly difficulty noted with the Standard/ Shield system could be partially from a lack experience of using the device and none color coding employed by the metal shield. Prior to joining in this study, the subjects already had one semester long use of the Standard and the Modified system in turn. The Standard/ Shield system was relatively new to them for being introduced by the study. Other than that, the heaviness of the Standard/ Shield made some students and patients

hesitate about using the system. This became obvious when the metal weight of the shield made it challenging for a radiographer to position and stabilize the device in patient's mouth or the patient experienced significant discomfort when having an edentulous arch and/ or weak mastication muscles. The hand grips on the metal shield would not be applicable for the patients with hand tremors since the resulting images would be blurred due to hand shaking of the patient who holds the metal shield.

Themes developed from the triangulation of the data from mean percentage of technique errors, CSQ and PSQ surveys suggested that preference of the device by the subjects is not solely determined by the technique errors occurred. Many factors influence the acceptability of the intraoral RPS at least from the following perspectives: instrument design, patients' comfort and compliance level of being used, the image quality resulted. For instance, although the Standard/ Shield system showed a trend of having lower mean percent of cone-cut errors (not statistically significant) compared to the other devices, student operators still preferred the modified system. First, a good device is expected to be light weighted, easy assembly and easy manipulation for patients' intraoral needs. Fewer components of the device are also preferred for shortening clinical time and sterilization clutters. Secondly, a good device should also be patient friendly meaning it is well tolerated and complied by patients when being used. At present time, maybe it is better to consider choosing specific PRS for specific group of patients. Among the three PRSs tested, the Standard/ Shield system may be more accepted by regular patients, especially who would be excited about participating in the process by helping to hand hold the device. As a note to that, the prongs on the positioning rod of the Modified system can also function as hand grips for patients to hold. High quality of images is the third key factor to be emphasized on since

it is the ultimate goal of the entire radiographing process. If the system can be used to produce consistent high quality diagnostically accepted radiographs, it would be on the high demanding side when possessing both operator acceptability and patient acceptability.

As mentioned earlier, the study findings suggest proper choosing and using an RPS for appropriate patients in order to achieve the best image quality. It is hoped that this information will provide helpful information on didactic teaching and clinical instruction on using the three RPSs.

Conclusion

Overall, our study suggests that any of the three devices are acceptable for use. It appears as though clinical use of any of the three receptor positioning systems would result in comparable image quality. No absolute advantage was noted from using one system over the other based on the number of technique errors that occurred in this study. Student operators who used all three comparative RPSs preferred using the Modified system. The intraoral radiographic RPSs may be improved in their design modifications considered patient compliance, ease of use to the clinician, and minimal errors as a result of improved collimator adaptations.

APPENDICES

Appendix A: Clinic Study Questionnaire

Directions: Please answer the following questions based on your experiences today using the three intraoral radiographic receptor-positioning systems (XCP®, XCP-ORA™ and XCP®/JADRAD™. Once you have completed your answers, please place them into the envelope provided, seal it, and return it to the principal investigator. Do **not** place your name on the questionnaire.

Patient EPR number:_____ Your *unique* study number:_____

Question 1: Which Intraoral Radiographic Receptor-Positioning System did you use for this full series? Please circle:

XCP® XCP-ORA™ XCP®/JADRAD™

Question 2: Did you experience any difficulty with assembling the device?

Yes _____ No _____

Question 3: Did you experience any difficulty with placement of the device?

Yes _____ No _____

Question 4: If you used more than one receptor-positioning system today, did you *prefer* one over the other?

Yes _____ No _____

If yes, please circle the one that you preferred:

XCP® XCP-ORA™ XCP®/JADRAD™

Question 5: Please circle the management difficulty of your patient? If appropriate, please indicate the type of difficulty.

Easy Neutral Difficult

Please specify type of difficulty: _____

Question 6: In general, how comfortable do you feel exposing radiographs on patients? Please circle:

Comfortable Neutral Not comfortable

Appendix B: Post-Study Questionnaire

Directions: Please answer the following questions based on your experiences with using the three intraoral radiographic receptor-positioning systems (XCP®, XCP-ORA™ and XCP®/JADRAD™). Additional paper has been included in the envelope if you need it for your responses. Once you have completed your answers, please place them into the envelope provided, seal it, and return it to the principal investigator. Do **not** place your name on the questionnaire.

Question 1: Please describe your feelings about the use of the XCP® receptor-positioning system to expose radiographs on patients? State the strengths and weaknesses of the system?

Question 2: Please describe your feelings about the use of the XCP-ORA™ receptor-positioning system to expose radiographs on patients? State the strengths and weaknesses of the system?

Question 3: Please describe your feelings about the use of the XCP®/JADRAD™ receptor-positioning system to expose radiographs on patients? State the strengths and weaknesses of the system?

Question 4: Please state your preference of Intraoral Radiographic Receptor-Holding Device (XCP®, XCP-ORA™ and XCP®/JADRAD™) and why you would choose to use it when exposing intraoral radiographs? If you do not prefer one system over the other, then please state why.

Question 5: Please feel free to provide additional comments about the XCP®, XCP-ORA™ and XCP®/JADRAD™ if you choose?

Appendix C: Intraoral Radiography Performance Criteria

Periapical Examinations

A. General Consideration - All periapical views should demonstrate:

1. Images must display optimum density, contrast, definition, detail with the least amount of distortion
2. 1/4 inch (5mm) of alveolar bone visible beyond the apex of each tooth.
3. 1/16 - 1/8 inch (1 – 2mm) margin between the crowns of the teeth and edge of the receptor.

   The occlusal plane should parallel the occlusal edge of the receptor.

B. Specific Views

1. Maxillary Centrals (#2 receptor vertically placed)

The central/central interspace is centered on the receptor. Demonstrate the central incisors, lateral incisors, and proximal portion of canines, incisive foramen and nasal fosse. Interproximal spaces open with emphasis between central incisors.

2. Maxillary Lateral Incisor/Canine (#1 receptor vertically placed)

The lateral/canine interproximal space is centered on the receptor. Demonstrate the entire lateral incisor; entire canine; distal portion of central incisor and mesial portion of premolar. Interproximal spaces open with emphasis between the lateral incisor and canine (the canine and the premolar will appear overlapped; this is a result of the transition to a double row of cusps and the normal curvature of the arch).

3. Maxillary Premolar (#2 receptor Horizontally placed)

Demonstrate no less than the distal third of the canine; the entire first premolar, second premolar and first molar; and the mesial portion of the second molar. Interproximal spaces open with emphasis on the canine/first premolar and first premolar/second premolar.

4. Maxillary Molar (#2 receptor Horizontally placed)

Demonstrate the first, second and third molars. Interproximal spaces open with emphasis between the first and second molar. This can be achieved by placing the anterior portion of the detector no further forward than the distal portion of the second premolar or by centering the second molar on the receptor.

5. Mandibular Centrals (#2 receptor vertically placed)

The central/central interproximal space is centered on the receptor. Demonstrate the central incisors; lateral incisors and proximal portion of canines. Interproximal spaces open with emphasis between central incisors.

6. Mandibular Lateral Incisor/Canine (#1 receptor vertically placed)

The lateral incisor/canine is centered on the receptor. Demonstrate the entire lateral incisor; entire canine; distal portion of central incisor and mesial portion of premolar. Interproximal spaces open with emphasis between lateral incisor and canine (the canine and the premolar will appear overlapped; this is the result of the transition to a double row of cusps and the normal curvature of the arch).

7. Mandibular Premolar (#2 receptor Horizontally placed)

Demonstrate no less than the distal portion of the canine; the entire first premolar, second premolar and first molar and the mesial portion of the second molar. Interproximal spaces open with emphasis on the canine/first premolar and first premolar/second premolar.

8. Mandibular Molar (#2 receptor Horizontally placed)

Demonstrate the first, second and third molars. Interproximal spaces open with emphasis between the first and second molar. This can be achieved by placing the anterior portion of the detector no further forward than the distal portion of the second premolar or by centering the second molar on the receptor.

Interproximal (Bitewing) Examinations

A. General Consideration - All interproximal (bitewing) views:

1. The occlusal plane should parallel the occlusal edge of the **receptor**.
2. Equal distribution of maxillary and mandibular alveolar crest and maxillary and mandibular crowns.
3. The same criteria apply to both horizontal and vertical bitewings.

B. Specific Views:

HORIZONTAL BITEWINGS:

1. Premolar (#2 receptor Horizontally placed)

Demonstrate no less than the distal portion of the canine crowns, all of the first premolar, second premolar and first molar crowns and the mesial portion of the second molar crowns. Interproximal spaces open with emphasis on the canine/first premolar and first premolar/second premolar contacts. Emphasis should be on opening the maxillary contacts. Flat vertical projection geometry through open contacts is required for caries diagnosis and accurate assessment of crestal bone height.

2. Molar (#2 receptor Horizontally placed)

Demonstrate the first, second and third molars. This can be achieved by placing the anterior portion of the detector on the distal portion of the second premolar or by centering the second molar on the receptor. Interproximal spaces open with emphasis between first molar and second molar. Emphasis should be on opening the maxillary contacts. Flat vertical projection geometry through open contacts is required for caries diagnosis and accurate assessment of crestal bone height.

VERTICAL BITEWINGS:

If all posterior teeth are present, it may be necessary to take a six-image survey with vertical bitewings. Under these circumstances, it is necessary to use a #1 size vertical receptor in the canine/premolar position. This projection should demonstrate the distal portions of the canine crowns, all of the first premolar crowns, and the mesial portions of the second premolar crowns. Interproximal spaces open with emphasis on the maxillary canine/first premolars and first premolars/second premolars. Then, use a #2 size vertical receptor placed so as to demonstrate the distal portions of the second premolar crowns, all of the first molar crowns, and mesial portions of the second molar crowns. Interproximal spaces open with emphasis on the

maxillary first and second molars. A third receptor (#2 size vertical) is placed as to demonstrate the distal portions of the second molar crowns and all of the third molar crowns. Interproximal spaces open with emphasis on the maxillary second and third molars. On vertical bitewings include 5 mm of crestal bone distal to the most distal tooth. If necessary expose additional images to obtain the information needed.

If only two images are used for vertical bitewings, the following criteria should be used.

1. Premolar- #2 vertically placed

Demonstrate no less than the distal portions of the canine crowns, all of the first premolar, second premolar, and first molar crowns and the mesial of the second molar crowns. Interproximal spaces open with emphasis on the maxillary canine/first premolar and first premolar/second premolar areas. Emphasis should be on opening the maxillary contacts. Flat vertical projection geometry through open contacts is required for caries diagnosis and accurate assessment of crestal bone height.

2. Molar- #2 vertically placed

Demonstrate all of the first molar, second molar, and third molar crowns or the crowns of the most distal tooth present. This can be achieved by placing the anterior portion of the detector on the distal portion of the second premolar or by centering the second molar on the receptor. Interproximal spaces open with emphasis between maxillary first molar and second molar. Emphasis should be on opening the maxillary contacts. Flat vertical projection geometry through open contacts is required for caries diagnosis and accurate assessment of crestal bone

height. On vertical bitewings include 5 mm of crestal bone distal to the most distal tooth. If necessary expose additional images to obtain the information needed.

Appendix D: Intraoral Radiography Technical Performance Evaluation Form

University of North Carolina at Chapel Hill-School of Dentistry
Three Intraoral Radiographic Receptor-Positioning Systems: A Comparative Study
Intraoral Radiography Technical Performance Evaluation Form

Unique study ID number:_____

No.	Projection	Error	Retake
1	Maxillary Right Molar	RP VA HA CC OTHER OK	YES NO Reason:
2	Maxillary Right Premolar	RP VA HA CC OTHER OK	YES NO Reason:
3	Maxillary Right Lateral/Canine	RP VA HA CC OTHER OK	YES NO Reason:
4	Maxillary Central Incisors	RP VA HA CC OTHER OK	YES NO Reason:
5	Maxillary Left Lateral/Canine	RP VA HA CC OTHER OK	YES NO Reason:
6	Maxillary Left Premolar	RP VA HA CC OTHER OK	YES NO Reason:
7	Maxillary Left Molar	RP VA HA CC OTHER OK	YES NO Reason:
8	Mandibular Left Molar	RP VA HA CC	YES NO Reason:

		OTHER OK	
9	Mandibular Left Premolar	RP VA HA CC OTHER OK	YES NO Reason:
10	Mandibular Left Lateral/Canine	RP VA HA CC OTHER OK	YES NO Reason:
11	Mandibular Central Incisors	RP VA HA CC OTHER OK	YES NO Reason:
12	Mandibular Right Lateral/Canine	RP VA HA CC OTHER OK	YES NO Reason:
13	Mandibular Right Premolar	RP VA HA CC OTHER OK	YES NO Reason:
14	Mandibular Right Molar	RP VA HA CC OTHER OK	YES NO Reason:
15	Right Molar Bitewing	RP VA HA CC OTHER OK	YES NO Reason:
16	Right Premolar Bitewing	RP VA HA CC OTHER OK	YES NO Reason:
17	Left Premolar Bitewing	RP VA HA CC OTHER OK	YES NO Reason:
18	Left Molar Bitewing	RP VA HA CC OTHER OK	YES NO Reason:
19	Extra Projection:	RP VA HA CC OTHER OK	YES NO Reason:

20	Extra Projection:	RP VA HA CC OTHER OK	YES NO Reason:

Error Codes: RP =Receptor Placement (Packet Placement); VA =Vertical Angulation; HA= Horizontal Angulation; CC = Cone Cut; Other = Additional errors (i.e. double image, movement, etc); OK = Clinically Acceptable

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