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Research paper



Multiple Angle of Bisector Rinn Holder for Oral X-Ray

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Abstract

Multiple angle of bisector rinn holder is a film holder instrument that is yet to be developed that is able to use paralleling technique and bisecting angle technique in oral x-ray radiography. It is a device aimed to be able to use multiple techniques in oral radiography while getting a good image quality that helps the dentist in doing their work. This is a project that involves the development of the instruments and the effectiveness of the instruments compared to the existing one. The result of the radiographic image was compared and certain constraint was used to compare the instruments with the existing instruments. This project used CATIA V5 software for the design stage. In this project, the instrument was tested to validate the effectiveness where the testing was conducted at the faculty of dentistry. The outcome was the effectiveness of the instrument as compared to the existing instrument with other certain constraints.

Keywords: *bisector rinn holder, angle, film holder, effectiveness, oral radiography.*

1. Introduction

Radiography is widely used in the medical industry to determine many disease's state and condition of the patient to find the suitable treatment for them. In the dental industry, it is a method of getting the information needed of the root canal anatomy and the surrounding tissues. The use of radiography in dental industry will not be possible if the discovery of x-ray by a German researcher named Wilhelm Conrad Roentgen in the late 1895 [1]. When the announcement of the discovery broke the news, this caught the attention of an American dentist named Charles Edmund Kells [1]. He went on to test it on the dental industry and continue to promote the use of x-ray in dentistry by doing some publications and presentation [1]. He also designs the oral radiography instrument that is the film holder instrument. Since then, oral x-ray radiography undergo evolution of development keeps on evolving to this day with variety of technique and film holder instruments introduced. The modernization of the oral x-ray radiography need to be continue to ease the dental industry in keeping the oral health and welfare in optimum condition.

Some says that the apparatus used is one of the factors and the need to develop devices for radiographic standardization has been confirmed by various authors and one of them, Bender (1982) affirmed that the angle of the X-ray beam is responsible for the size and form of a lesion image, or even for its disappearance [2]. The film holder instruments have evolved as new technology arises and the development is continuing. A good and consistent image quality is yet hard to achieve if the bisecting angle technique is used. Plus, the inconsistent image quality leads to repetition of radiography. These repetitions are due to positioning error, improper angulations and improper film placement. Other causes that contribute to these repetitions are patient's movement, processing error, and incorrect exposure factors Plus, The need of an instrument for each technique is a nuisance for the dentist as this will increase their time in taking radiography in between technique. Some teeth need to use paralleling technique and some need to use bisecting angle technique to get the best result. There is also the comfort of patients, in which some cases reported that the paralleling technique is uncomfortable and may cause gagging. In short, a single modified film holder instruments that are applicable in both technique can reduce or eliminate this particular problem.

According to endodontic literature, two radiographic techniques have been employed to capture an image of the tooth and its root onto a periapical film namely the paralleling and bisecting angle techniques. Paralleling technique is a technique in which the x-ray beam is exposed to the teeth of the patient perpendicularly. The film or digital sensor need to be parallel to the long axis of the tooth [3]. Paralleling technique is more readily standardized and theoretically, the film is positioned parallel to the tooth at, a consistent target-film distance [4]. Rectangular collimation is used to ensure alignment. The paralleling technique produces more reliable, consistent and accurate results and has a geometrical advantage over the bisecting angle technique. However, bisecting angle technique is preferable in some circumstances and the technique need to be considered in order to get a good image quality. The bisecting angle technique is a technique works on the Cieszynski's rule, which says that two triangles are equal when they share a complete side and have two equal angles [5]. The procedure of this technique usually starts with the positioning of the patient's head which should be upright with sagittal plane vertical and occlusal plane horizontal [6]. Hence, a modification is done to the existing film holder instruments to support both techniques in order to get good image quality and eliminate the need to change instruments in using the techniques.

The project is essential to the development of the dentistry industry as it will help their work in treating patient a lot easier than before. Plus, the clinician errors in the dental radiography procedure can be greatly reduced and will get the best possible optimum result. Next, as the need for an instrument that can perform multiple techniques is demanding among dentist, the device developed

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will certainly met the demand. It is a small nuisance that sometimes goes unnoticed as the change of instrument to do different technique to diagnose a patient condition becomes common. An innovation which resulted in the ability to apply different x-ray techniques to eliminate this problem will certainly reduce time and cost. In addition, the comfort and tolerance of the patients treated will increase compared to the previous available film holder instrument. Finally, the repetition in x-ray radiography in intraoral radiography can be reduced. As the bisector rinn holder is for multiple techniques, the repetition is reduced as less room and time for error is given. Hence, the innovation will certainly benefit all involved.

2. Methodology

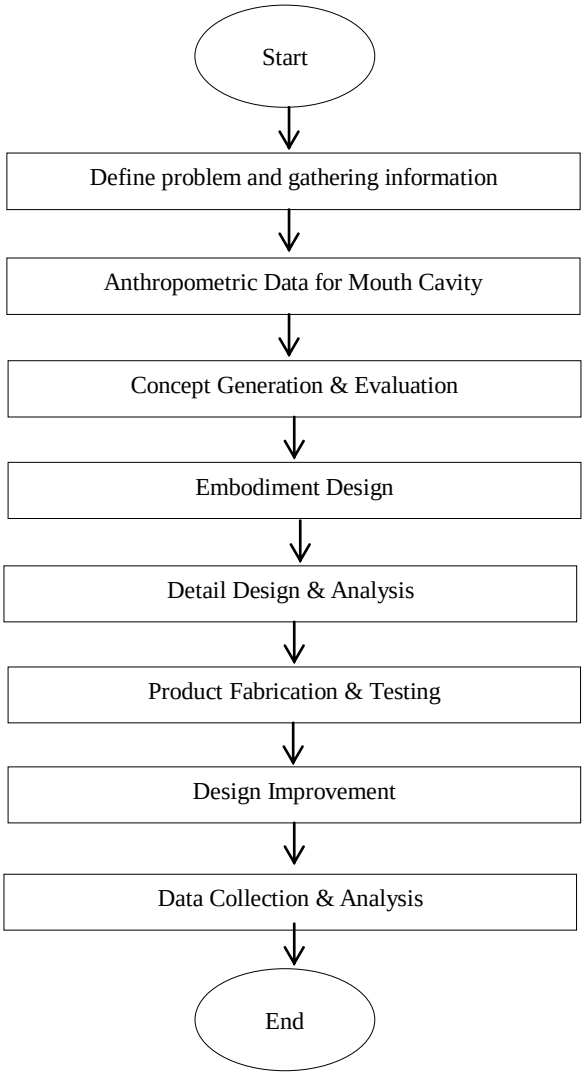

Figure 2.1: The Flowchart of the project.

2.1. Define Problems and Gathering Information

The first step of the whole project begins with defining the problems as in Figure 2.1 and it involved the current and available film holder instrument. Firstly, the problems need to be established so that a solution can be clearly identified and applied to the developed product. The main problem is identified in which is the inability of the film holder instrument to apply multiple techniques. Furthermore, the limited ability of the existing film holder instrument which only able to apply a single technique. Plus, there is the tolerance and comfort issue regarding the existing film holder instrument. Next, the repetitions in taking dental radiography need to reduce. Hence, information was gathered and studied from dental radiography, the techniques used in taking dental radiography, mechanical methodology, and material selection to ergonomic factors. The gathered information will be essential in the ideas generated to create the improved version of the film holder instrument.

2.2. Anthropometric Data for Mouth Cavity

Anthropometric data collection is a tool widely used today in design and development of a product [7]. As the project involved the mouth cavity, the anthropometric data was collected. The width and height of the mouth is collected for reference in designing the film holder instrument. The data is as followed in Figure 2.2 and showed a summary of previously reported mouth opening measurements [8]. From the data gathered, the measurement of 52mm was used as it is the maximum.

The width of the mouth cavity can be referred in Figure 2.3 [9]. The following dental arch width measurements were recorded between reference points of canines, between the first premolars, and between the first molars respectively: upper jaw: men: canines: 35.1 ± 0.13 mm; first premolars: 37.5 ± 0.13 mm; first molars: 48.1 ± 0.19 mm; women: canines: 33.4 ± 0.13 mm; first premolars: 35.6 ± 0.15 mm; first molars: 46.7 ± 0.19 mm [9]. The data was used as a guideline in the design.

Reference	Year	Mouth opening measurement, mean or range (mm)
Posselt[6]	1952	43.3
Braus[7]	1954	32–62
Shore[8]	1959	33–45
Nevakari[9]	1960	Men 57.5; Women 54.0
Travell[10]	1960	Men 59.0; Women 53.0
Posselt[11]	1962	50–60
Sheppard and Sheppard[12]	1965	46.9
Posselt[13]	1968	43.4
Ingervall[14]	1970	51.3
Ingervall[15]	1971	52
Bosman[16]	1974	Men 54.4; Women 53.6
Agerberg[5]	1974	Men 42–77(mean = 58.6); Women 39–75 (mean 53.3)
Rosenbaum[17]	1975	44.9
Rieder[18]	1978	Men 40–60; Women 35–55
Szentpetery[19]	1993	51.7

Figure 2.2: The height of the mouth cavity from previous study [8].

	control group (medical faculty students)			computer evaluation: patients before treatment			patients after therapy			recall after 5 years		
dental arch width	number of persons	mean	SE	number of persons	mean	SE	number of persons	mean	SE	number of persons	mean	SE
maxilla - men												
3 - 3	356	35.1	0.13	9	35.29	0.83	10	↑ 36.39	0.96	12	36.65	0.79
4 - 4	343	37.5	0.13	8	34.59	1.28	7	↑ 37.65	0.78	8	37.70	1.07
6 - 6	327	48.1	0.19	13	* 43.70	0.81	13	44.28	1.01	13	44.55	1.22
mandible - men												
3 - 3	358	26.4	0.19	10	26.53	0.62	11	27.03	0.57	12	27.11	0.59
4 - 4	-	-	-	7	29.09	1.04	9	31.05	0.56	11	30.72	0.90
6 - 6	-	-	-	12	38.64	0.69	12	39.83	0.62	12	40.26	0.76
maxilla - women												
3 - 3	327	33.4	0.13	16	33.62	0.39	22	↑ 34.53	0.39	23	34.02	0.33
4 - 4	312	35.6	0.15	16	34.91	0.46	16	↑ 36.06	0.30	16	↓ 35.20	0.50
6 - 6	318	45.7	0.19	24	* 44.12	0.45	24	43.86	0.55	24	43.40	0.53
mandible - women												
3 - 3	334	25.2	0.12	18	25.30	0.43	21	25.78	0.32	24	25.28	0.28
4 - 4	-	-	-	14	28.96	0.48	17	30.30	0.35	20	29.67	0.33
6 - 6	-	-	-	23	38.78	0.41	22	39.21	0.69	24	39.26	0.67

* significant difference in comparison to control group (P < 0.05)
↑ significant increase (P < 0.05)
↓ significant decrease (P < 0.05)

Figure 2.3: The data for width of the mouth cavity.

2.3. Concept Generation and Evaluation

Concept generation involves the generation of ideas that would be implemented to the product in order to solve the problem identified. Activities like brainstorming ideas based on the information

gathered, discussion and consultation were done to generate ideas. After the concept is generated, the concept would be consulted to the supervisor and would be evaluated based on morphological chart. Afterwards, multiple concepts were chose to be design to get the concept in a visual manner.

2.4. Embodiment Design

The embodiment design is the process of designing the product based on the concept generated and evaluated prior. The design was done by 3D CAD software called CATIA V5. When the design was done, the concept can be conveyed in a visual manner that made the visualization of the product based on the idea more clearly. This is the stage where multiple concepts were generated in a visual manner before carrying forward. With visual expression of the ideas, the concepts were evaluated and if one of the designs of the concepts meets the satisfaction, the concept is chose.

2.5. Detail Design and Analysis

The detail design is the process of refining the embodiment design of the chosen ideas or concept. This stage is crucial as criteria such as measurement, geometry and material to be used need to be agreed and decided.
Afterwards, design of the concept agreed was drawn and refined in CATIA V5 software before undergo analysis using the same software. The analysis process is where the product will be analysed to predict the product response to certain force that was applied. The analysis process for the project involves analysis to the critical parts of the product and would be tested for the displacement, deformation and Von Mises Stress. The critical parts that were analysed were film holder, bite block, arm and collimator and can be referred to in Figure 2.4.

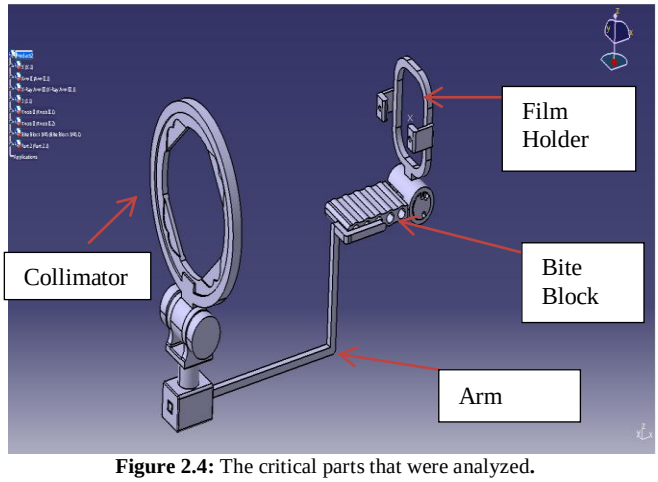

Figure 2.4: The critical parts that were analyzed.

The data from the analysis stage that were shown are from the improved design as the initial design had many complication such as the inability to align between the collimator and the film holder when different angle is applied as the height of the collimator cannot be locked at a specific height. The first part that was analysed was the film holder. The distributed load of 600N was applied to the top and front of the part as the part would be inside of the mouth cavity. The estimated applied load of 600N was used because the jaw force of a human is estimated to be in the range of 0-600N. Hence, the distributed force of 600N was used in the analysis of the part. The part is clamped at the bottom of the part. The part did not undergo any deformation after the loads were applied. The maximum displacement the part undergoes was at 59.5 mm and at the top of the part. The maximum Von Mises stress of the part was 3.85E8 N/m². Maximum stress occurred at the lower region of the part. The second part was the bite block. The bite block is the part where the patient bites during intraoral radiography. The distributed load of 600N was applied to the top and bottom of the bite block and also to the region in which the bite block was connected to the film holder. The part had deformation in the contact region of the bite block and film holder. The maximum displacement was 0.253 mm and it occurred in the same region as the deformation happen. Next, the maximum Von Mises stress of the part recorded was 8.84E7 N/m². Next, the part that was analysed was the arm. The arm was analysed twice with two different material, steel and ABS. This is done to compare the arm durability and strength between the two materials. The first arm analysed using the ABS material. The applied load was around 80N and the load value is the estimated maximum value of pinch of the hand. The arm had an obvious deformation in the region where it would be in contact with the bite block while the maximum displacement recorded was 47.5 mm. The maximum Von Mises stress occurred at the bottom intersection region of the arm at 2.22E8 N/m². The arm was again analysed with the steel material applied. Same distributed load was applied to the same region of the part and the deformation occurred is better than using the ABS material. The maximum displacement was 0.613mm which a drastic change compared to the ABS material. Meanwhile, the maximum Von Mises stress was 2.25E8 N/m². Lastly, the collimator was analysed as the part was assumed to be one of the commonly handled parts by personnel. The applied distributed load was 80N at the upper region and the front region of the collimator. There was a slight deformation to the structure of the part and the maximum displacement of 7.7 mm occurred at the upper region of the collimator. While the maximum Von Mises stress recorded at 3.03E7 N/m² occurred at the bottom region of the collimator. Overall, the analysis data can be referred in Table 2.1.

Table 2.1: The overall analysis stage data gathered**.**

Parts	Deformation	Displacement (mm)	Von Mises Stress (N/m²)
Film Holder	No	59.5	3.85E8
Bite Block	Yes	0.253	8.84E7
ABS Arm	Yes	47.5	2.22E8
Steel Arm	Yes	0.613	2.25E8
Collimator	Yes	7.7	3.03E7

Afterwards, the designs that passed the analysis stage will be prepared to be fabricated by 3D printing.

2.6. Product Fabrication and Testing

This stage involved two processes in which fabrication process and testing process. The fabrication process focused on the product fabrication via 3D printing using ABS material.
The testing process can be divided to two stages. The first stage is the product test in which the product is checked for deformities and according to the design. Next, the second stage is the clinical study. The product would be tested in real life situation in which the product will be tested to the patient in taking dental radiography. As the study involved the lives of patient, ethic approval is obtained from UiTM Research Ethics Committee. The person handled the study is Dr Yusmiaidil. For each Rinn holder, the number of patient tested is 30 people each. Overall, it consisted of 60 patients. There are no criteria of the patient that were tested and only those who volunteered. The criteria that were tested were the tolerance of patient and the effectiveness of the product. The tolerance of patient tested the comfort the patient experienced when the product is used. It would be measured using Visual Analog Scale (VAS) for pain severity measurement. The effectiveness of the product would be measured based on the repeat rate of the readings taken. The product would be tested at the faculty of dentistry in UiTM Sungai Buloh.

2.7. Design Improvement

Design improvement is a precautionary stage where the prior design is tested, produced unsatisfactory result and hence, the design would be improved as a correction to the product. Afterwards, the product undergoes the detail design and analysis stage again before it is fabricated once again.
As in previous design had the design flaw in which the collimator was not able to lock in places when dental radiography is taken, an improved design was done and can be referred in Figure 2.5. Changes were done to many parts of the product design. In the arm section, the arm design is improved while in the collimator section, the height of the section was able to be adjusted at specified height. In addition, each rotation of the collimator is labeled at specified angle to be able to differentiate the angle the collimator was position at. Overall, the numbers of part was nine and the additional part was in the collimator section correction.

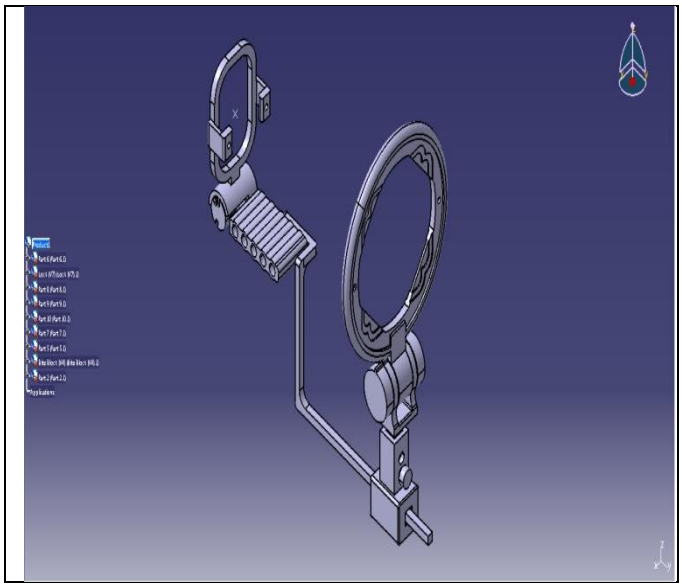

Figure 2.5: The improved design of the bisector rinn holder.

2.8. Data Collections and Analysis

This stage involved data and information after each testing of the design is collected before being analyse and produced result. The data and information gathered from the product testing would be compared to the existing product. A conclusion is drawn and recommendation can be suggested based on the result obtained. Hence, the project was concluded.

3. Results and Discussion

3.1 The Fabricated Product

In this process, the material used was ABS material. This design consists of nine parts and all would be fabricated using ABS material except for the arm that is made up from stainless steel and did not need to be fabricated. Initially, the arm is to be fabricated through 3D printing using ABS material but after comparison, it was agreed to use the available arm which was used in the available film holder instrument. In the existing rinn holder, the number of parts only consist of three in which the film holder, the arm and the collimator. The film holder is connected to the bite block while the developed rinn holder is not connected at all. Although the advantage is quite clear in terms of number of parts, but the inability of the existing rinn holder to apply multiple technique is a bigger disadvantage compare to the rinn holder developed. The final fabricated product can be referred in Figure 3.1.



Figure 3.1: The fabricated multiple angle of bisector rinn holder**.**

3.2 Tolerance of Patient

The first criteria tested were the tolerance of patient using the product.. This procedure involved the patient rate their comfort after the product is tested on the patients on a rate from no pain, mild pain and to moderate pain. In the test, the developed product was assigned as novel rinn holder while the available film holder instrument was assigned as conventional rinn holder.

Table 3.1: The number of patient assigned for each case of the tolerance toward the product.

Pain Scale	Number of Patients		Mean	Standard Deviation
	Conventional Rinn Holder	Novel Rinn Holder		
No Pain	19	17	18	1.41
Mild Pain	9	10	9.5	0.71
Moderate Pain	2	3	2.5	0.71

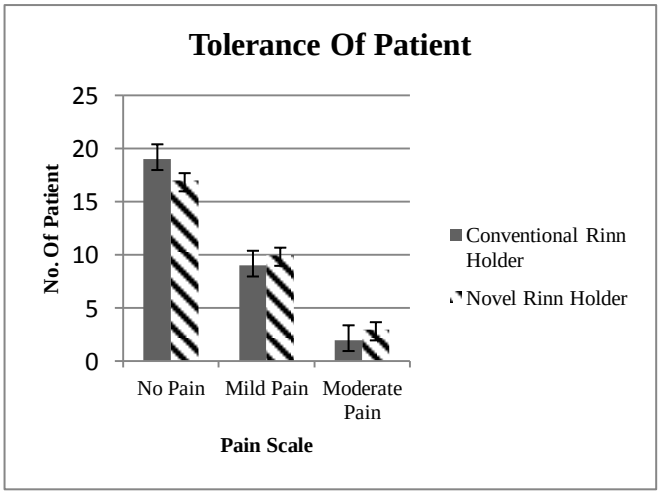

Figure 3.2: The bar chart that showed the number of patients for each tolerance for each rinn Holder.

Based on the Figure 3.2, and Table 3.1, the data gathered showed that the conventional rinn holder was slightly more tolerable than the novel rinn holder by 3.33% at 2/60 patients in the no pain scale. Plus, in the mild pain scale the novel rinn holder indicates 1.67% increase from the conventional rinn holder. Next, at moderate pain, an increase of 1.67% from novel rinn holder slightly less tolerable compared to conventional rinn holder. This is due to the design of the rinn holder that was different to the product developed and the angulation of the film holder that connect to the bite block. As the conventional rinn holder has a fixed shape and 90˚ angle, the difference in comfort is expected. Plus, the factor of the cavity size of the mouth among patients tested certainly played a role as the cavity size of the mouth is different between humans. The test is conducted among 60 patients in whom 30 were tested using novel

rinn holder while the other 30 was tested using the conventional rinn holder Nevertheless, both rinn holder produce more or less the same result and the tolerance of patient is almost the same with only a small difference.

Table 3.2: The number of patients tested for tolerance between genders in using the conventional rinn holder.

Pain Scale	Number of Patients		Mean	Standard Deviation
	Male	Female		
No Pain	7	12	9.5	3.54
Mild Pain	6	3	4.5	2.12
Moderate Pain	1	1	1	0.00

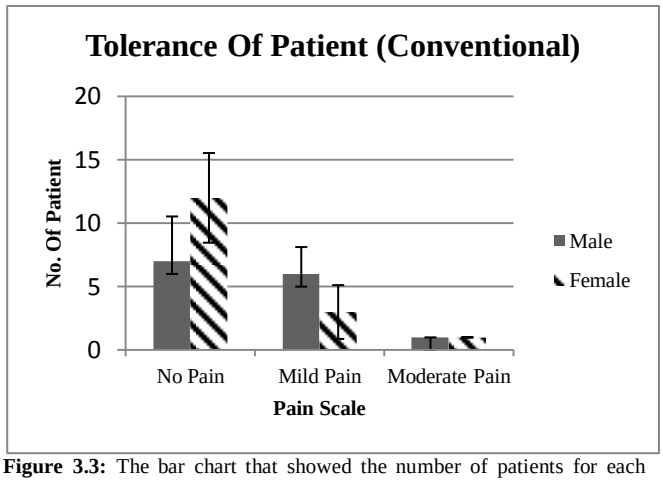

Figure 3.3: The bar chart that showed the number of patients for each tolerance based on gender using conventional rinn holder.

Next, the tolerance of patient is tested between genders in which 14 male and 16 female patients were involved. Based on the Figure 3.3 and Table 3.2, it can be concluded that the comfort for the conventional rinn holder for female is higher than male by 16.67% at 5/30 patients in the no pain scale. In the mild pain scale, the female showed a decrease of 3 patients among the 9 patients by 10% compared to the male. At the moderate pain scale, the male and female are at equal. In a nutshell, female can tolerate more using the conventional rinn holder compared to novel rinn holder due to their mouth cavity size. The conventional rinn holder is much more compact and the shape is much more tolerable for small mouth cavity.

Table 3.3: The data for the comparison between genders in using the novel rinn holder.

Pain Scale	Number of Patients		Mean	Standard Deviation
	Male	Female		
No Pain	10	7	8.5	2.12
Mild Pain	4	6	5	1.41
Moderate Pain	2	1	1.5	0.71

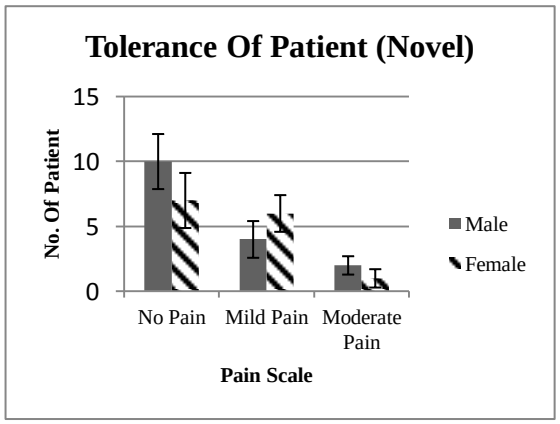

Figure 3.4: The bar chart that showed the number of patients for each tolerance of comfort based on gender using novel rinn holder.

As expected, for the novel rinn holder, the male is more tolerable to the product than the female by 3/30 patients at 10% in the no pain scale based on the Figure 3.4 and Table 3.3. At the mild pain scale, 4 out of 10 patients were male and showed that the novel rinn holder is more tolerable and the other 6 patients were female. At the moderate pain scale, the male has a higher intolerance towards the novel rinn holder by 1/30 patient at 3.33% compared to the female. The test is conducted among 16 male and 14 female patients. Hence, due to the male's mouth cavity size is bigger, the male is more tolerable to the novel rinn holder due to the ability of angulation. In short, both rinn holder is tolerable and gives enough comfort to the patients as there are no cases of gagging and feeling of nausea. The novel rinn holder is much more tolerable to the male because of the ability of angulation but the female is the opposite due to their mouth cavity sizes.

3.3 Effectiveness of the Developed Film Holder Instrument

The testing process for the effectiveness of the product is done by comparing the repeat rate for taking intraoral radiography for a patient using the product and was compared by the repeat rate for the available film holder instrument. Afterwards, the data was gathered and the information and data was used to compare the product and the available film holder instruments. In addition, the data is also compared between genders for the repeat rate. This is due to the difference size of cavity of the mouth between man and woman

Table 3.4: The number of patients for each repeat rate for the two rinn holders tested.

Repeat Rate	Number of Patients		Mean	Standard Deviation
	Convetional Rinn Holder	Novel Rinn Holder		
0	22	26	24	2.83
1	4	1	2.5	2.12
2	4	3	3.5	0.71

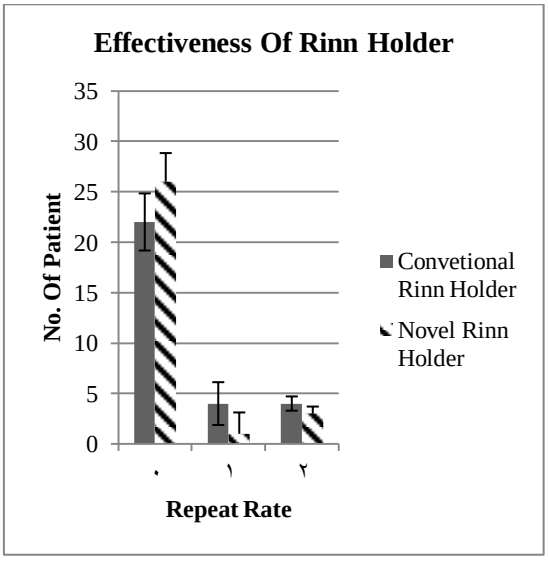

Figure 3.5: The bar chart that compared the two rinn holder repeat rate.

Based on the Figure 3.5 and Table 3.4, the novel rinn holder had less repeat rate than the conventional rinn holder. An increase of 4/60 patients at 6.67% of the novel rinn holder at 0 repeat rate compare to the conventional rinn holder. While 8/60 patients at 13.33% had repeat rate of 1 and 2 for the conventional rinn holder and 4/60 at 6.67% had repeat rate of 1 and 2 for the novel rinn holder. This showed that the product was more effective compared to the conventional rinn holder as they produced less repeat rate due to the ability to be at different angle certainly helped the efficiency of the product.

Table 3.5: The number of patients for repeat rate of the conventional rinn holder tested based on gender.

Repeat Rate	Number of Patients		Mean	Standard Deviation
	Male	Female		
0	10	12	11	1.41
1	2	2	2	0.00
2	2	2	2	0.00

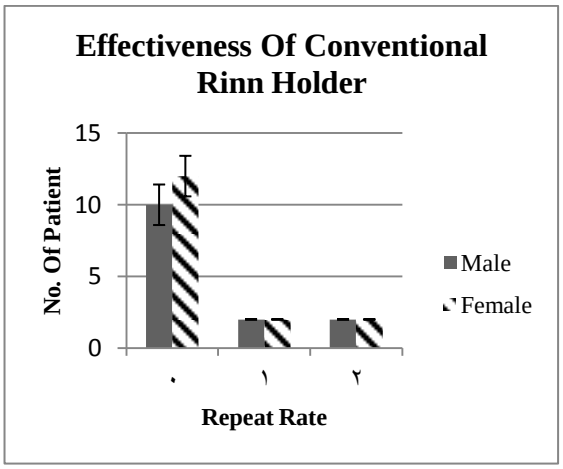

Figure 3.6: The bar chart that compared the conventional rinn holder repeat rate based on gender**.**

Next, the repeat rate between genders for the conventional rinn holder showed that the female patients produced less repeat rate than male patients. 12/16 female patient showed 0 repeat rate while 10/14 male patient showed 0 repeat rate which is an increase of 6.67%. At repeat rate 1 and 2, the male and female patients were equal at 4 patients each. The repeat rate was affected due to two factors, the movement of the patient during intraoral radiography and the film holder instrument itself. Plus, comfort played a factor that affects the efficiency of product between male and female.

Table 3.6: The number of patients for repeat rate of the novel rinn holder tested based on gender**.**

Repeat Rate	Number of Patients		Mean	Standard Deviation
	Male	Female		
0	14	12	13	1.41
1	0	1	0.5	0.71
2	2	1	1.5	0.71

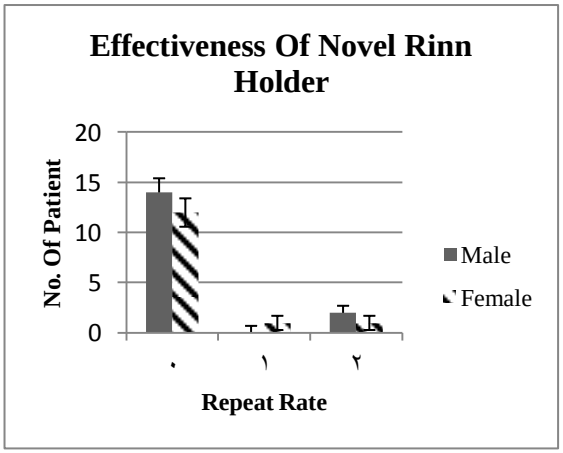

Figure 3.7: The bar chart that compared the novel rinn holder repeat rate based on gender.

Lastly, the novel film holder instrument produced less repeat rate in male patients than female patients based on the Figure 4.16 and Table 4.15.14/16 male patient indicated 0 repeat rate while 12/14 female patient showed the same repeat rate. This is an increase of 6.67% for the male patients. While 2/16 male had repeat rate while 2/14 female also had repeat rate. In short, the male is more suited to the novel rinn holder in terms of effectiveness.

In conclusion, both film holder instruments are effective but it can be concluded that the novel rinn holder is more efficient as the angulation produces better result and less repeat rate.

4. Conclusion and Recommendation

Over the course of this project, a prototype of the multiple angle of bisector rinn holder was designed, built and tested. The objectives of this project were achieved. The first objective was achieved as the developed film holder instrument was able to apply multiple oral radiography technique to a satisfaction. Next, the second objective was achieved as the effectiveness of the developed film holder instrument and tolerance of patient in intraoral radiography was studied. Lastly, the final objective which the best design for multiple angle of bisector film holder instrument was determined among the designs that were developed. In a nutshell, the developed multiple angle of bisector rinn holder need more improvement before it can be developed to be use by consumer. In order for the product to be in the market, the fabrication process need to be change and the design need to be render to suit the consumer to satisfaction according to relevant safety standard. Overall, the product is a step further in modern dental industry in creating an instrument that helps the personnel to get the best possible in intraoral radiography.

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