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Original Article

Design of Hospital Equipment Multiple Angle Bisector Rinn Holder

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Abstract *- The multiple-angle bisector Rinn holder is a film holder instrument capable of using paralleling and bisecting angles in oral X-ray radiography. The original film holder is medical equipment that has helped dentists identify and diagnose patients throughout many years by giving high-quality images in oral X-ray radiography. The techniques used in oral X-ray radiography are called the paralleling technique and bisecting angle technique, which require different types of film holders. Nik Amirul Khalid designed a previous prototype to tackle this problem. However, further improvements in the design will enhance the overall experience of using the device by improving its effectiveness. This project utilises the Solid Works software for the design stage and is fabricated using 3D printing. The results from the radiographic images are compared with those of existing instruments. The design created for this project was successfully analysed and improved using CAD Simulation software; hence, it could be implemented for real-world applications and improvement for the future. This effort shall ensure resource efficiency and the overall sustainability with respect to the cradle-to-grave manufacturing process. In addition, this project also managed to show the differences between fabrication using FDM 3-D printing and SLA 3-D printing. The outcome of this project was the effectiveness of the newly designed 00000000multiple-angle bisector Rinn holder compared to the original design.*

Keywords *- Bisector Rinn holder, Film holder, Oral radiography, Resource efficiency, Cradle to cradle.*

1. Introduction

Medical equipment has become a miraculous lifesaving engineering marvel as it provides a means to an end, with the end being disease prevention, disease correction, or disease rehabilitation. Nonetheless, advancements in medical equipment must be continuously researched as carefully or as thoroughly as the world moves towards a brighter future. Designing medical equipment combines methods from multiple sectors, such as the engineering specialities, independent certification and compliance firms, and governmental regulatory bodies [1]. In the medical field, particularly the dentistry field, radiography is frequently used to assess a patient's disease and symptoms and identify the best course of therapy. In radiography, the earliest discovery in medical equipment was made when Wilhelm Conrad Rontgen accidentally produced an image from the cathode ray generator in 1895 [2]. This discovery led Charles Edmund Kells, a dentist from America, to develop dental radiography and promote the use of X-rays in dentistry [2]. Charles Edmund Kells was also the individual who designed the film holder instrument that is still being used widely in the industry for radiographic imaging. This medical equipment has helped medical practitioners identify and diagnose patients for years. Nonetheless, continuous developments in oral X-ray radiography must be done to help the dental industry keep oral health and welfare in optimum condition [3].

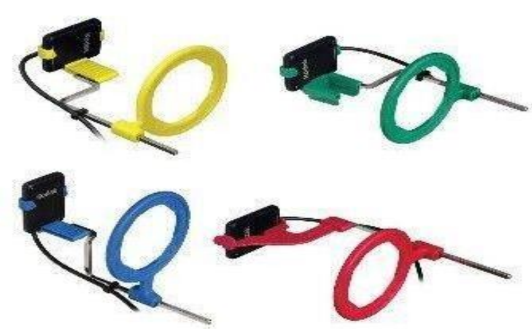


Fig. 1 Original design of film holder

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. The paralleling method has a geometrical advantage over the bisecting angle method and yields more accurate, consistent, and dependable results [3]. But in some situations, the bisecting angle technique is better, and it should be taken into account for high-quality images. Radiographic imaging is an important part of the primary diagnosis for endodontic treatment, as pathological conditions frequently present no clinical symptoms [4]. Dental radiographic imaging started in the late 1890s after a dentist named Charles Edmund Kells attended a presentation by Professor Brown Aryes on X-rays [2]. Kells used the knowledge obtained and conducted the first dental X-ray on a living person in mid-1896 [2]. This was the first attempted intervention at integrating radiography and dentistry.

Kells was also involved in designing tools for oral radiographs, such as the film-holding device [5]. The film holder designed by Kells used highly permeable materials, such as aluminium and rubber, to provide a clear image [6]. According to Kells, “It is essential that the object be as close as possible to the plate upon which it is to be produced, and simultaneously, their plane surfaces should be parallel” to achieve accurate mouth imaging [6]. The contributions of Kells in dental radiography are vital in further improving dental radiography to achieve better imaging. Kells put importance on the design of the film holder as it is vital to achieve an accurate image. Through Kells's efforts, dental radiography has continued to develop to ease the dental industry in keeping oral health and welfare in optimum condition [3].

The major design issues concerning the rinn holder generally fall under (i) ergonomics, (ii) patient comfort, and (iii) imaging accuracy. The details are as follows:

Firstly, it is on user-experience or patient-related issues. From the investigation made by this study, the rigid plastic bite block can be uncomfortable. This is especially true for patients with small oral cavities, as the default design is a “one-size-fits-all” and lacks adjustable features for different anatomical variations. This leads to gagging or an inability to hold the device steadily. Furthermore, for patients with limited jaw opening, Temporomandibular Joint (TMJ) disorders, or pediatric patients, these respective patients may find it hard to bite down on the holder correctly. In addition, the sharp edges of the bite block may irritate or cut the gingiva or oral mucosa during placement, resulting in unwanted soft tissue trauma. All of these shall result in an overall poor user experience.

Secondly, it is with respect to the dentist’s or practitioner’s related challenges. The default rinn holder design shall warrant that a proper alignment requires careful placement of the film/sensor, arm, and ring, which can be time-consuming and prone to errors for an inexperienced practitioner. On top of this, due to the time-consuming nature, the patient may move or exhibit variations of gripping during the entire process, which may result in blurred images and require multiple retakes.

Finally, from both patients’ and practitioners’ related issues, these shall be compounded, resulting in radiographic discrepancies. Examples of radiographic discrepancies are misalignment between the X-ray beam and the sensor/film, which leads to partial images, reducing diagnostic value, and incorrect angulation causes elongation or foreshortening of the image, compromising diagnostic accuracy. All of these shall negatively affect the radiographic qualities of the process.

This study aims to improve the existing design of the multiple-angle bisector Rinn holder. In achieving this aim, CAD Simulation software shall be utilized. Further improvements in the design will enhance the overall experience of using the device by improving its effectiveness. Th novelty of this study shall benefit user experience, diagnostic quality, and workflow efficiency. The novelty lies in integrating ergonomic and adaptive design features that improve usability and diagnostic reliability, which are not fully addressed by current static Rinn holder models. This study shall contribute to the 3rd and 8th United Nations’ 17 Sustainable Development Goals.

2. Techniques Used in Dental Radiography

The film's dimensions are influenced by the radiographic technique [4]. Different types of teeth require different techniques and methods when taking a radiographic image of the oral cavity. To achieve the best result, some teeth use the paralleling or bisecting angle technique [7]. Clinical practice uses the parallel imaging technique, which is a radiography procedure in which the X-ray beam is aimed perpendicularly at the patient's teeth [7]. In contrast, the bisecting angle technique makes use of Ciezkynski's rule, which stipulates that two triangles are equal if they have two equal angles and a whole side in common [8]. The principal X-ray beam's path in the bisecting angle technique is perpendicular to the angle formed by the film and the tooth's long axis [7]. The position of the patient’s head is also important in the bisecting angle technique, as it is critical for the upper or lower occlusal plane to be parallel to the floor [7]. Different techniques, which also use different instruments, are used to accommodate different tooth sets.

In the medical field, particularly the dentistry field, radiography is frequently used to assess patients' status and diagnose various diseases in order to decide the best course of therapy. Two radiographic techniques-the paralleling and bisecting angle techniques-have been used to record an image of the tooth and its root into a periapical film, as stated in endodontic research. The paralleling method has a geometrical benefit over the intersecting angle method and yields more accurate, consistent, and dependable results [3]. Nonetheless, in certain situations, the bisecting angle technique is better, and it should be taken into account to obtain high-quality images.

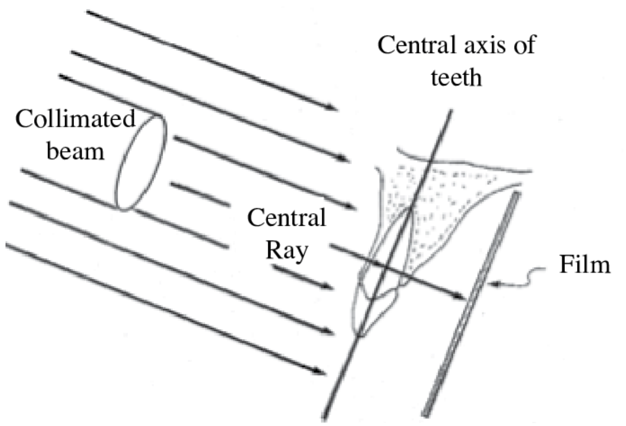


Fig. 2 Paralleling technique

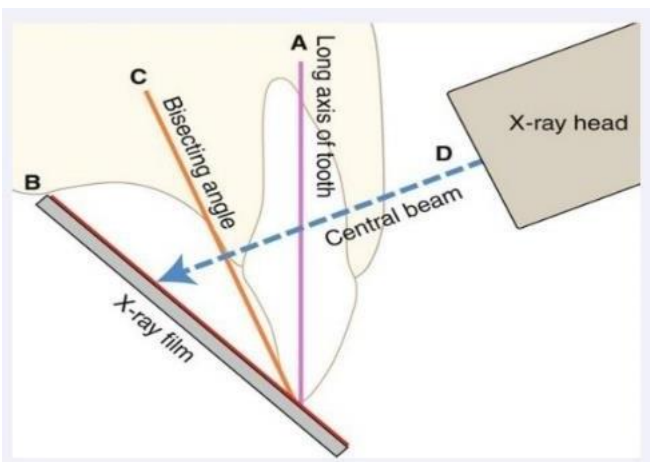


Fig. 3 Bisecting angle technique

Nik Amirul Khalid designed, built, and tested a multiple-angle bisector ring holder prototype. Before it can be made available to consumers, the bisector rinn holder's multiple angle needs to be improved further [3]. The fabrication method must be modified, and the design must be created to satisfy the customer without adhering to applicable safety regulations, before the product can be put on the market.

Thus, this study would like to review and analyse the prototype and further improve its design to enhance the experience of medical practitioners and patients using it. For this project, several objectives were recognised to set a goal to study and utilise the engineering design process to create a new design for hospital equipment, design the best modification to the bisector rinn holder to improve the prototype, and to provide a bisector rinn holder that can help ease the dental industry. This project's scope is to create and improve the current design of the film holder used for dental radiography. This design will provide medical practitioners with a more convenient way of conducting the paralleling and bisecting angle techniques used for dental radiography. This project will also focus on giving the patients a design that can further improve their comfort during the process. There are several limitations to this project. One limitation is that the film holder will be designed using the CAD modelling software Solid Works. This is one of the software programs capable of designing a working engineering model for the film holder. Next, the sizes of the oral cavity can differ between patients, thus creating a challenge in developing an accurate design that can provide the same comfort level to every patient. Finally, the fabrication process will use 3D printing.

3. Materials and Methods

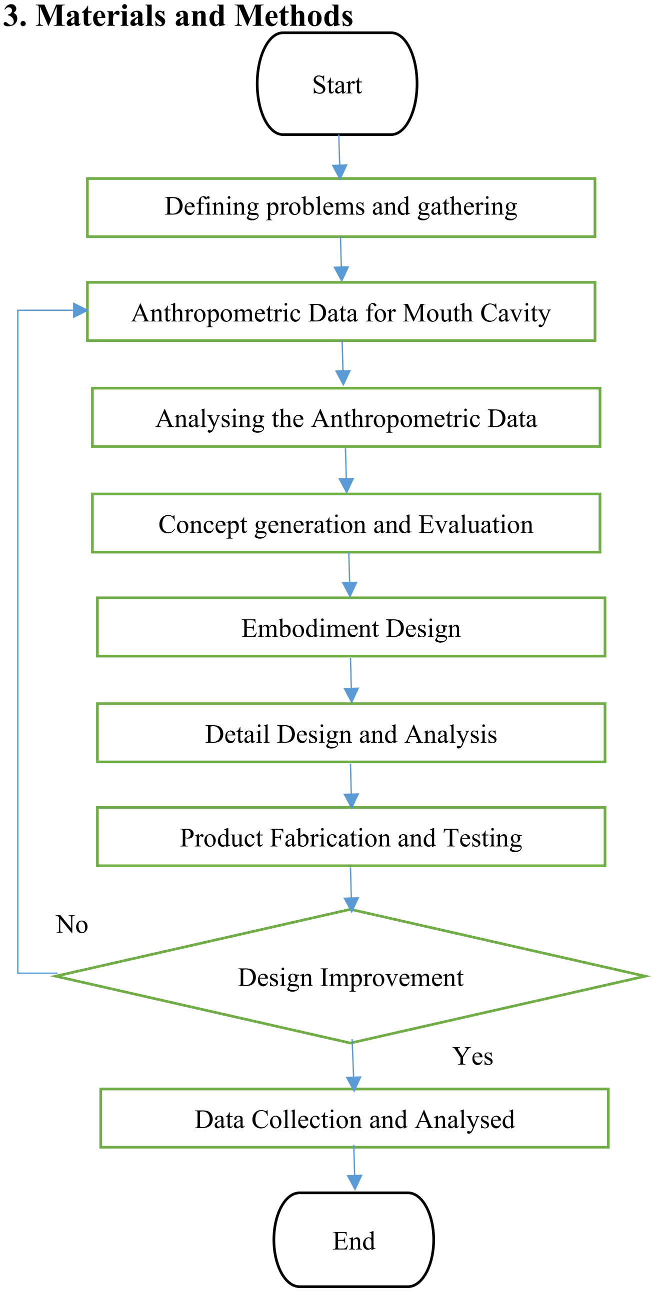


Fig. 4 Research flowchart

Figure 4 above is the flowchart for the whole project from start to end. This project will utilise the engineering design process while incorporating the anthropometric data for the mouth cavity used in previousresearch. The design process and data are important for this project as they help design a film holder capable of achieving its objectives.

3.1. Defining Problem and Gathering Information

The first step in the Engineering Design Process is identifying the problems and gathering information about the project. In this project's case, the problem identified is that the current design of the film holder is inefficient, needs multiple repetitions, and causes pain to patients. Thus, information regarding the design of Previous film holders and methods used for this process was gathered to understand the topic further.

3.2. Analysing Anthropometric Data for Mouth Cavity

The Anthropometric Data for the Mouth Cavity will be used in the design and development of the product [3]. This project will require data on the width and height of the mouth from previous research conducted to create an optimal and accurate design. The data will be taken from the last research, so that accurate data is used. From the data analysed, we can gather information that will be used to design the film holder.

Table 1. Height of the mouth cavity from the previous study [9]

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	43.2
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
Szentpetery19	1993	51.7

From the data gathered, we can refer to the figures above on the height and width of the mouth cavity. According to the data in Table 1, the highest measurement is 52mm, which is used as the maximum height for the film holder part, as it is the part that is inside the mouth cavity. Regarding width, Table 2 data displays canine points of comparison among the first premolars and first molars, respectively; upper jaw: Men's canines measure 35.1 ± 0.13 mm, whereas women's canines measure 33.4 ± 0.13 mm, first premolars measure 35.6 ± 0.15 mm, and first molars measure 46.7 ± 0.19 mm [10]. According to the data, the film holder's largest dimension is 47 mm.

3.3. Concept Generation and Evaluation

Concept generation and evaluation involve generating ideas to solve the problems identified. During this process, activities such as brainstorming ideas are conducted using previously gathered information. Several concepts are generated, and the best concept is chosen as the device's final design. This process also involves discussing and choosing the material used during fabrication.

The bisector ring holder has several critical parts, such as the film holder, bite block, collimator, and arm. These parts are vital to any film holder and must be present. Next, to generate the designs for this product, several designs were brainstormed and researched using previous and existing designs (see Table 3). A final design is generated using the best design for the parts. A morphological chart was constructed to lay out the multiple options for each vital design component.

From the morphological chart, a preliminary design for the new rinn holder will be created using the chosen options. For the film holder, option 1 is chosen as it is the simplest design and can hold the sensor andfilm together easily. This design is also used previously for the bisector rinn holder by Nik Amirul Khalid. Regarding material, option 2 is chosen as it is more durable and stronger than option 1, while also being more accessible compared to option 3.

The rotating mechanism is an important part of this design as it is the innovation applied to the previous design. Option 1 is chosen as it is a simple method that only requires slotting in the mechanism while still being effective. With option 1 it is easy to manage by just pulling it out in case of any damage or faultiness. The collimator shape is another important aspect of this design, as multiple shapes can be used. For dental radiography, option 3 is chosen as dental practitioners widely use it, and it willnot experience any compatibility problems.

3.4. Embodiment Design

Next, embodiment design is where the product design starts using the concept generated in the previous section (see Figure 5). The 3D CAD software Solid Works was used for this project to design the device. This process is important as it provides a concept that can be seen visually to provide a clearer vision of the device to be created. By having a visual concept, further improvements to the design can be made and implemented for the final product.

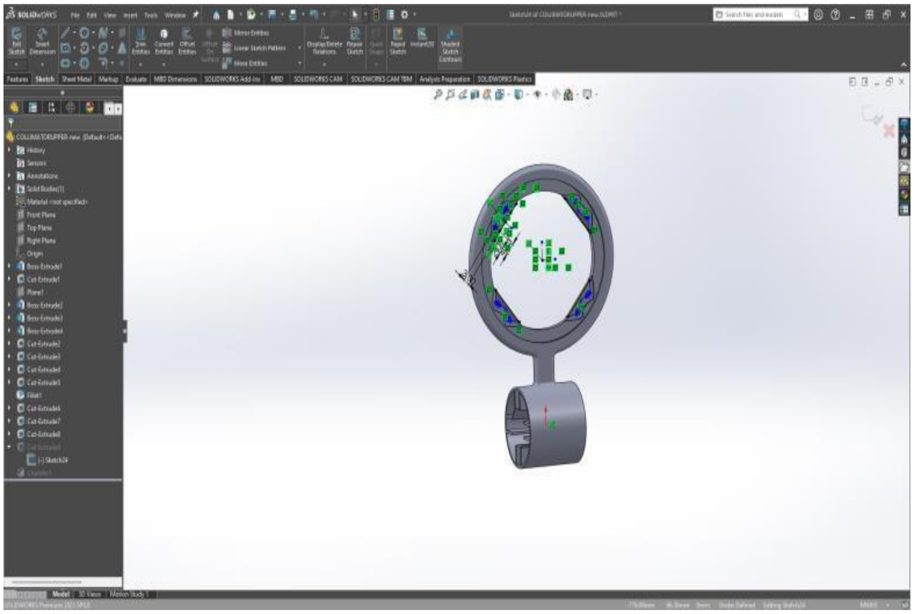
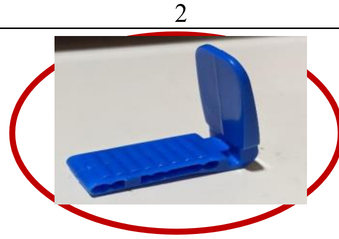
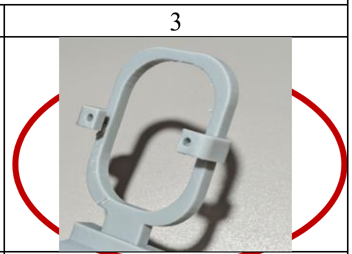


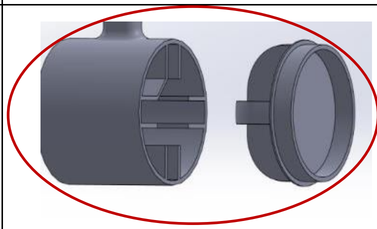
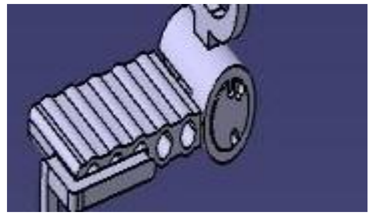
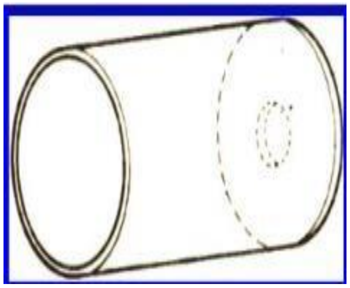
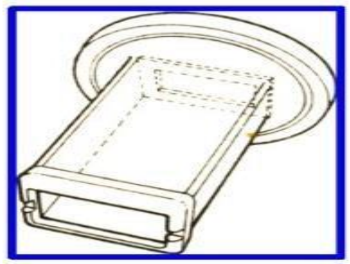
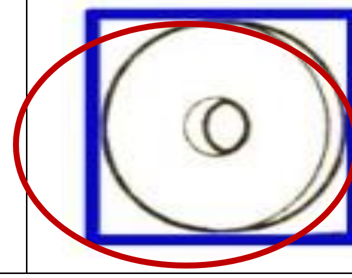
Fig. 5 Designing parts of the design using solid works

Table 2. The width of the mouth cavity from the previous study [10]

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	37.7	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	0.9
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	0.3	16	↓ 35.20	0.5
6 - 6	318	45.7	0.19	24	* 44.12	0.45	24	43.86	0.55	24	43.4	0.53
mandible - women												
3 - 3	334	25.2	0.12	18	25.3	0.43	21	25.78	0.32	24	25.28	0.28
4 - 4	-	-	-	14	28.96	0.48	17	30.3	0.35	20	29.67	0.33
6 - 6	-	-	-	23	38.78	0.41	22	39.21	0.69	24	39.26	0.67

Table 3. Component design alternatives

Components	Options		
	1	2	3
Film Holder			

Material	PLA Plastic	ABS Plastic	Resin
Rotating Mechanism			
Collimator Shape			

The initial design of the bisector rinn holder was done completely on Solid Works, as it is the easiest and simplest software to use. The dimensions used for the design were completely based on the dimensions from the original film holder, as several parts require specific sizes. The anthropometric data is also considered during the designing phase, as it is important to create a design that ensures comfort for both the handler of the device and patients.

3.5. Detail Design and Analysis

Detail design and analysis is the process by which the design made during the embodiment of the design is improved. During this process, design analysis will also be conducted by conducting tests on displacement, deformation, and Von Mises Stress. This is done to predict how the design will react to forces applied to the final product. The data collected will then be used to improve the design. After conducting the stress analysis and stress test, the design did not encounter any failures. Thus, the design then undergoes a fabrication process (see Figures 6 to 8).

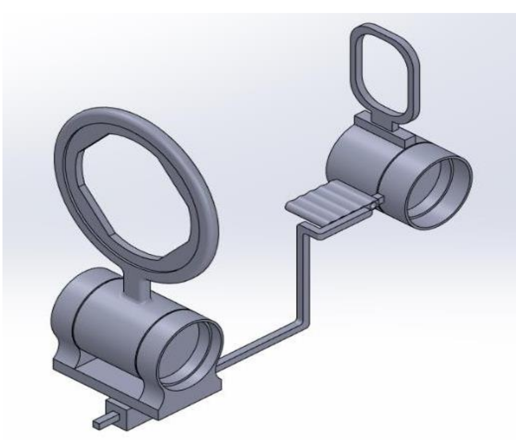


Fig. 6 Final design of the new bisector rinn holder

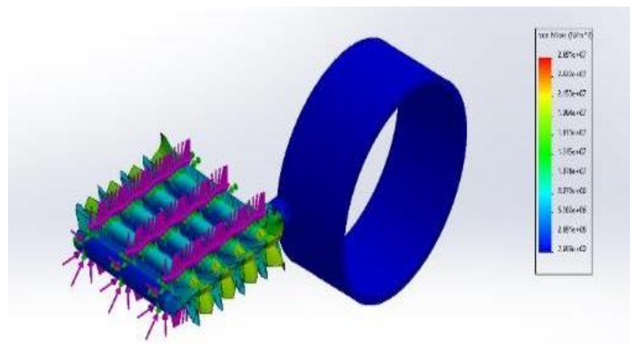


Fig. 7 Stress test on bite block

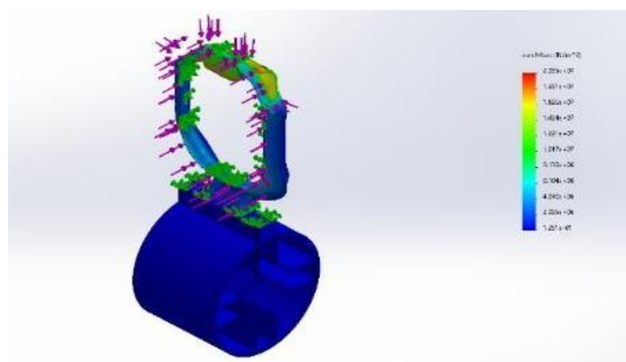


Fig. 8 Stress test on film holder

3.6. Product Fabrication

In the product fabrication phase, the design is fabricated into the product for testing.For this project, the product will undergo fabrication through 3D printing. The first fabrication for this product will be conducted using ABS Plastic and an FDM Printer. During the pre-processing of the fabrication process, it was found that the material used for the design would undergo failure and could not replicate the complex shape of the collimator. The 3-D printed part will not replicate the original design due to the number of supports it will need.

Several parts of the design encountered the same problems, and thus, changes were made to ensure the fabricationprocess could continue smoothly. For the next batch, the material was changed from ABS Plastic to SLA Resin for the design. This is dueto the complex shape of the rotating mechanism, and the collimator requires strong support for the 3-D printing, so that it does not fail. The SLA printer creates solid objects using a laser beam to photopolymerise monomers [11]. This also requires the usage of an SLA 3-D Printer instead of an FDM Printer. Resin as a material is much stronger than ABSPlastic, and the SLA Printer prints faster than the usual FSM Printer. The material is also able to replicate complex shapes accurately (see Figures 9 and 10). The post-processing of the fabrication process consists of cleaning the printed parts, as the Resin needs to becleaned using alcohol and dried under UV light. This was followed by cleaning any excess and support materials used during the process. The process time for this fabrication phase was very smooth, and the parts were successfully printed. The results from the fabrication process can be seen in the images below (see Figures 11 and 12).

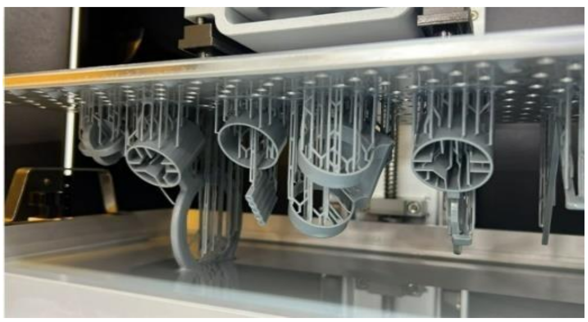


Fig. 9 Fabrication of parts using SLA printer

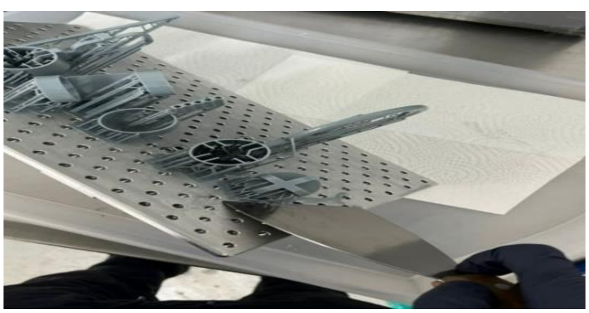


Fig. 10 Removal of parts from the metal plate

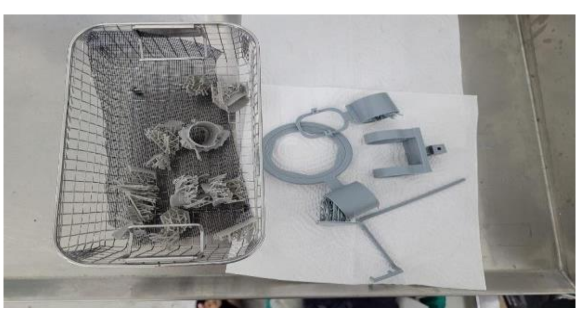


Fig. 11 Removing any excess parts of the product and cleaning with an alcohol solution

Fig. 12 Drying parts under UV light

3.7. Design Improvement

Design improvement is the very last phase of this project, as it uses the information and data gathered during the test phase. The tests conducted in the previous phase will help decide what improvements can be implemented. After the last batch of fabrication, several problems were noticed, such as the fitting for the design could not fit the intended parts. This might have been due to the material used and the tolerances not fitting.Another problem was also noticed: the size of the film holder and bit block when connected is ±65mm, which cannot fit the mouth cavity. This was due to a mistake during the design and an oversight of the size. Changeswere made to fit the parts and the design for the film holder and bite block.

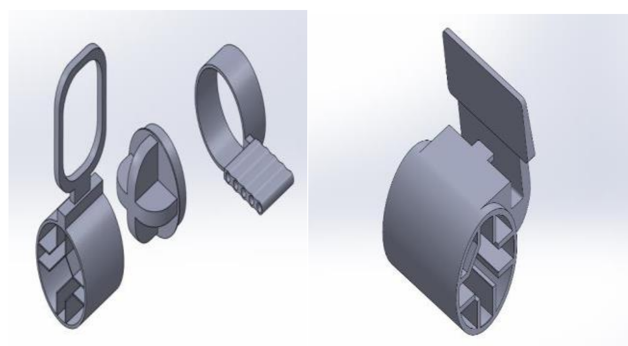


Fig. 13(a) Previous design of film holder, and (b) New design of film holder.

The rotating mechanism connects the bite block and film holder and uses the exact sizes of the collimator and collimator holder. Thus, to fix the issue, the size of the rotating mechanism was made smaller. The design was completely changed for the film holder, as it is impossible to create the same design for the film holderand make it less than 35mm±. The design was altered using a more current design of the film holder that slots the film in between a small slit (see Figure 13). The bite block did not undergo any design change, as the size did not affect the height of the part. For the fitting issue, several dummy parts were made to ensure sufficient changes were applied to the design before fabrication. The first dummy part used 0.15mm, followed by 0.20mm and 0.25mm. After several tests, it was decided that 0.25mm was the best tolerance for the design as it ensures the parts fit and does not affect other connected parts. A method also used was chamfering the edges, which allows a small clearance for the parts to fit at the entrance. Figure 14 shows the final prototype made.

Fig. 14 (a) Fabricated design using SLA printing, and (b) Prototype using all Resin material.

3.8. Data Collection and Analysis

At the end of this project, data analysis, such as the Von Mises stress and displacement test, between the previous design and the current design is compared to see any difference in material strength and deformation. This is important as it helps provide further information on what parts can be improvedand redesigned to strengthen them. All the data can be identified in the section below.

4. Results and Discussion

The testing sessions found that the arm's resin-printed part is unstable and does not allow the collimator and film holder to be parallel to each other, which is important during the X-ray process. The Von Mises Stress and Displacement Stress Test was conducted for the design analysis using Solid Works Simulation software. This analysis helps in analyzing the critical parts of the product. The tests were done on the ABS Plastic and Resin parts to test the difference when using different materials. A stress test using steel material was also conducted for the arm since steel is widely used for film holders.

Table 4. Performance of parts produced

Parts	Deformation	Material	Displacement (mm)	Von Mises Stress (N/m^2)
Bite Block	Yes	ABS Plastic	8.628E-03	2.542E+07
	Yes	Resin	8.416E-05	3.013E+07
Collimator	Yes	ABS Plastic	3.520E-01	2.377E+07
	Yes	Resin	1.322E-02	3.201E+07
Film Holder	Yes	ABS Plastic	2.870E+00	1.487E+08
	Yes	Resin	5.787E-01	2.978E+08
Arm	Yes	ABS Plastic	6.245E-03	5.998E+07
	Yes	Resin	4.809E-02	3.049E+07
	Yes	Steel	7.7E+00	2.250E+8

Table 4 above shows the differences between the materials in Von Mises Stress and Displacement. For each part, ABS Plastic has a higher displacement than Resin. This shows a big difference in the stress analysis when using other materials for the design. The same can be said with the Von Mises Stress Test, as it can be analysed that the Von Mises Stress for Resin is higher than the results for ABS Plastic.

Table 5. Comparison of the improvement with the existing design

Parts	Von Mises Stress (N/m^2)		Displacement (mm)	
	Previous Design	Current Design	Previous Design	Current Design
Bite Block	8.84E+7	3.013E+07	2.530E-01	8.416E-05
Collimator	3.03E+7	3.201E+07	7.700E+00	1.322E-02
Film Holder	3.85E+8	2.978E+08	5.950E+01	5.787E-01
Arm	2.22E+8	3.049E+07	4.750E+01	4.809E-02

Table 5 compares the previous design of the Bisector Rinn Holder, designed by Nik Amirul, with the Bisector Rinn Holder designed for this project. From the data gathered, it can be observed that for the Von Mises Stress test, the previous design had a higher stress value, while the current design was slightly lower for the Collimator, Film Holder, and Arm. For the Bite Block, there is a significant difference of 5.82E+7N/m2 between the previous and current designs. Regarding displacement, the previous and current designs differ significantly for all parts. The current design for the parts recorded a much lower displacement value than the previous design.

5. Discussion

After analysing the stress analysis results, several points can be identified in the design of the parts that use Resin as the material. The first part to be discussed is the film holder. The distributed load applied on the part is 600N. The film holder is placed inside the mouth cavity, and a human's estimated jaw force is between 0 and 600N.

From the results obtained, the maximum stress the film holder can withstand before deformation is 2.978E+8N/m2. The result from the stress test shows that deformation will occur on the top and front parts of the film holder. The part does not encounter failure when the maximum stress is applied. The next part is the bite block, which uses 600N as its distributed load. This is because the bite block is where the patients bite to hold the film holder in their mouth cavity. Thus, their jaw force is applied to the part. The load is placed on the top and bottom parts of the bite block (see Figures 15 and 16).

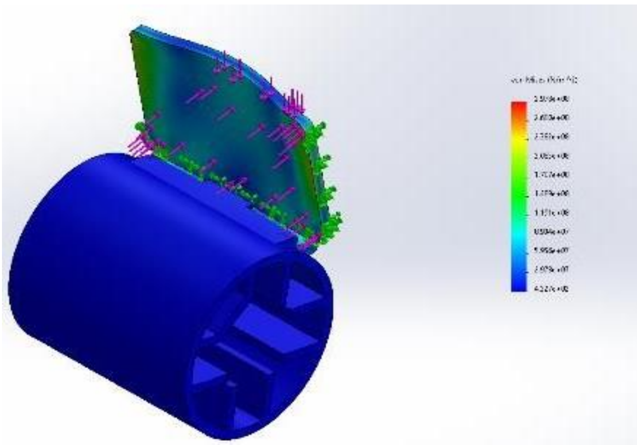


Fig. 15 Von mises stress test for film holder

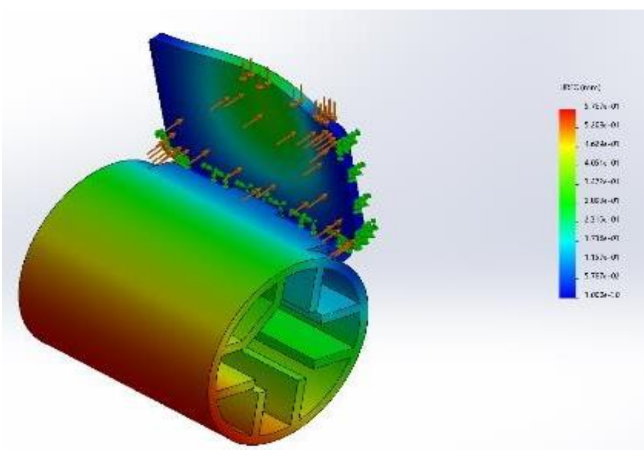


Fig. 16 Displacement test for film holder

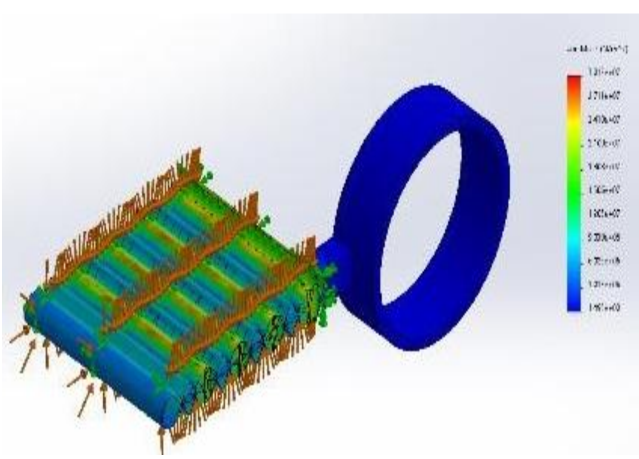


Fig. 17 Von mises stress test for bite block

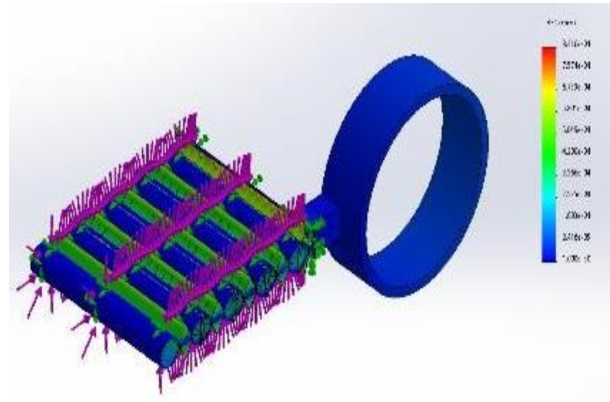


Fig. 18 Displacement test for bite block

For the bite block, the maximum stress of 3.013E+7 is required before the part deforms, while the maximum displacement is 8.416E-4mm. The deformation occurs in the hole into which the arm is slotted. This might have been caused by the lack of support inside the hole of the bite block. An improvement on the design would be to design supports throughout the hole to ensure they are supported. The next part that is analysed is the collimator, and a distributed load of 80N is applied to the outer and front parts of the collimator (see Figures 17 and 18). This is because the collimator is mostly handheld by users.

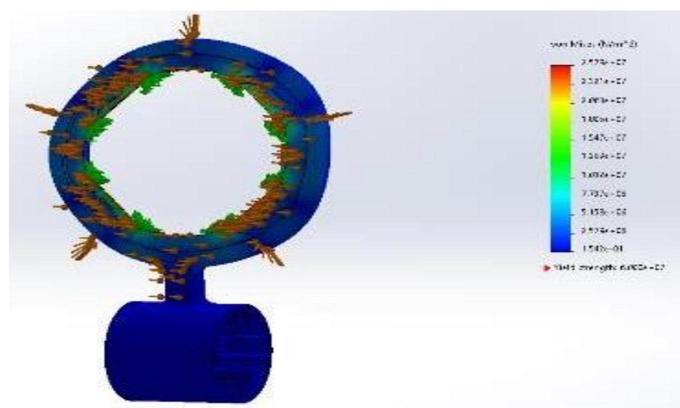


Fig. 19 Von mises stress test for collimator

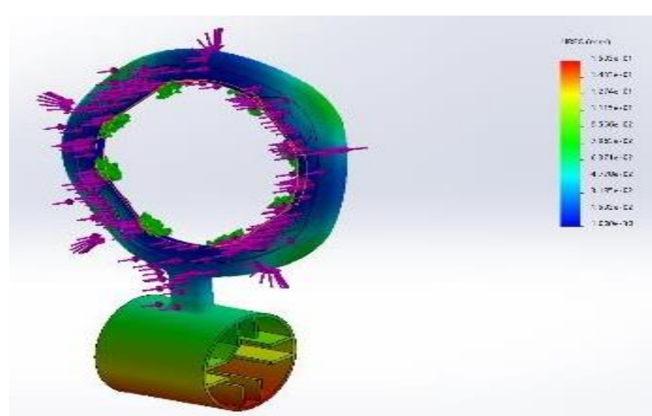


Fig. 20 Displacement test for collimator

After the stress analysis test, a maximum stress of 3.201E+07 N/m2 is needed to create deformation on the part, while the displacement is 1.322E-02 mm. The deformation can be observed on the front region of the collimator and the surrounding edges. The final part analysed is the arm for the rinn holder [12]. The arm is also handheld, similar to the collimator. Thus, a distributed load of 80N was applied on the top and sides of the part (see Figures 19 and 20).

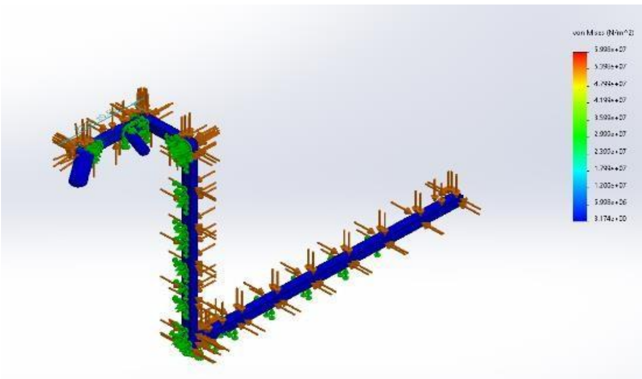


Fig. 21 Von mises stress test for arm

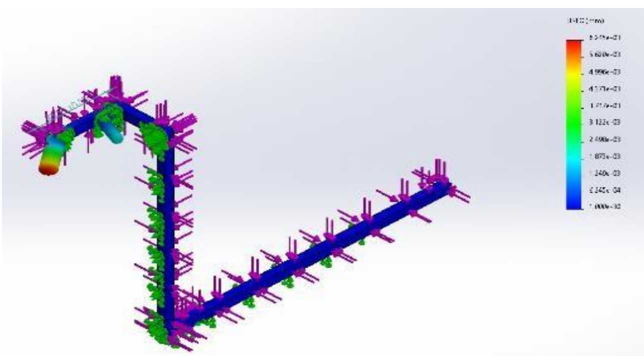


Fig. 22 Displacement test for arm

The arm encounters deformation on the top part of the design. The maximum stress needed for the part to deform is 3.049E+07, while the deformation that occurs is 4.809E-02. For the arm, the resin-printed part does not hold the film holder and collimator well, as it cannot align the two parts parallel [13]. For this reason, the arm must use steel to ensure that he collimator and film holder are parallel (see Figures 21 and 22). For future studies, other approaches in the fundamentals of engineering design could perhaps be considered. For instance, the study by Ali et al. [12] incorporates a modern design thinking approach in their studies [14, 15]. Other than that, 3D printed components or prototypes could be tested by new testing methods, such as the study by Ismail et al. [15]. Application of smart and sustainable materials (or waste material) as shown by [16] and [17]. This will improve the operational ability and reduce the weight of the product, whilst ensuring responsible consumption.

6. Conclusion

The aim of this study is to improve the existing design of the multiple-angle bisector Rinn holder. In achieving this aim, CAD Simulation software shall be utilized. This project has utilized the engineering design process, which helped further the design process. The design created during the duration of this project was successfully analysed using CAD Simulation software to identify any further improvements that can be implemented for future reference. Anthropometric data were also referred to during the designing phase of this study; thus, this enabled the creation of a novel product that ensures comfort for both the practitioner and patient. This project also successfully demonstrated the differences between fabrication using FDM 3D printing and SLA 3D printing. Further improvements in the design will enhance the overall experience of using the device by improving its effectiveness. The novelty of this study shall benefit the user experience, diagnostic quality, and workflow efficiency. The novelty lies in integrating ergonomic and adaptive design features that improve usability and diagnostic reliability, which are not fully addressed by current static Rinn holder models. This study shall contribute to the 3rd and 8th United Nation's 17 Sustainable Development Goals.

For future studies, the following recommendations are made:

- Clinical validation could be made with a real-world application.
- Material and manufacturing-related research.
- Ergonomic and usability studies.
- Technological integration into existing design.

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