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Original Research

Design and Prototyping of Portable Tabletop Cassette Holder Support in X-Ray (CASIX)

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ABSTRACT

Lateral X-ray, is a medical imaging technique that involves capturing X-ray images from the side of the body or a specific body part. In a lateral X-ray, the X-ray beam is directed laterally, with the central ray perpendicular to the midsagittal plane. Positioning of the cassette on the table for lateral image projection requires the patient to hold the x-ray cassette during the examination. This can be challenging for patients with certain physical conditions and may cause unnecessary radiation exposure. Therefore, this study proposed a prototype for lateral X-ray imaging. The prototype was designed using 3D-modelling software, SOLIDWORKS, and subsequent prototyping for a portable tabletop X-ray cassette holder addressing patients' difficulties in holding cassettes during clinical examinations. The prototype was developed with the inclusion of an adjustable fast-locking mechanism, caster wheels for mobility, and an innovative adjustable arm for flexibility. A prototype demonstrates the potential benefits, emphasizing improved efficiency and patient comfort. Future development involves using durable materials and conducting comprehensive usability tests to refine the design for practical clinical application. Overall, the prototype offers a promising advancement in lateral X-ray imaging technology.

INTRODUCTION

Lateral x-ray, also known as lateral radiograph, is a type of medical imaging technique in which its projection is taken with the central ray perpendicular to the midsagittal plane. It provides a side view of the body or a specific body part. Lateral X-ray image projections are commonly obtained in examinations of the spine, chest, abdomen, extremities, knees, traumatic cases, and upon specific request by the radiologist (Faro et al., 2004; Almazedi et al., 2011). Positioning of the cassette on the table for lateral image projection requires the patient to hold the x-ray cassette during the examination. This can be challenging for the patients with certain physical conditions, some patients do not have enough strength to hold the cassette steady which will produce weak x-ray images because of tremulousness. Therefore, this paper introduces a tabletop x- ray cassette holder design that could ease the lateral image projection issue in x-ray imaging. This will be achieved by 3D designing and developing a prototype of a portable tabletop x-ray cassette holder for lateral imaging known as Cassette Support in X- Ray (CASIX).

According to a study published in the Journal of the American College of Radiology, approximately 62 million X-rays are performed in the United States each year (Abalo et al., 2020). Of these, it is estimated that about 20 % are lateral x-rays (Johnston et al., 2019). This means that around 12.4 million lateral x-rays are performed annually in the US. The utilization of a lateral x- ray stands as an invaluable diagnostic resource

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when assessing individuals with injuries, furnishing crucial insights into the condition of the thoracic cage, pleura, lungs, pericardium, heart, mediastinum, and upper abdominal region (Gaber et al., 2005). In the realm of chest trauma, employing a lateral perspective proves instrumental in discerning diverse injuries, including fractures, irregularities in the costophrenic angles, or other bone anomalies within the thoracic cage (Gaber et al., 2005; Ittyachen et al., 2017). Additionally, it has the capacity to furnish essential insights into the heart, lungs, pleura, and mediastinum, areas that might be impacted by the injury itself or the corresponding therapeutic interventions (Gaber et al., 2005; Dentagama., 2022).

There are four primary reasons necessitate the utilization of a lateral chest x-ray in individuals who have sustained injuries (Faro et al, 2004), which are: (a) Localizing a lesion seen on the frontal CXR, (b) Clarifying lobar collapse/consolidation, (c) Exploring a retrosternal or retrocardiac shadow, and (d) Confirming the presence of encysted fluid. For individuals experiencing significant blunt trauma, a chest x-ray, particularly the lateral view, may not offer added advantages in comparison to CT (computed tomography) scans, which are deemed more superior in these instances (Gaber et al., 2005). Nonetheless, lateral chest x-rays retain utility in specific scenarios, such as when CT scans are unavailable or contraindicated (Ittyachen et al., 2017).

Cassette holder is an equipment that maintains or fixes the position of an x-ray film cassette or computed radiography (CR) cassette during an x-ray medical imaging procedure. Cassettes are employed to ensure that the process is uncompromised, and the best image can be produced while ensuring both examiners and patients are exposed to x-rays radiation as minimal as possible. Imaging plates and films need to be exposed to radiation. Even though there is regarded to be minor risks to the patient, dentist, or radiologist, the shorter the exposure period, the better. X-ray cassettes shorten exposure times by facilitating the operator's ability to capture a high-quality image more quickly (Dentagama., 2022). Tabletop cassette holders achieve the same thing and can aid in the patient's comfortability during x-rays process without moving too much. These kinds of cassette holders are intended to lessen the radiation exposure that patients and medical personnel receive. The cassette can be tilted and moved into any required position, and they can be placed behind an upright patient (Dentagama., 2022).

MATERIALS AND METHOD

The essential elements that were carried out in this study was as shown in Fig 1, that shows the flow chart of the research methodology for the development of portable cassette holder prototype. The project was stated with pre-market survey on the existing cassette holder and followed by a user need assessment in a health clinic facility at the medical imaging department. Based on the findings from these two steps, conceptual design of the prototype was developed using 3D-modelling software, SOLIDWORKS. Finally, the prototype was developed using selection of suitable material for the prototype.

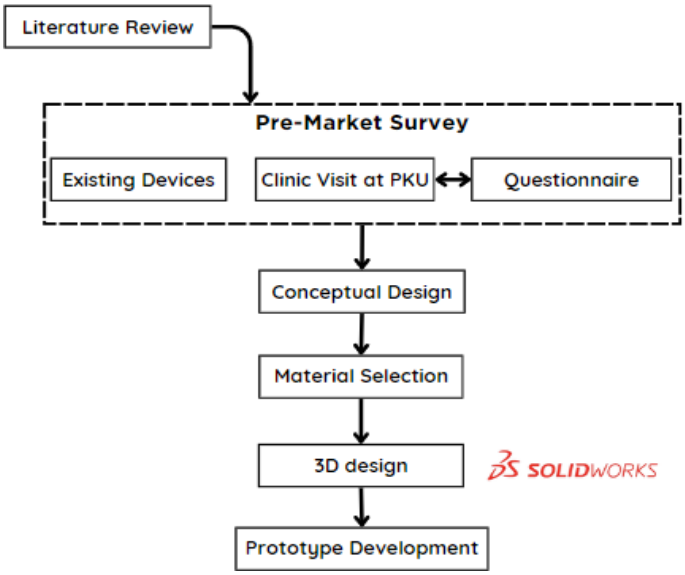

Fig 1 Flow chart of the research methodology.

Pre-Market Survey

Pre-market survey was conducted on a selection of four existing tabletop or lateral x-ray cassette holders in the market to identify the strengths and weakness in existing products and understanding the features and improvements needed to be included in our design. The review criteria focused on flexibility (size accommodation), ease of use (locking mechanism), and mobility.

Table I summarizes the results of the existing product in the market for cassette holder. Based on results, key features were lacking across existing devices, including a fast-locking mechanism, adjustable height/angle, and enhanced mobility. These deficiencies directly impacted clinical efficiency, particularly during high-volume periods, and thus were critical considerations in the development of the proposed CASIX prototype design.

Table 1 Comparative Analysis of Four Existing Devices in the Market for Cassette Holder

Brand \ Features	Adjustable to different X-ray sizes	Mobile	Fast lock mechanism	Suitable size
Techno-Aide's Tabletop Deluxe Cassette Holder	/	X	X	X
Techno-Aide's Mobile CR/DR Panel Holder	/	/	X	X
X-ALMOR Tabletop Cassette Holder	/	X	/	/
QR-LCH Rolling Lateral Cassette Holder	/	/	/	X

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User Need Assessment

A clinical visit took place at medical imaging department of PKU (UTM Health Centre) to further understand the radiographers' needs for lateral X-ray tabletop cassette holders and evaluate existing devices (if any). Based on the clinical observation, several considerations were pointed out by two radiographer from the medical imaging department for the design of lateral x-ray cassette tabletop holders. The feedback session was conducted informally via an observational study and a structured interview lasting approximately one hour with the staff involved.

Firstly, in term of flexibility, the design should fit multi sizes and different types of cassettes (computed radiography and digital radiography). 3 different sizes were available in the clinic: (a) 35 cm × 35 cm, (b) 25 cm × 30 cm, and (c) 25 cm × 22 cm. Therefore, the proposed design should at least accommodate those sizes. Moreover, another consideration was the use of a fast and safe locking mechanism. During rush hours, radiographers took hundreds of X-ray images per day, therefore, the design requires a locking mechanism that allows for fast inserting and taking out X-ray cassettes for improved efficiency. Lastly, the use of durable and radiolucent materials (x-ray absorption must be as minimal as possible).

Conceptual Design and 3D Modelling of the CASIX Prototype

Based on the pre-market survey, a conceptual design was developed. To accommodate different x-ray sizes efficiently, the CASIX prototype was required to implement an adjustable fast locking mechanism, consisting of two handles that can be pulled away from each other to insert the x-ray cassette. The two handles were connected to each other using a coil spring, which will pull the holders back to their original size once the x-ray cassette was removed. The base of the cassette holder was securely attached and build to withstand the load when the holder was holding the x-ray cassette. The cassette holder drawing can be seen in Fig 2 (All sizes are in cm).

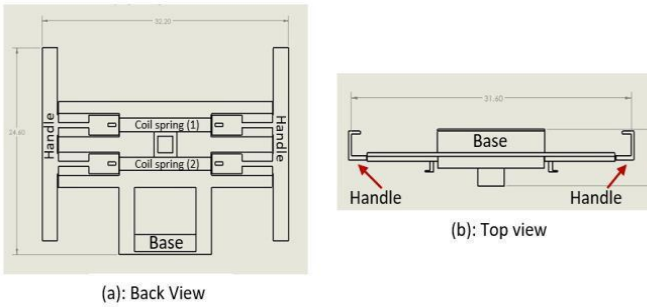

Fig 2. Cassette holder: (a) back view and (b) top view.

Moreover, to accommodate for a mobile x-ray cassette holder design, a base with four caster wheels was designed. The caster wheels were equipped with a quick locking mechanism for safety and stability during examination. Instead of using a static vertical rod between the holder and the base, the CASIX prototype has considered to have an adjustable arm to provide flexibility in term of the height, angle, and position of the device. Additionally, by using an arm, the device can be either attached to the wheels if mobility is needed, or can be placed to the side of a x-ray table (similar to table microphone arms). The addition of an adjustable arm also allows the device to be folded, for easier storage weather under the x-ray table or in the equipment room. The complete drawing of the conceptual design can be seen in Fig 3.

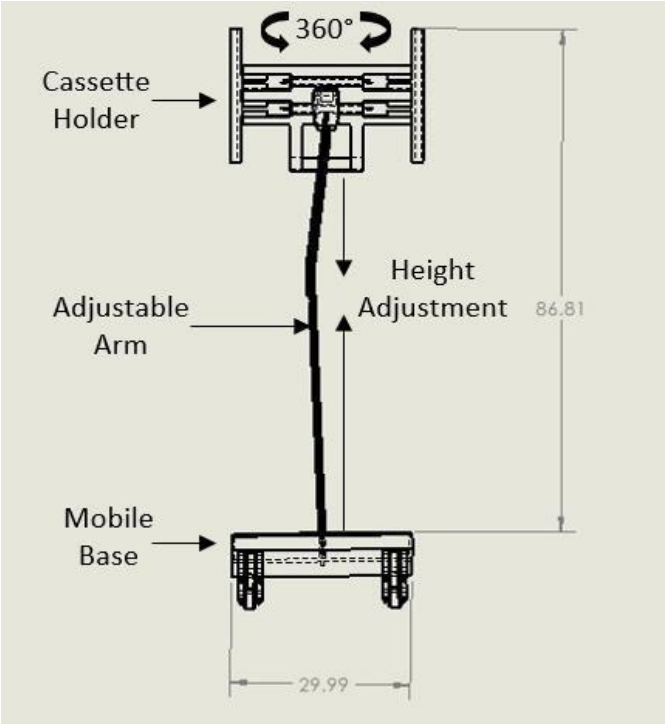

Fig 3. Conceptual design drawing.

The prototype of the portable tabletop x-ray cassette holder was first developed using 3D computer-aided design (CAD) to visualize and refine the overall structure of the product. The design process was carried out using SOLIDWORKS, which enabled precise modelling of each component, including the arm, base, and holder mechanism. This approach allowed the design to be evaluated and modified efficiently before fabrication. The use of 3D design also helped ensure proper dimensions, structural alignment, and functionality of the prototype.

Prototype Materials Selection

Two materials were used to develop the initial prototype. Polylactide (PLA) polymer was used for the base of the cassette holder, which is known for its radiolucent properties (Johnston et al., 2019). As for the arm, a flexible metal rod with spring was used, and a thick plastic board for the base to secure the rod and caster wheels in placed. Due to the emphasis on evaluating the product's design, the prototype was developed using more economical and readily available materials. However, for practical applications, more suitable materials such as zinc-plated steel are recommended for the arm and base components to provide greater durability, improved corrosion resistance, and enhanced structural stability.

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RESULT AND DISCUSSION

The CASIX prototype was first designed using SOLIDWORKSto produce a detailed 3D model of the product. Based on thisdesign, the initial CASIX prototype was then fabricated toevaluate the structure, functionality, and overall suitability of the proposed design.

3D Design and Modelling of the CASIX Prototype

Fig. 4 shows the 3D design created using SOLIDWORKS of the complete prototype after assembly in three different views for (a) back view, (b) front view, and (c) side view. These views illustrate the overall structure and arrangement of the main components of the CASIX prototype. The multiple perspectives also provide a clearer understanding of the prototype's design features and spatial configuration. Figure 5 shows the back and front views of the cassette holder 3D design from back view, and (b) front view , while Figure 6 presents the top and side views. These views highlight the structural design and shape of the cassette holder component. They also provide a clearer visualization of the holder's dimensions and orientation within the overall prototype structure.

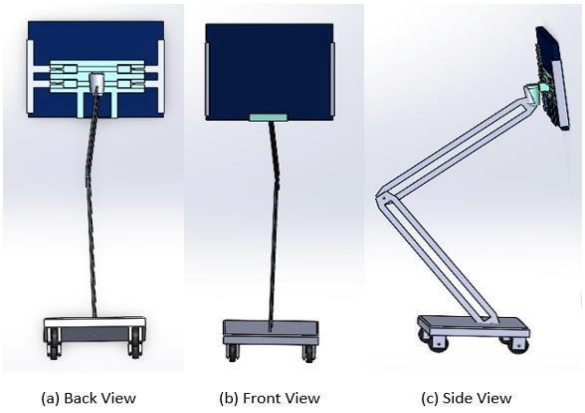

Fig 4. 3D design using SOLIDWORKS: (a) backview, (b): Frontview, and (c): Sideview.

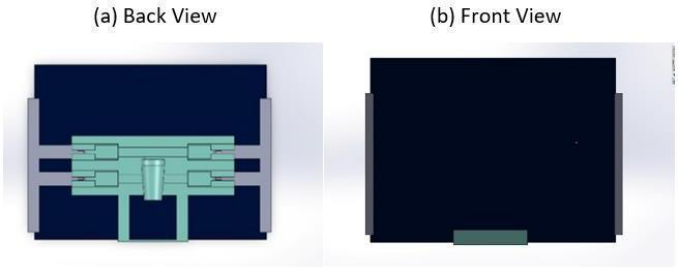

Fig 5. Cassette holder 3D design: (a) Backview, and (b) front view

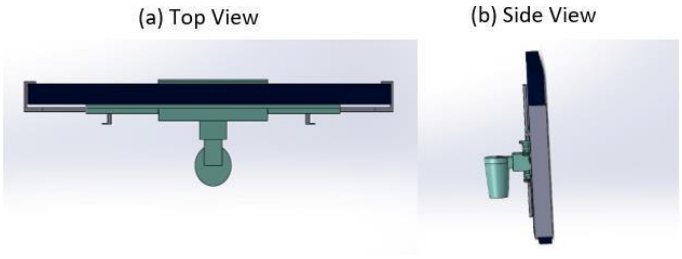

Fig. 6. Cassette holder 3D design: (a) Top View and (b) Side View

CASIX Prototype

A prototype was developed as shown in Figure. 7 focusing on the design features for enhanced usability, rather than the functionality at this development stage. The cassette holder is designed to accommodate different cassette sizes, up to 35 cm × 35 cm, and features a fast-locking mechanism to efficiently insert and remove x-ray cassettes. Moreover, the cassette holder can be rotated left and right 360 degrees and titled up and down 90 degrees. Such flexibility is due to the adjustable arm, where the height can also be adjusted as shown in fig. 7 (b) side view.

The adjustable arm not only provides versatile positioning of the cassette but also contributes to practical aspects of usage. It enables the product to be easily folded, as demonstrated in Figure 8, facilitating convenient storage and transport. Beyond that, adjustable arms are convenient in tight spaces, ensuring seamless movement and manoeuvrability. Lastly, caster wheels are added for mobility with quick locking mechanism to ensure stability during examination.

The x-ray cassette holder has around three degrees of freedom: move up/down (z-axis), forward/backward (x-axis), and left/right (y-axis) which ensures optimal positioning for various anatomical regions particularly in orthopedics, cardiology, and pulmonology. Moreover, the fast-locking mechanism is very useful compared to the current locking mechanisms in the market (screw adjustment). This is because during rush hours, radiographers take hundreds of x- ray images, and therefore, requires an efficient way for insertion and removal of x-rays cassettes.

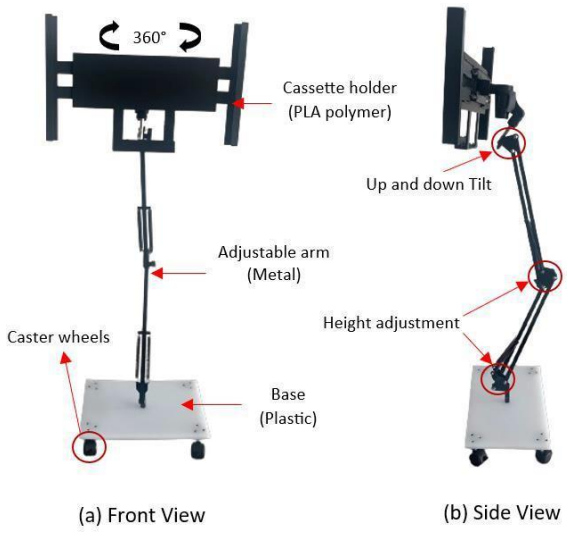

Fig 7. CASIX prototype: (a) Front View, and (b) Side View on stand mode.

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Fig 8 CASIX Prototype in folding mode.

The addition of an adjustable arm provides a greater advantage over other existing products that use a static arm. Widely embraced in the medical sector, these adjustable arms boast unparalleled flexibility in positioning, adaptability to diverse body types, user-friendly operation, and optimal space utilization. More importantly, it ensures patient comfort and accessibility, setting them apart from static tabletop x-ray holders. Traditional static tabletop x-ray holders demand dedicated space on the table, rendering them less suitable for individuals with obesity. In contrast, the innovative adjustable arm design facilitates customization, empowering healthcare providers to tailor customization to the unique needs of each patient. This adaptability ensures a higher level of patient comfort and accessibility.

It is important to note that the prototype focusing on the design features rather than functionality due to limited time and budget. Therefore, in the future, a proper prototype with suitable materials ensuring durability and efficiency should be developed. Moreover, comprehensive usability tests should be carried out on the product.

CONCLUSION

In conclusion, lateral X-ray imaging remains a valuable diagnostic tool due to the detailed information it provides. Proper positioning of the cassette for lateral projections typically requires the patient to hold the X-ray cassette, highlighting the need for an effective support device. To address this, a lateral cassette X-ray holder was 3D designed using SOLIDWORKS, and a CASIX prototype was subsequently developed. The incorporation of a rapid locking mechanism, wheels, an adjustable arm, and an adjustable arm is intended to enhance its functionality and offers an alternative to existing cassette holders for lateral X-ray examinations. Future development should focus on using more durable materials and conducting comprehensive usability tests to refine the design and confirm its practicality across diverse clinical settings.

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CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

ETHICS DECLARATION

This study did not involve human participants, animal subjects, or sensitive data. Consequently, formal ethical approval was not required

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