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Design and Analysis of Adjustable Headrest for Total Body Involvement Cerebral Palsy

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Abstract*: Cerebral palsy children especially those with total body involvement cerebral palsy (TBICP), use a wheelchair with headrest attachment all the time. Headrest is used to provide support and positioning of the head and neck of the user. In the matter of positioning and posture of the total body involvement cerebral palsy patient, there seem to be a few lacking with the current wheelchair in the market. The overall problem concerning this task including the head and neck alignment, head control technique and safety are identified. Gathering information and analysing is used to find the best method to overcome these problems. After thorough research, the major problem is identified and focused to develop the headrest design. The objective of this research is to introduce a new device which is the adjustable headrest for TBICP. Computer-aided design (CAD) and computer-aided engineering (CAE) such as Solidworks is used to assist in designing the device. Analysis is performed to determine the best thickness of the headrest when the user leans on it, effect towards model when a different load is applied on it and effect of load toward device at a different angle of headrest position. All the analysis is determined by using Finite Element Model (FEA). The device is fabricated by 3D printing using polylactic acid, (PLA) as the filament.

***Index Terms*: Total body involvement cerebral palsy; Adjustable headrest; Finite Element Analysis; 3D printing; Polyactic acid**

I. INTRODUCTION

Human posture can be defined as, "the position of one or many body segments in relation to one another and their orientation in space". Patients with cerebral palsy especially one affected with total body involvement have a very loose head control [1]. Most children who need a wheelchair or special seat have severe weakness in parts of their bodies or muscles that pull them into awkward or deforming positions. Seating should, as much as possible, keep these children in healthy and useful positions. It must provide support, but also allow them enough freedom to move, explore, and develop greater control of their bodies [2]. Based on available market's product, research and development towards headrest are not as wide as other research for supporting device such as a wheelchair. The headrest attached with a wheelchair provide stiff support as the patient cannot move their head with the correct posture. Other than that, the current design of headrest available does not provide for the movement of head horizontally and some of them also did not provide support for the neck. There is also lack of neck support in current common headrest used by the patient. There is a lot of improvement for the current headrest in the market especially for patients with total body involvement cerebral palsy. Adjustable mechanism is to be considered to give adjustability height of the headrest with its support. There are a few possible mechanisms considered to be implanted to the design. Press fitting is a very simple assembly method that uses no additional components or fasteners. Press fitting can be used to join components made from the same or different materials, and all material properties must be considered when the joint is designed. This assembly combines two parts together by using the friction between two components to hold something in place [3]. A C-clamp is used by means of turning the screw through the bottom of the frame until the desired state of pressure or release is reached. In the case that the clamp is being tightened, this is when the objects being secured are satisfactorily secured between the flat end of the screw and the flat end of the frame. If the clamp is being loosened, this is when enough force is released to allow the secured objects to be moved [4].

Unfortunately, there is yet model based on attachable headrest that can be adjusted. This research is intended to design attachable headrest with mobility function that also provides neck support. Using CAD software, the design is generated. Static analysis is carried towards the headrest to find the best thickness for the headrest. There is also analysis on the effect of the rigid body of the headrest assembled when the load is applied on it and various load are applied to it to find the fracture point of the assembled device.

II. METHODOLOGY

This project involved three main phases which are (i) the design process consists, (ii) design analysis of the adjustable headrest and (iii) fabrication using 3D printing technology.

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A. Design Process

There are a few conceptualizations made for the adjustable headrest device. Fundamentally, the concept of the design generated was almost the same. The difference between these designs is the way to move or adjust the headrest. To make the visualization of these concepts clearer, sketches had been made at the early stage of idea generation and evaluated.
There are four concepts generated with different feature after some research and design patent comparison. Figure 1 is the concept generated that will be taken into consideration for finalization. Pugh Method is used to find the best concept for the headrest design from few considerations such as comfortability of headrest and head movement rotation.

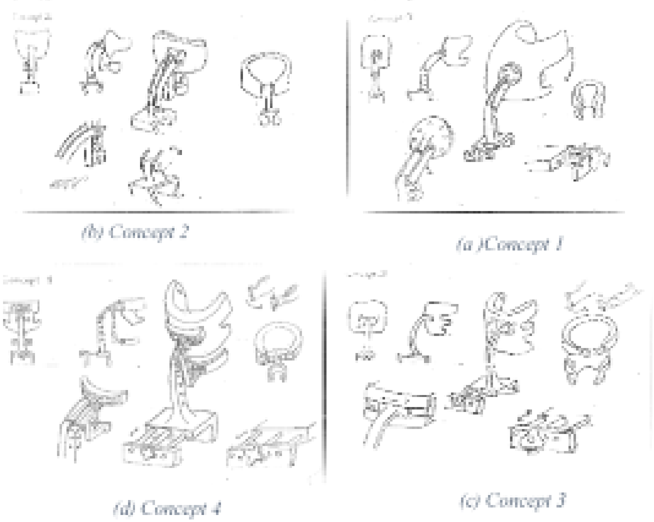


Fig. 1: Design concept of the adjustable headrest (Concept 1 – 4)

The product is then modelled and assembled from sketches to 3Dimension using Solidworks software. The headrest provides mobility function towards the user to move their head as it can rotate to the left and right. It also has neck support to support the patient's neck. Moreover, it has an adjustable function as the height of the headrest and neck support can be adjusted according to preferences. Based on Figure 2, strap and buckle were added to the headrest to support the head of the user. The whole device use c-clamp to support and clamp it to the seat.

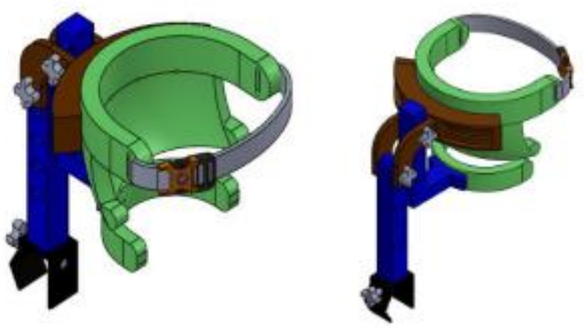


Fig. 2: 3D model of the adjustable headrest

B. Design Analysis

Analysis of the device is done based on the pressure applied towards the headrest. There are three different considered in the analysis which are the analysis towards the pressure on the headrest, the different positions of the adjustable device and various value of pressure applied to the adjustable headrest.

Headrest thickness

This analysis is carried out to identify the optimum thickness of the headrest. There are three different thickness applied towards the headrest which are 12.7 mm, 25.4 mm and lastly 38.1 mm. Based on literature research, the pressure of 1.8 kPa is applied towards the headrest when the human head is resting on it [5]. Thus, the pressure of 1.8 kPa is applied to the headrest to find the deformation of it based on different thickness as illustrated in Figure 3.

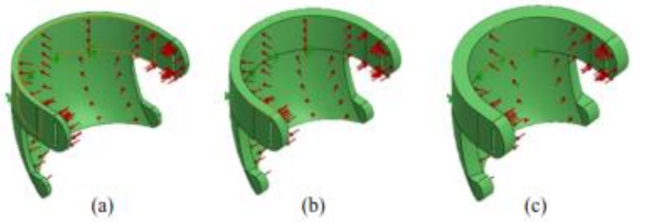


Fig. 3: Pressure distribution on the headrest at different thickness (a) 12.7mm thickness, (b) 25.4mm and (c) 38.1mm.

C. Different position of the headrest

This analysis is carried out to find the deformation occur on the device when the pressure of 1.8kPa is applied to it in a different position. Based in Figure 4, there are three positions of the headrest to be analysed for the effect of the pressure towards the device which is the position of headrest when it is in straight (0^0) position, rotated 30 degrees to the left and right which is the maximum angle the headrest can turn.

D. Fabrication using 3D printing technology

The model is printed using a 3D printer. It uses polylactic acid, PLA as the filament for the printing. The first step of the fabrication process is to convert the part or model from Solidworks part to STL format. The model part is saved as STL is open using Qidi software and adjustment is made for the optimum position of the part on the platform as illustrated in Figure 5. Every part is printed using settings of 0.2mm layer height with density infill of 15%. Support is also printed on the part to support any overhang edge or face. After slicing, Qidi software shown the amount of time, length of filament and its weight and the volume used when printing the model. Then, the part is saved in X3G format and saved on a removable driver such as SD card. The SD card then attached to the 3D printer for the final step which is the printing process.

III. RESULT & DISCUSSION

A. Final Design

Using Pugh Method, the final concept is selected based on the criteria's such as simplicity of design, head movement rotation. There are more criteria taken into consideration for selection of concept as shown in Table 1. The final concept selected is Concept 4 that is finalized and fabricated using 3D Printer with PLA as the filament.

Figure 5 shows the model view after 3D modelling using Solidworks 2016.

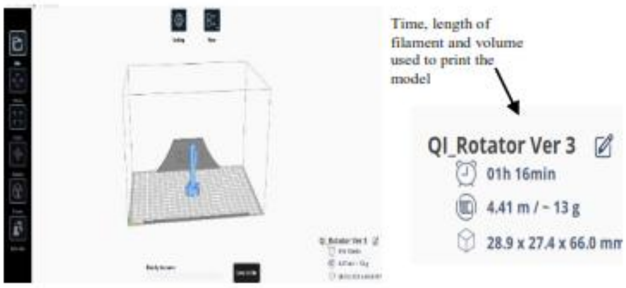


Fig. 4: Qidi software for 3D printing set up

Table 1: Pugh method selection

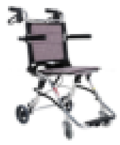
Criteria	Importance	Concept				Standards
		Concept 1	Concept 2	Concept 3	Concept 4	
Simplicity of design	0.2	8	7	6	5	
Comfortability of headrest	0.3	5	7	7	9	
Head movement rotation	0.3	6	7	9	9	
Ease of fabrication	0.5	7	6	6	7	
Ease of installation	0.5	7	6	7	6	
Long service life	0.1	8	5	9	9	
Total ranking	1.0	12.7	12.1	13.4	13.8	

Fig. 5: Isometric view of the adjustable headrest at different orientation

B. Computational analysis of headrest model

Maximum displacement which is shown in red colour is located at the area where there is a slot for buckle strap to be attached to the headrest as illustrated in Figure 6. The location of the displacement is related to the pressure transition from the head to the headrest with the most minimum contact area. The deformation of the headrest with different thickness can be clearly seen with the most critical area coloured in red and the most lenient area in blue. Thus, when the pressure of 1.8 kPa is applied to the headrest, it experienced different deformation based on the different thickness respectively. The maximum displacement is 1.32mm in is 12.7 mm thick model while only 0.033mm for 38.1 mm thick model. Hence, increasing in thickness of the headrest will result in decreasing deformation of the headrest.

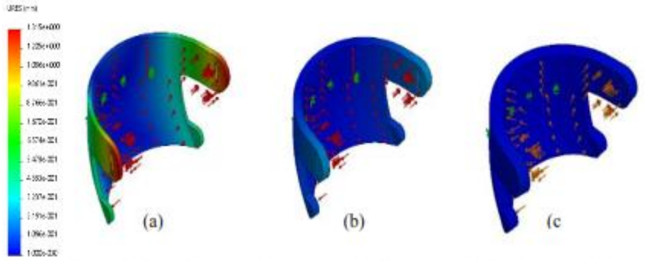


Fig. 6: Deformation analysis of the adjustable headrest (a) 12.7mm, (b) 25.4mm and (c) 38.1mm thickness

The device experienced a different range of deformation at a different position. The maximum displacement occurs when the headrest is in position 30 degrees to the left with deformation of 0.01075mm and the minimum deformation at the normal position with deformation of 0.009397 mm. This result shows that the adjustable headrest experienced different deformation at a different position. However, it does no effect greatly on the device that it will cause the device to be damaged. 7 shows the distribution of deformation the device experienced when pressure 1.8 kPa is applied to the headrest and neck support. The displacement distribution of the headrest is almost relatively the same. However, the headrest of the adjustable headrest device experienced more deformation to the left if it rotated 30 degrees to the left and more deformation to the right if the headrest is rotated 30 degrees to the right.

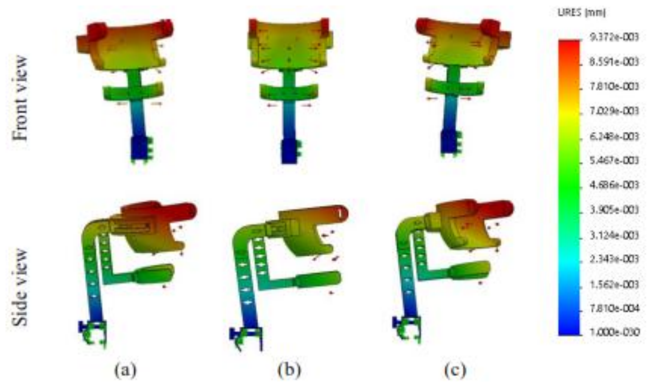


Fig. 7: Deformation of the device at different position (a) 30 degree to the left, (b) straight position and (c) 30 degree to the left

IV. CONCLUSION

(i) The device's design had gone through concept selection because of its advantages in various functions and ergonomically perspective than others concepts and is modelled using commercial CAD software.

(ii) The simulation findings suggested that different thickness affects greatly on the deformation of the headrest when pressure is applied to it.

(iii) 3D printing is used to fabricate the product using PLA filament with specific setting, adjustable and more economical to be developed.

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