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# DESIGN AND PROTOTYPING OF AN AUTOMATED MECHANISM TO PREVENT BEDSORE

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**Abstract**

Pressure ulcers or commonly known as bedsores are areas of concentrated injuries on the skin and the structure of the soft tissue of the patient mainly cause by excessive pressure and shear force applied at the 3 main bony premises of the patient's body such as the sacrum, heel and the occiput area. The main purpose of this project is to conceive, design, implement and operate an automated mechanism to prevent pressure ulcers by repositioning the patient. A mechanism consisted of 12 plates and 17 hinges integrated with a 3-piece mattress is introduced in this project at which it is designed by "Solidworks 2014" to be installed on to an available hospital bed. This 12 mechanism is driven by an automated power screw that is devised to reposition the patient from supine to any intended position by the user. These proposed designs are then manufactured using the defined materials and components and eventually installed on to the purchased hospital bed to perform the repositioning operation. Pressure mapping studies is done in order to measure the interface pressure applied at the critical locations of the body. The sensing area of this sensor array is 27×14 cm which is anticipated to cover the sacrum area of the subject in this experiment. The interface pressure is measured for a duration of 5 minutes at the supine position as well as 15,30 and 60 degree of lateral rotation in order to measure the pressure applied at this position which could eventually define the required repositioning time and also select the most suitable repositioning angle. The required repositioning time is defined by comparing the measured interface pressure with the literature hence resulting into a 2-3 hours repositioning time as the optimum duration for every cycle. Moreover, the time –pressure relationship of the patient is investigated for both positions at every 10 seconds to gauge the change in the interface pressure value across time at which minor fluctuation across this 5 minutes' period are recorded.

Keywords: Pressure ulcer prevention, Repositioning, Interface pressure, Lateral position.

## 1. Introduction

Pressure ulcers commonly known as bedsores are areas of confined injuries on the skin and its beneath tissue structure mostly caused by prolonged static pressure and shear stress applied at the critical areas of body [1]. Pressure ulcers mostly occur at the bony locations of the patient that is in direct contact with the surface of the mattress, which is mostly due to the greater amount of pressure applied at these locations [2]. There are a few factors that lead to the occurrence of pressure ulcers such as excessive pressure for a long duration of time, shear stress and also moisture at the critical regions. The accumulation of blood due to prolonged extreme pressure applied at the skin results into restriction of nutrition delivery to the tissue cells of the skin. Inadequate nutrition supplied to the tissue cells results into the breakdown of skin [3].

Pressure decubitus are divided into 4 categories based on its development stage, which is identified by comparing the severity of ulcers to a set of fixed rules and regulations. Mild redness and a firm skin are the first symptoms of a pressure ulcer that falls into stage 1 of the bedsore development. Followed by further application of pressure for a longer duration which eventually results into deepening of the pressure ulcer to the muscles and bones where it creates a widespread damage. Majority of bedsore patient are the elderly and the patients which have been paralyzed due to different reasons like accidents. The age group and the situation of the patients define the type of treatments that should be given to these patients [4].

There are a set of different bedsore treatments, which is done depending on the development of the ulcers as well as the general condition of the patient where in the case of a first and second stage pressure decubitus, treatment is solely done by cleaning and rotating the patient by the nurse. This is done to relieve the pressure from the critical areas of the body while avoiding any sort of dirt and moisture at these areas. Bedsore treatment is a very costly procedure at the third and fourth stage of its development where skin flap surgery is necessary with a cost of about 63000 $ [5]. In addition to these costly procedures, pressure decubitus can lead to life threatening situations, extended stay in the hospitals and unbearable pains where all these can be avoided by the right practice of repositioning and distributing the pressure.

This shows the importance of this research in order to develop a better mechanism to prevent bedsores from happening. The current practice of bedsore prevention involves 2-3 nurses in order to reposition and clean the patient, which is a very exhausting procedure. Based on the data collected in the hospital visitation patients are repositioned every 2-3 hours to ease the pressured parts where lack of knowledge, poor intentions and attitude among the caregivers about bedridden patients may boost the probability of this incident [6]. A study done by Mallah et al. [7] show that in 50% of the cases pressure ulcers occur at the coccyx sacrum followed by the heel and occiput area.

According to the research done by the European Pressure Ulcer Advisory, frequent repositioning of the patient can result to a better pressure distribution at the contact surface of the body and this can eventually eliminate the prolonged excessive pressure applied at the occiput and sacrum area [1]. Patients with lack of mobility require help from the caregivers in order to rotate and reposition based on a defined duration of time. Frequently repositioning the patient based on a fixed interval of time is a very costly and time-consuming act. There are two major things that have a vital effect on the formation of the pressure ulcers where those are the lateral angle of the patient after the act of repositioning as well as the time interval that this act is done.

Ros-Mar et al. [8] conducted a research on 49 healthy individuals in order to compare the effect of double regression hospital bed and the normal hospital bed. In addition, the interface pressure at different lateral angles is compared to find the best lateral position of the patient in the act of repositioning. Interface pressure results are taken at four supine positions of 0, 30, 45 and 65 degrees where they are called the supine, semi follower, follower and seated positions respectively. The generated outcome from this study shows that the 0 and $30^{o}$ lateral positions result into a lower interface pressure in compare with the other lateral positions in the experiment.

One of the major considerations in designing the mattress is how often should the patient be repositioned in the bed to prevent bedsore from creating. A literature review study done by Hagisawa et al. [9] shows that there are a set of different studies done on this matter which they mostly resemble a 2-hour turning period based on medical practice that is not established on critical pressure versus tissue breakdown studies. This 2-hour period have initiated from 1870's where it was stated that this is the duration that takes for a nurse to go around on one side of the ward [10]. This has followed by several critical studies by Guttmen et al [11], which suggests a 30 minutes to 1-hour period for the daytime and 2-hour for the nighttime. In addition, a study done by Gefen [14] reveals a graph about the hours of continues pressure against the applied pressure, which is used as the basis of repositioning period for the proposed prototype.

One of the major uncertainties in using a new automated device to deal with a variety of patients is the question of its effectiveness in solving that particular challenge. A study done by Woodhouse [12] shows that there is no substantial difference in terms of the interface pressure between the automated and manual way of repositioning. This interface pressure is the primary factor to focus on, in this area of research where by reducing the interface pressure the probability of bedsores decreases significantly. This interface pressure varies at different lateral positions defined by the caregiver or the automated mechanism.

The identified research gap for this research is to design and manufacture a hospital mattress compatible mechanism that is capable of repositioning the patient and to quantify its effectiveness with the current accepted methods. Hence in order to address this issue, this research is conducted to design and prototype an automated mechanism that simulates the current nursing practice to prevent pressure ulcers from happening. Moreover, the main advantage of this mattress over the current products is the flexibility of the usage and the possibility of employing it on to the current hospital beds. Three dimensional design of the proposed mechanism is modelled in "Solidworks 2014" by setting the dimensions based on the current literature review in relation with the human body dimensions. As a result of that this design is manufactured with the defined materials and components in an actual scale and implemented on to a hospital bed in order to assess the adoptability of the design in accordance with the current hospital beds. Lastly the interface pressure is measured using a pressure mapping system that is specifically developed in this project. A pressure mapping system is consisted of multiple pressure sensors where in this case Force Sensitive Resistor (FSR) is used to perform this task.

## 2. Research Methodology

As this project involves designing and prototyping a product, CDIO framework is used as an approach to tackle the issue of pressure ulcers. This framework provides a stressing on engineering fundamentals which is used in the context of Conceive, Designing, Implementing and Operating (CDIO) in order to solve engineering challenges. This framework was initially proposed by Massachusetts Institute of Technology (MIT) as a structure to be thought to engineering students [13]. It all starts with conceiving on methods to prevent pressure ulcers based on basic medical knowledge that is attained through literature review and Sungai Buloh hospital visitations that is a local hospital located in Kuala Lumpur, Malaysia.

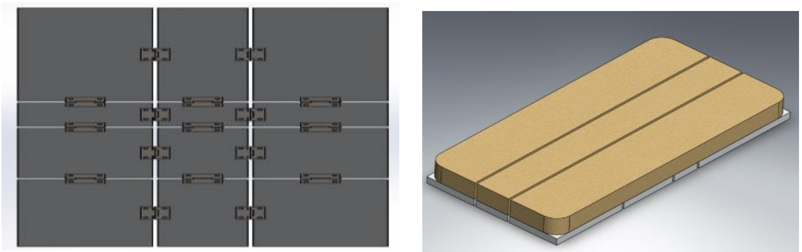
In fact, the mattress is designed to perform the repositioning practice where preliminary ideas are given and final design is modelled progressively by compiling all the necessary factors. Therefore, the final design of the mattress and its mechanism is prototyped using the defined materials and components where the manufactured model is implemented on a manual hospital bed to prove the functionality of this proposed product.

Interface pressure study is performed based on the pressure mapping method in order to evaluate effectiveness of the proposed model in preventing pressure ulcers. Force Sensitive Resistor (FSR) is used to measure the force applied at different positions of the body where a FSR 402 with a force sensitivity of 1 to 100 N and sensitivity area of 0.5 inch is used in the context of this project. An array of 10 sensors are positioned in an arrangement of 5 columns and 2 rows on a 33×30 cm pleksi board and connected to an Arduino microcontroller board in order to interface pressure of the mattress and the body. This plate is positioned at the sacrum region which is identified as the most critical location in the current literatures.

### 2.1. Conceive and design of the proposed mechanism

The time consuming practice of manual repositioning can be solved by introducing a mechanism to perform this practice. This mechanism is aimed to be implemented on the current hospital beds in order to allow lateral movement without discretizing the basic movement of the bed to elevate the upper body and the legs. The standard dimension of the hospital bed is 1×2 meters which means that the overall dimension of this mechanism have to be limited to this dimension. Preliminary a 2-piece plate with the defined size is modelled in order to prepare a platform for the repositioning of the patient. After further analysis and hospital visitation it was found that, the patients are mostly positioned in the middle of the mattress and having a 2-piece mechanism does not reposition the patient on its side. This may also cause the patient to be stuck in the middle of these 2 sections which may create further medical issue for the patient. Therefore, in order to prevent this from happening it was decided to divide the mechanism into 3 sections in order to use the middle section as a medium of repositioning and the side section to secure the patient on the bed.

This 3-section mechanism can be integrated with a 3-piece mattress to provide the necessary comfort for the patient. However, implementing this 3-section mechanism compromises the required back and leg elevation performed by the bed. This is resolved by defining a 12-piece plate with an arrangement of 4 rows and 3 columns in order to create the required degree of freedom upper body, leg and lateral movements. These 12 pieces are connected with 17 hinges and integrated with a 3-piece mattress at every column of this structure shown in Fig. 1. A 9-mm plywood is used in the manufacturing stage to allow an easier prototyping process. The rear view of the mechanism consisted of the hinges is shown in part (a) of Fig. 1 and the front view of the mechanism is illustrated in part (b) of the mentioned figure.



**(a) Rear view of the mechanism** **(b) Front view of overall assembly**

**Fig. 1. Design of the 12-piece mechanism.**

This 12-piece mechanism is designed to perform the repositioning practice based on the defined time interval where the rotation of the middle section in a clockwise manner results in to the repositioning of the patient to the left arm. Similarly, after a period of 2 hours' patient is brought back to to his/her neutral position and repositioned again with an anticlockwise rotation of the middle section causing the patient to land on the right arm. This have to be done every 2 hours in order to relocate the pressure from the left side of the body on to its right side as it is defined by Gefen [14] and many other researchers in this field. This period is in a direct relation ship with the accumulation of the blood flow and the creation of the pressure ulcers. Moreover, the patient has to be repositioned to the most efficient angle that results into the least amount of interface pressure applied at the patient's critical areas. A study done by Ros-Mar et al. [8] demonstrates that $30^{o}$ lateral position yields the least interface pressure applied at the coccyx sacrum, heel and the occiput area. Therefore, this 12-piece mechanism is set to perform lateral repositioning up to $30^{o}$ and in a 2-hours time interval. The result of this $30^{o}$ repositioning for clockwise rotations is shown in Fig. 2.

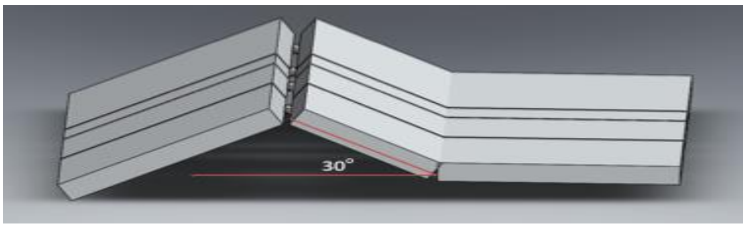



**Fig. 2. 30 degree clockwise lateral position.**

Subsequently this 12-piece mechanism requires a system to perform the lateral repositioning based on the defined criteria where initially a linear actuator is selected to drive the targeted pieces by contacting the middle and the side plates. However, a heavy duty linear actuator with a maximum load of 100-150 kg was found to be very expensive. Hence, an automated power screw is designed to perform a similar task with a much lower cost in compare with a linear actuator (Fig. 3). This automated power screw is similar to a car hydraulic jack implemented with a 120W electric motor which is used to perform this action automatically based on a 2-hours time interval. In addition, a structure is added on to the arm of this hydraulic jack in order to drive the first 2 rows separately rather than using 2 automated power screws at each side of the mechanism. The stroke of this automated power screw is in direct relation with the repositioning of the mechanism where in this case the power screw is designed to have a maximum stroke of 30mm allowing the bed to reposition from 0 to $60^{o.}$ One automated power screw is implemented on each side of the mechanism to perform clockwise and anticlockwise rotations.

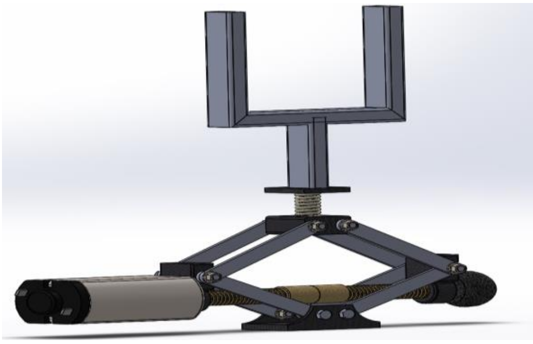


**Fig. 3. The automatic power screw.**

## 2.2. Implementation

The designed components are manufactured precisely in a 1:1 scale based on the defined dimensions in the conceive and design stage. All the 12 pieces of this mechanism are constructed and then assembled using 12 mm steel hinges in order to allow the plates to rotate at every orientation that is required. It is very important to ensure that aligned hinges are concentric as it can strongly affect the lateral rotation of the plates as well as the upper body and leg elevation. This is done by assembling each part individually and drilling on the next plane in accordance with the first assembled part.

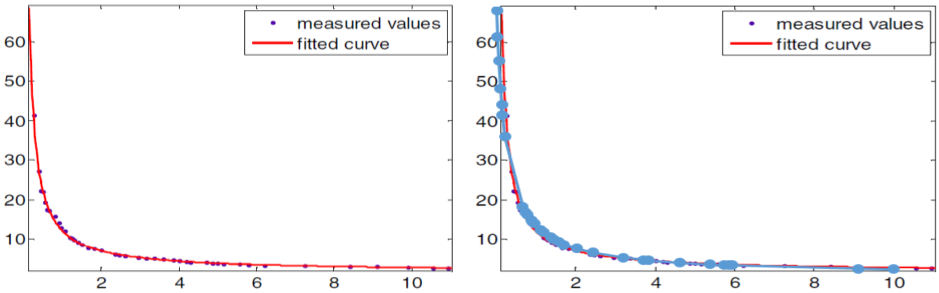
Subsequently the 3-piece mattress is attached on to the 12-piece mechanism and a cover sheet is used to cover this mattress. The 12-piece mechanism and the 3-piece mattress are shown in Figs. 4 and 5 respectively. This combination is then placed on the purchased hospital bed to verify the adoptability of this manufactured mattress mechanism on to an available hospital bed in the market. Lastly the automatic power screw is prototyped by manufacturing the structure that was designed in the first stage and assembling it on to an available car scissor jack. This scissor jack is then automated by integrating a 120 W electric motor with the built structure that was mentioned.

Fig. 4. 12-piece mechanism.

Fig. 5. 3-piece mattress layer.

## 2.3. Pressure mapping

It is established that pressure ulcers are formed due to the high interface pressure causing the accumulation of the blood flow at the bony premises of the body. Therefore, pressure mapping studies is done in order to measure the interface pressure applied at the critical locations of the body. In this project pressure mapping is carried out using an Interlink Force Sensitive Resistor (FSR) which shows a drop in resistance with a rise in the amount of force applied to the surface of the FSR. It is extremely important to make sure that the results generated from the sensors are of good quality and close to what is done generally in this field of research in order to verify the produced results from this experiment. Calibration of Force Resistive Sensors is done through application of multiple force on the active area of the sensor and measuring the change in resistance due to the force applied on to the sensor. The measured results from this experiment is then plotted which is shown as a blue line in part (b) of Fig. 6. It is clearly shown that the Force-Resistance relationship exhibits an exponential behavior due to the nature of this type of sensor since the measured resistance at 0 N of force is defined to be as infinity. This exponential graph is then compared with a study done by Fard et al. [15] where such sensor is used to monitor the interface pressure measurement in order to assess the occurrence of pressure ulcers. The plotted graph based on the retrieved data from this experiment is very similar to the data generated by the mentioned experiment where this graph has also been done for a similar reason of calibrating a Force Sensitive Resistance as shown in part (a) of Fig. 6.




a) Calibration done in the literature b) Exponential graph matching the literature

**Fig. 6. Force vs Resistance for calibration compared with literature [15].**

In this project ten FSR 402 series sensors are arranged in five columns and two rows on a 33×30 cm pleksi sheet with a sensing area of 27×14 cm in order to measure the interface pressure at the sacrum area of the patient. Sacrum region is selected as the controlled pressure mapping area as it is the most critical region for the occurrence of pressure ulcers. The dimension of this sheet is defined based on the average dimension of the sacrum region and 10 sensors are used to cover this area. There are many more sensors used in pressure mapping systems compared to this study but 10 sensors are used in this experiment to avoid the complication of adding a multiplexer to the Arduino system and also reduce the cost of this experiment. This array of sensors is connected to an Arduino controller in order to process the generated data from the sensors. The interface pressure is measured at the supine position and eventually compared with the graph extracted from the literature. In addition, this measurement is done for a duration of 5 minutes to investigate about the relationship between the pressure and duration that this pressure is applied. A healthy 27 years old male with a weight of 90Kg is the subject of this experiment.

## 3. Results and Discussion

### 3.1. Finalized design

The mattress mechanism and the automated power screw system are implemented on to a normal hospital bed to indicate the adoptability of the proposed design on to the available hospital beds. The design of the hospital bed is in accordance with the purchased hospital bed. The design of the bed may slightly affect the structure on the automated power screw where in this case the distance between the 2 opening underneath the bed is about 26 cm which is the same size as the length of the mentioned structure. In addition, existence of side protectors has to be assured as it is important for the safety of the patient when the repositioning practice is performed. Clockwise and anticlockwise lateral rotation of the patient on the hospital bed using the automated powers screws is shown in Fig. 7.

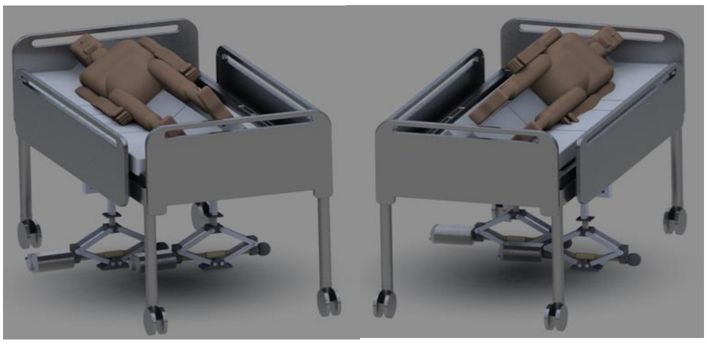


**Fig. 7. Clockwise and anticlockwise lateral rotation.**

### 3.2. Prototype operation

The repositioning practice is performed for 3 different individuals with BMI values of 28, 24 and 18 who are categorized in the overweight, average and underweight category. These subjects are successfully repositioned from supine position to a range of angles between 0 and 60 which is the operating range of the APS system. The safety aspect of this product is taken care of by the available side protectors in the hospital bed, which can stop the patient in the necessary cases (Fig. 8). However, the speed of the repositioning practice is set as only 11.4 centimeters per minute where based on the performed operation on the prototype it did not result into any sudden movement of the patient. This can be further investigated in future studies where multiple patients can be repositioned and the feedback by the patients can be recorded in a form of a survey. The underweight patient is placed on the prototype at supine position and is eventually repositioned which is shown in Fig. 8 respectively.

**(a) Patient at supine position**

**(b) Patient and 30$^o$**

**Fig. 8. Patient laying down at supine position.**

### 3.3. Interface pressure measurement at supine position

The interface pressure of the patient is measured for the overweight volunteer at supine position with a Body Mass Index (BMI) of 28.1 as shown in Fig. 9 where the average and the standard deviation of pressure applied at supine is shown underneath every sensor. This patient is then repositioned as presented in Fig. 10 in order to ensure the functionality of prototype for a patient with a higher BMI value compared to the previous subject.

It is clearly shown that highest amount of interface pressure for the supine position is applied at the sensor located at Column 3, Row 1 that is positioned exactly at the middle of the patient’s sacrum. Moreover, the interface pressure of the middle sensors is much higher that the side sensors, which means that there is higher, amount of pressure applied at the sacrum region in compare with pressure applied at the sides and the pelvis region. The standard deviation of the collected data across the time is calculated where it is in a range of 1 to a maximum of 2.58 calculated at the sensor located at Column 1, Row 2 of the array. This maximum value of standard deviation is caused by the slight fluctuations that are measured across time. This may be due to the minor movement of the patient during the interface pressure measurement experiment. It is extremely hard to keep the subject of the experiment in a stand still position which is why minor fluctuation are expected across the time of the experiment.

It is established that the occurrence of pressure ulcers is highly dependent on the duration of the pressure applied at a certain location. Therefore, a repositioning interval of 2-3 hours is suggested by comparing the measured interface pressure with the graph generated by Reswick and Rogers shown in Fig. 10. According to this graph and considering the highest pressure point of 110.97 mmHg the patient has to be repositioned in a duration of 2-3 hours as any repositioning interval more than this falls in to the unacceptable region defined by Gefen [14]. The pressure measured by the sensor exhibits a higher value with an increase in time where in reality there is no change in the interface pressure of the patient and the supporting surface. Creep is basically the distortion of material caused by a lifted temperature as well an excessive static pressure applied for a long duration of time [16].


**Fig. 9. Mean and standard deviation of the measured pressure at every sensor (mmHg).**

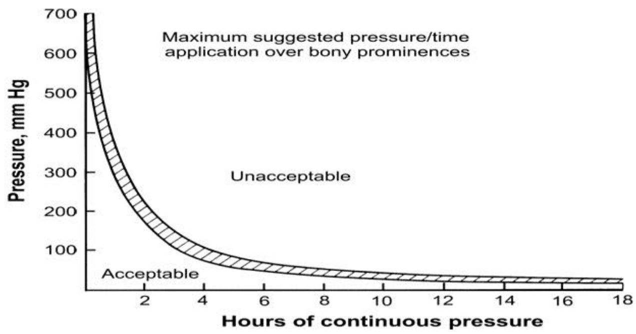



**Fig. 10. Pressure versus the hours of continues pressure [14].**

## 3.4. Investigation on the relationship of lateral repositioning angle and the interface pressure

In the second stage of pressure mapping studies the patient is repositioned from the supine position up to 15, 30, 45 and 60 degree of lateral position. This is done to examine the effect of lateral repositioning on the interface pressure between the patient and the supporting surface. The average interface pressure of the supine position and the mentioned lateral positions are plotted in a candlestick graph in order to show the distribution of the pressure at different lateral angles as well as showing the highest pressure experienced by the patient at that certain location. This graph is displayed in Fig. 11. Based on the presented graph there is no specific pattern between the increase in the lateral position of the patient and the measured interface pressure at different positions. The pressure experienced by the patient at 15 degree of lateral position is mainly distributed from 60 to 80 mmHg with the highest interface pressure of 89 mmHg, which is lower than the highest interface pressure measured at the supine position. On the other hand, the distribution of the pressure at supine position ranges from 40 to 80 mmHg, which means the pressure, is more distributed in compare with the 15-degree lateral repositioning trial.

The interface pressure measured at 30 degrees lateral position is distributed from 15 to 80 mm hg with a high pressure point of 89.6 mmHg at the right side of the pressure-sensing array. This means that the 30-degree trial has a similar maximum pressure point as the 15-degree trial whereas the 30-degree lateral position is showing a better pressure distribution across the sensing array which makes it for favourable in that sense.

Lastly, the interface pressure measured for the 45 and 60 degrees of lateral rotation shows a maximum pressure point of 105.2 and 124.1 mmHg respectively, which is higher than the supine, 15-degree and 30 degree of lateral position. According to this measurement, repositioning the patient to such angles may worsen the situation rather than relieving the pressure to prevent pressure ulcers.

According to a study done by James [17] the average interface pressure experienced by the patient at the supine position ranges from 45 to 90 mmHg, which is very similar to the interface pressure measurement done at this experiment. Moreover, the interface pressure is measured for a 30-degree lateral position where in the case of this experiment the patient is repositioned by placing a pillow under the patient in order to elevated the patient to the required position. The pressure measured for the 30-degree lateral turning is shown in Fig. 12 where it ranges from around 60 mmHg to 84 mmHg. The maximum interface pressure at the lateral repositioning performed by James is very similar to the measurement done at this experiment whereas the distribution of the pressure shown in graph 6 is in a wider range in compare with the measurement done by James. There is no pressure measurement at 15, 45 and 60-degree lateral position reported at this paper. The other 4 bars presented in graph 9 shows the pressure measurement done at upper body elevation which is not related to this experiment.

According to a study done by Rosmar et al. [8] pressure mapping study is done for a sample group of 49 healthy individuals where the maximum interface pressure measured at the supine position is reported as 42.8 mmHg for the case of a standard hospital bed. The maximum interface pressure measured at supine position is higher than the pressure measurement reported at this experiment. This can be due to multiple factors such as the BMI of the patient, type of the mattress and the positioning of the force sensitive array performed at this experiment. Rosmar et al. also performed pressure-mapping study for lateral angles of 30, 60 and 90 degrees where this measurement is done for the shoulder, pelvis and the ankle area rather than the sacrum area of the patient. Nevertheless, lateral position of 30 degrees is preferred in compare with the other lateral angles due to the higher interface pressure reduction achieved at this angle. This proves the higher effectiveness of the 30 degree suggested at the current performed research.

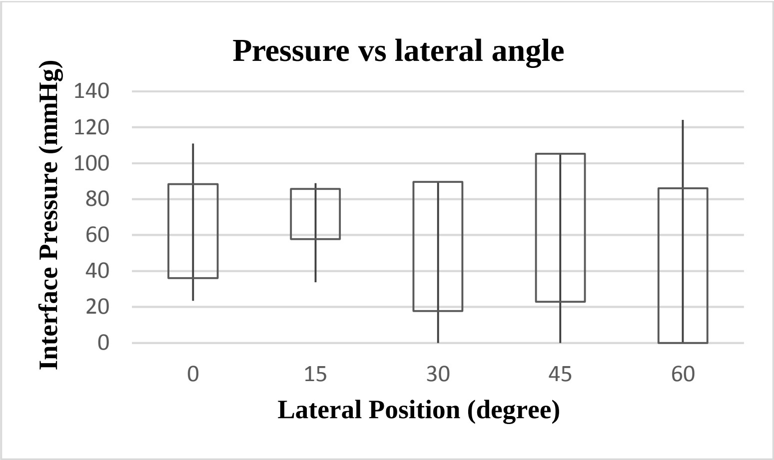



**Fig. 11. Interface pressure-lateral position relationship.**

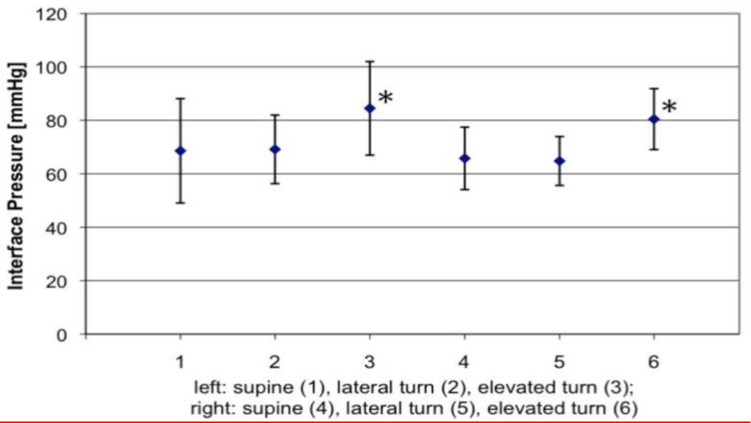



**Fig. 12. Effect of lateral position on interface pressure done by James.**

### 3.3. Investigation on the interface pressure and time

Lastly the effect of time on the applied interface pressure is investigated on all 10 sensors for supine,15,30,35 and 60-degree lateral position in order examine the change in the interface pressure with respect to time. Time dependent interface pressure graph of supine and all the lateral positioning trials is shown in Fig. 13. As it is shown the interface pressure measured at 5 minutes has a linear characteristic where the interface pressure measured for different positioning represents almost a straight line with a minor increase toward the end of the duration of the measurement. This minor change of the interface pressure may be due to the creep error of the sensor which is associated with most of the interface pressure measurement systems [18]. The pressure measured by the sensor exhibits a higher value with an increase in time where in reality there is no change in the interface pressure of the patient and the supporting surface. Creep is basically the distortion of material caused by a lifted temperature as well an excessive static pressure applied for a long duration of time [16]. It is mainly associated with the deformation of the sensor across time where in this case it is due to the static stress applied by the volunteer on to the sensor.

Moreover, slight fluctuations are measured across time, which may be due to the minor movement of the patient during the interface pressure measurement experiment. It is extremely hard to keep the subject of the experiment in a stand still position which is why minor fluctuation are expected across the time of the experiment.

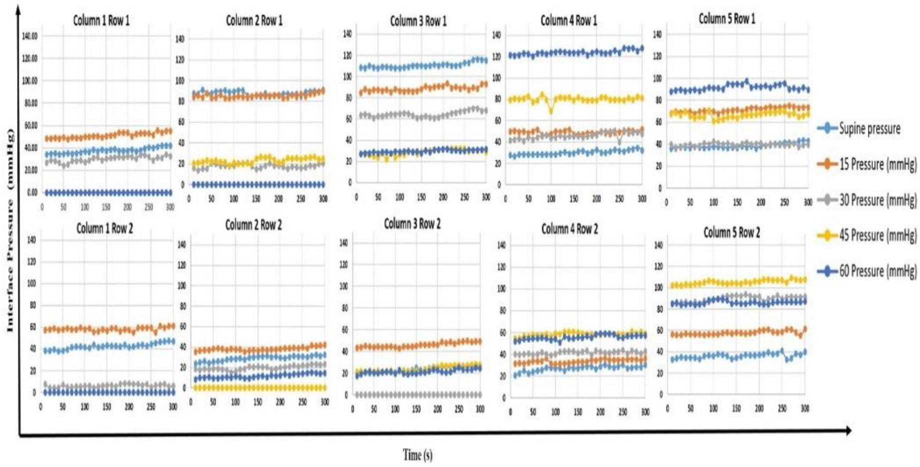



**Fig. 13. Interface pressure measurement across time.**

## 4. Conclusion

In a nutshell, a repositioning mechanism was successfully introduced in this research where the proposed components are compatible with the current hospital beds available in the market. A 12-piece mechanism integrated with a 3-piece mattress and an automated power screw are the main components that were presented in this research. The 12-piece mechanism is designed and manufactured according to the available hospital bed dimensions where every piece is dimensioned based on the available upper body elevation and leg elevation in the hospital beds. The repositioning mechanism is then implemented with a special 3-piece mattress that was dimensioned based on the 3 columns of the proposed design. Automatic Power Screw (APS) was proposed in this project in order to perform the repositioning practice by an application of linear force on the connection of the side and the middle plate. As a result of this linear force on the connection of the middle and the left section, the mechanism performs a clockwise rotation. Furthermore, with an application of a similar force on the right and middle section an anti-clockwise repositioning is performed. These 3 components are then assembled on to a standard hospital bed in order to assess the compatibility of the proposed designs. `

The repositioning action was successfully performed by repositioning 3 volunteer from supine to 15,30,45 and 60-degree lateral positions. The performance of the proposed prototype demonstrates the ability of the mechanism in repositioning 3 patients from different groups of BMI values. Pressure mapping studies were done using the developed FSR array where measurement was done for a duration of 5 minutes and a sampling rate of 10 seconds for the overweight patient at supine position. It was concluded that the pressure measured at 5 minutes has a linear characteristic where the interface pressure measured for different positioning represents almost a straight line with a minor increase toward the end of the duration of the measurement. This minor change of the interface pressure may be due to the creep error of the sensor which is associated with most of the interface pressure measurement systems.

The interface pressure of the first volunteer was compared at supine,15,30,45 and 60-degree lateral positions where supine and 30 degree of lateral repositioning were identified as the most suitable options. This was backed up with 2 different literatures on the same area of study where 30 degrees results into the smallest maximum interface pressure as well as a better pressure distribution across the patient’s sacrum. Pressure measured at supine position demonstrates its highest value at the middle sensors whereas the pressure measured by the side sensors is in the low margin of the interface pressure. This pressure distribution tends to relocate on to the side sensors with an increment of the lateral angle where the pressure at 30-degree lateral position exhibits the best distribution and relocation of pressure across the study area.

Moreover, the interface pressure of the overweight volunteer at supine position was compared with the pressure versus hours of continues pressure graph provided by Reswick and Rogers [14]. It was concluded that a 2-3 hours repositioning interval is the most suitable duration for an automatic repositioning performed by the mechanism. It is very important to understand that considering the right interval can largely reduce the chances of pressure ulcer occurrence.

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