

**Pressure Ulcer Wound Healing Using a New Pressure Relief Seating Design in Wheelchair Users with SCI**

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**ABSTRACT**

Excessive pressure for extended periods of time leads to the formation of pressure ulcers (PU). Since continued pressure on these sores retards the healing process by depriving the tissues of the oxygen and nutrients carried in the blood, patients in the treatment of established PU usually avoid sitting for long time. In an attempt to find a more effective solution, a new wheelchair seat design, characterized by releasing the contact pressure on ischia and coccyx, was evaluated in clinical PU management in conjunction with normal wound treatments. Results showed a statistically significant improvement in wound closure using the new seating system over using the regular seat in wheelchairs.

**KEY WORDS:** Pressure ulcers, wheelchair, seating, wound healing

**INTRODUCTION**

Individuals that spend extended periods of time seated, such as wheelchair users, can develop serious medical conditions. Prolonged sitting without proper repositioning results in excessive pressure over the ischial tuberosities, sacrum, and coccyx [1] and significantly increases the risk of pressure ulcers (PU). In turn, this imposes a tremendous burden in terms of cost and the impact on quality of life and the functional status of the long-term wheelchair-user population. A new seat design, **Intelligent Automated Pressure Relief Seat (IAPRS)**, in which the back part of the seat (BPS) can be dynamically tilted downward with respect to the front part of the seat (FPS), was proposed by Makhsous et al. [2]. Two postures are presented with the design. The **Normal** posture is when the BPS is even with the FPS. The **WOBPS** (Without Back Part of Seat) posture is when the BPS is tilted down 20° or more with respect to the FPS. Since the **WOBPS** posture releases the supporting contact under the ischia and the coccyx, it was hypothesized that the IAPRS would help improve the PU wound healing.

The purpose of this study was, therefore, to investigate the PU wound healing in wheelchair users with established PU wound when using our IAPRS, and to compare the wound closure with that of individuals using conventional wheelchair seats.

**MATERIALS AND METHODS**

**Participants:** A total of wheelchair users with SCI and established PU wounds participated in this IRB approved study. Each of them gave written informed consent before entering the trial. Five of them (60.6±8.8 years old; 84.6±17.5 kg; 180.3±17.5 cm) were assigned into the control group who used a regular wheelchair for mobility needs, and two others (36.5±21.9 years old; 63.0±1.0 kg; 174.0±9.0 cm) were entered as the IAPRS group using our new modified wheelchairs featuring the **WOBPS** posture. Each participant had one or multiple wounds initially assessed as stage II or III in the sacral or ischial region.

**Wheelchair:** A modified wheelchair, on which the IAPRS was installed, was used for each participant in the IAPRS group. The BPS can be tilted downward and the angle of the BPS was controlled by an electro-pneumatic system and had a range of motion of 20° downwards or more with respect to the FPS.

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A BASIC Stamp<sup>®</sup> (BASIC Stamp 2p, Parallax Inc., Rocklin, CA) processor was used to control to the posture change, and switched between the **Normal** and **WOBPS** positions every ten minutes.

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Figure 1 goes here: Wheelchair used in the study  
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**Protocols:** Each participant was fitted for either a control or IAPRS wheelchair, and was asked to use it during the course of their daily activities. Participants using the IAPRS wheelchair were taught how to operate and maintain the device. Wound assessment was done for each participant approximately twice a week until discharge.

**Measurement:** Digital photographs for each wound were taken approximately twice a week, with a standard target plate placed in the same plane as the wound to allow consistent calculations and evaluation. Physical measurements of the length and with of each wound were also taken at the time of the wound assessment. In the case when a participant had multiple wounds in the studied regions, each wound was individually tracked and each was entered as a single entry into the data set. As a part of the patient's normal therapy, their treatment modality was reassessed during each visit to ensure the patient's health and well being, and any changes in therapy or patient health were recorded. Photo measurements and treatment modalities were collected and documented until all wounds were closed or the patient was discharged or transferred. Using of the IAPRS wheelchairs continued until discharge.

**Data processing and analysis:** Digital photographs were then loaded into the VeV MD Measurement Documentation Software (Vista Medical Ltd., Winnipeg, Canada). The image was automatically oriented and scaled based on the location of the standard target plate in the image. The outlines of the wound was then traced, and the greatest length, width and area of the wound were calculated by the software. These values were then plotted as a function of time (days) over the course of the experiment, and fitted to a curve to estimate wound dimensions for the intervening days. As the dimension varied substantially for each wound, the healing process was characterized by the percentage of wound dimension changes over the initial value. Therefore, for a healed or a healing wound, a negative value would obtained, and for a worsened wound, a positive value would be seen. Since the patient stayed in PU treatment for various number of days, the comparison between the groups was made on the values of 15 days after the trial started. A two-sample t-test with different group variance was used to compare the healing process of the wound area, length, and width between the groups, with a significance level of 0.05. In addition, a paired t-test of the healing rate with zeros was performed to evaluate whether the healing was significant.

## RESULTS

There were 4 sacral/coccyx wounds in the IAPRS group, and 9 sacral/coccyx/ischial wounds in control group. At 15 days after the trial started, the majority of the wounds were either totally healed or in some stage of healing (negative values in Table 1). Two of the wounds were worsened and one of them was worsened almost 90% (89.0%).

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Table 1 goes here: PU wound healing rate at 15 days in the trial  
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Two typical wound healing examples are shown in Figure 2. The top one is from IAPRS group, and the bottom one from control group.

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Figure 2 goes here: Typical PU wound healing processes for IAPRS group and control case  
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Average values of healing rate showed that wounds from both groups were in an general healing process for the measures of area, length, and width. The overall average values of the wounds decreased in area, length, and width for both groups during the course of a 15 day assessment. For the area of the wounds, the average healing rate at 15 days was  $82.7 \pm 22.0\%$  and  $30.8 \pm 69.9\%$  for IAPRS and control groups, respectively. The area closure for the IAPRS group was statistically significant ( $P=0.002$ ) while that in control group was not ( $P>0.05$ ). For the width of the wound, the decrease of the width in IAPRS group was significant ( $P=0.007$ ) but not that in controls ( $P>0.05$ ). There was a significant difference in the healing rate between these two groups in the measures of area and width. However, for the measure of the wound length, both groups had significant decrease at 15 days,  $P=0.029$  and  $P=0.034$ , respectively, for IAPRS and control groups. There was no significant difference in wound length decrease between the groups.

### DISCUSSION & CONCLUSION

During sitting, trunk weight is carried mainly by the ischial tuberosities, coccyx and their surrounding soft tissues[3]. Serious skin breakdown in the SCI population has been reported most frequently over the ischial tuberosities and sacral region, presumably because of the amount of time spent sitting combined with muscle atrophy and absent or impaired sensation[4]. The effectiveness of using the **IAPRS** system to reduce pressure in the seating regions has been demonstrated[5] previously. The current study initially confirms our hypothesis that the pressure relief effect of the IAPRS may have substantial benefits in accelerating the healing process in wheelchair users with established PU wounds. The findings show that relieving pressure in the area of a wound can greatly help to close the wound. It can be concluded that incorporating our IAPRS system into a rehabilitation and treatment program for individuals who have sitting-related PU wounds may prove beneficial and reduce recovery time. Further research on a larger sample size should be carried out to confirm this. Recruitment of subjects into this study is currently ongoing and more comprehensive results are expected.

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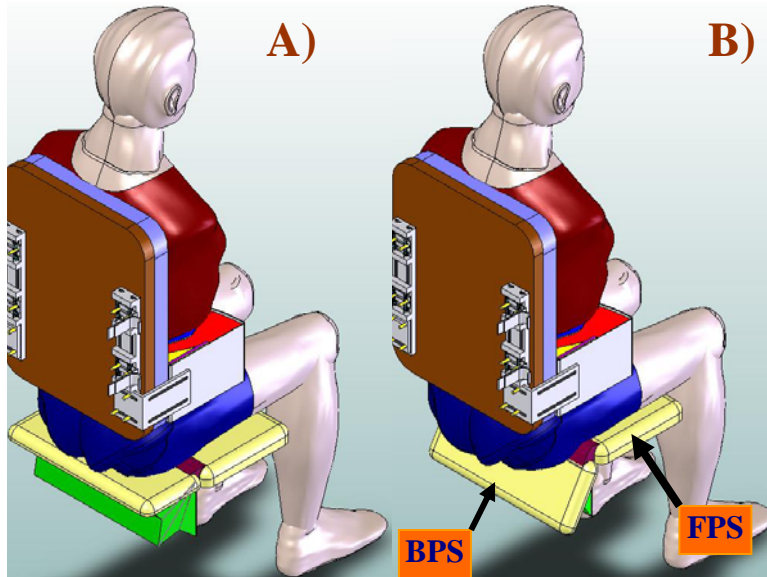
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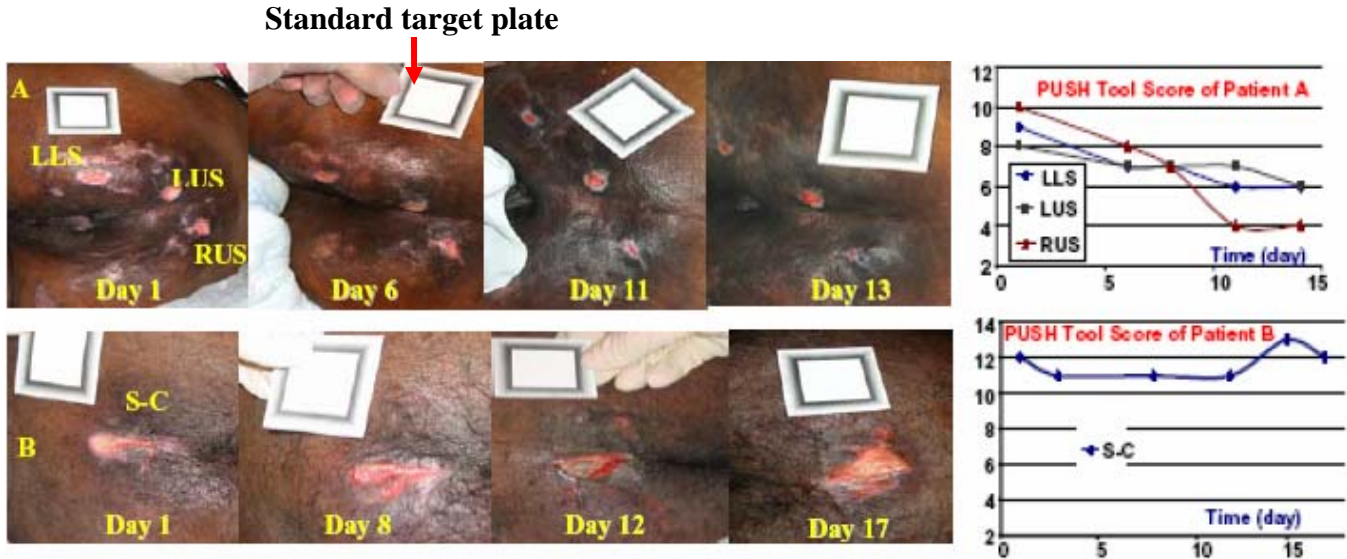
Figure 1. A new seat design, **Intelligent Automated Pressure Relief Seat (IAPRS)**. The back part of the seat (BPS) can be tilted down to fully release the sitting contact load over rear buttocks and the coccyx. (A) The IAPRS is shown in a normal posture, similar to a regular chair; (B) The IAPRS is shown in a WOBPS posture, when the BPS is tilted down.



**Alternative text for Fig. 1:**

Figure 1 shows a new seat concept called **Intelligent Automated Pressure Relief Seat (IAPRS)**, in which the back part of the seat (BPS) can be dynamically tilted downward with respect to the front part of the seat (FPS). Two postures are given, A) The **Normal** posture: when the BPS is even with the FPS and B) The **WOBPS** (Without Back Part of Seat) posture: when the BPS is tilted down 20° or more with respect to the FPS.

Figure 2: Typical examples of sacral pressure ulcer healing. Top row: Patient A from IAPRS group; Bottom row: Patient B from control group.



**Alternative text for Figure 2:**

Figure 2 shows two patients who had pressure ulcers in the sitting area and came to a rehabilitation center for wound treatment. Top row: Patient A with pressure ulcers at Left Lower Sacrum (LLS), left upper sacrum (LUS), and right upper sacrum (RUS) who used a wheelchair equipped with the **Intelligent Automated Pressure Relief Seat (IAPRS)** > 4 hours daily; Bottom row: Patient B with a sacral-coccyx (S-C) pressure ulcer who used a regular seat cushion. The right diagrams show their wound healing progress as a function of time. The patient who used the IAPRS had a faster healing process than the patient who used a regular wheelchair.

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Table 1: PU wound healing rate (%) at 15 days in the trial for both IAPRS and control groups. P values of comparison to zeros ( $P_1$ ) and between the groups ( $P_2$ ) are also given. A bold font indicates a statistical significance.

Wounds	Total Area		Width		Length	
	IAPRS (%)	Control (%)	IAPRS (%)	Control (%)	IAPRS (%)	Control (%)
1	-100.0	26.6	-77.7	6.3	-100.0	18.7
2	-100.0	-29.2	-100.0	-18.0	-67.5	-19.7
3	-76.6	-100.0	-66.6	-91.2	-69.8	-91.3
4	-54.2	-93.2	-35.3	-74.5	-4.5	-76.8
5		89.0		94.8		44.4
6		-73.3		-52.4		-35.2
7		-66.8		-38.0		-41.3
8		-28.4		13.8		-18.8
9		-2.0		47.7		-52.2
Mean±SD	-82.7±22.0	-30.8±69.9	-69.9±26.9	-12.4±59.7	-60.5±40.1	-30.2±48.5
$P_1$	<b>0.002</b>	0.086	<b>0.007</b>	0.275	<b>0.029</b>	<b>0.034</b>
$P_2$	<b>0.024</b>		<b>0.018</b>		0.140	

**Alternative text for Table 1:**

Table 1 shows the wound healing rates for different wound measurements, i.e. Total Area, Width and Length of each wound, for both control patients and the patients using IAPRS concept. A negative value indicates that the wound had a smaller dimension at the time of assessment.

$P_1$  is the P value when the data was compared to zero. This comparison is used to detect if the average changes in wound healing rate was statistically significant. A P value smaller than 0.05 indicates a statistical significance.

$P_2$  is the P value when comparing the data between groups. This comparison is used to detect if there is significant difference between patients using regular wheelchair and those using IAPRS wheelchair. A P value smaller than 0.05 indicates a statistical significance.