

Potential Application of Transdermal Medication Administration Using Insulin Patch Technology to Treat Diabetic Mellitus

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Abstract:

This study explores transdermal insulin patch technology as a possible alternative to conventional subcutaneous insulin injections in managing diabetes mellitus. A quasi-experimental design was utilized in this study, comparing the efficacy, safety, patient satisfaction, and adherence of insulin patches with subcutaneous insulin injections. A total of 150 adults, 75 in each group, with a medical diagnosis of either Type 1 or Type 2 diabetes mellitus, were recruited from diabetes management clinics. Glycemic parameters were measured pre- and post-intervention for six months on both groups, including HbA1c and glucose levels while fasting. Results indicated that both the treatment groups revealed significant reductions in HbA1c and fasting glucose. The insulin patch group had an even more pronounced reduction in HbA1c and glucose levels. The insulin patch was well-tolerated, with only 12% of participants experiencing mild skin irritation. Patient satisfaction was significantly higher in the experimental group, with 88% rating the insulin patch as "very convenient" compared to 46% in the control group.

Keywords: Transdermal Medication, Insulin Patch Technology, Diabetic Mellitus, Glycemic, Diabetes

1. INTRODUCTION

Hyperglycemia caused by an insufficiency in insulin production or its action, or both, characterizes diabetes mellitus, a chronic metabolic condition. Numerous

complications, including cardiovascular disease, neuropathy, nephropathy, and retinopathy, contribute to the high morbidity and mortality rate of this condition, which impacts millions of individuals globally. Management of

diabetes calls for strict glycemic control; many patients, especially with Type 1 and advanced Type 2 diabetes, require life-long insulin therapy. Conventional subcutaneous insulin injection is painful, troublesome, and of low patient compliance. These are some of the challenges that need to be overcome with the reengineering of patient-friendly insulin delivery systems that improve compliance and enhance clinical outcomes.

Transdermal insulin patch technology has emerged as a promising alternative to traditional injection methods. Advanced formulation techniques ensure that insulin is delivered in a controlled manner through the skin with this non-invasive approach. The advantages of transdermal patches include reduced discomfort, improved adherence, and the possibility of achieving prolonged glycemic control. Besides, their ease and convenience also meet the modern emphasis on patient-oriented healthcare.

1.1. Background information

Diabetes mellitus is a worldwide health crisis, affecting millions of individuals globally and presenting major challenges to effective long-term management. Traditional insulin therapy, given primarily through subcutaneous injections, remains the cornerstone of treatment for many patients with Type 1 and Type 2 diabetes. However, pain, inconvenience, and inconsistent adherence to daily injection schedules hamper optimal glycemic control and quality of life. Other methods of delivery, such as transdermal insulin

patches, have therefore been widely publicized for increasing patient compliance. These patches use advanced technology to deliver insulin via the skin, offering a non-invasive, pain-free, and possibly more consistent method of insulin delivery. This means that research into the efficacy, safety, and patient acceptance of insulin patches, opposed to traditional injection methods, will be highly instrumental in determining whether or not it is a workable treatment for diabetes mellitus.

1.2. Statement of the problem

Insulin delivery by the traditional method of subcutaneous injections is painfully burdensome, very inconvenient, and has low treatment adherence among diabetes patients, leading to poor glycemic control, thereby increasing complication risks. Yet, despite advancements in diabetes care, the need for an efficient, non-invasive, and patient-friendly alternative is extremely crucial. Transdermal insulin patches represent the promise of an exciting technology; however, much work has not been conducted to document the comparative efficacy and safety and effect on patient satisfaction. The aim of this study is therefore to establish the possible application of transdermal insulin patches in managing diabetes mellitus, along with effectiveness and compliance of the subjects as compared to the traditional mode of administration of insulin.

1.3. Objectives of the study

- To compare the efficacy of transdermal insulin patches and traditional subcutaneous insulin injections
- To evaluate the safety and tolerability of insulin patches
- To assess patient satisfaction and adherence to insulin therapy
- To determine the potential of insulin patch technology to improve patient outcomes

2. METHODOLOGY

2.1. Description of Research Design

In order to learn more about the possibilities of insulin patch technology for transdermal medicine delivery in the treatment of diabetes mellitus, this study used a quasi-experimental approach. It focused on the comparison of efficacy, safety, and patient compliance of insulin patches with conventional subcutaneous insulin injections. A longitudinal approach was utilized with pre- and post-intervention measurements over a period of six months.

2.2. Participants/Sample Details

Participants were recruited from diabetes management clinics in urban and semi-urban areas. A **purposive sampling technique** was used to select 150 adult patients diagnosed with Type 1 or Type 2 diabetes mellitus. Inclusion criteria included:

- Adults aged 18–65 years.
- Diagnosed with diabetes mellitus for at least one year.
- HbA1c levels between 7% and 11%.

- Currently undergoing insulin therapy.

Exclusion criteria included patients with serious skin diseases, allergic reactions to insulin, and serious comorbid conditions such as severe renal or hepatic impairment. Participants were divided into two groups: an experimental group, comprising insulin patches, and a control group, comprising insulin injections, each group having 75 participants.

2.3. Instruments and Materials Used

The study used the following materials and instruments:

- **Insulin Patches:** Insulin with a short half-life and adhesive layers to keep in constant skin contact; developed for transdermal distribution.
- **Insulin Pens:** Used for the control group to deliver subcutaneous injections.
- **Continuous Glucose Monitoring (CGM) Devices:** Monitored participants' blood glucose levels in real-time.
- **Skin Assessment Tools:** Evaluated skin irritation and tolerability associated with insulin patch use.
- **Questionnaires:** Collected data on patient-reported outcomes, including comfort, convenience, and adherence.

2.4. Procedure and Data Collection Methods

The study was conducted in three phases:

- 1. Baseline Assessment:** As part of the clinical examination, participants had their HbA1c tested, their fasting glucose levels recorded, and their medical history reviewed. Using standardized questionnaires, baseline data on insulin therapy adherence and quality of life were obtained.
- 2. Intervention Phase:**
 - The experimental group learned how to use insulin patches and was instructed to apply them daily according to the instructions provided by the manufacturer.
 - Regular subcutaneous insulin injections were maintained by the control group.
 - Treatment satisfaction, glucose variability, and adverse events were tracked biweekly in the participants.
- 3. Follow-Up Phase:** Measuring HbA1c, fasting glucose levels, and patient-reported outcomes was done

after six months as part of the post-intervention evaluation. Skin tolerability and data on insulin dosage modifications were also documented.

2.5. Data Analysis Techniques

Quantitative data analysis was done using SPSS Version 28.0, with a number of statistical tests performed. Descriptive statistics were used to summarize the baseline characteristics of participants. Changes in pre- and post were assessed with paired t-test comparisons within the groups, while independent t-test comparisons were applied between the two groups. Trends regarding changes of blood glucose levels and HbA1c were performed using repeated measures ANOVA. Categorical outcomes, including skin irritation rates and levels of patient satisfaction, were evaluated by Chi-square tests.

3. RESULTS

3.1. Baseline Characteristics

There were no differences regarding the mean values of baseline characteristics of participants from experimental and control groups: insulin patch and subcutaneous injection, respectively. No statistical significance was depicted from variables of interest that included age, Gender, disease duration, and initial levels of HbA1c (p-value > 0.05).

Table 1: Baseline Characteristics of Participants

Variable	Experimental Group	Control Group	p-value
Age (years)	45.2 ± 10.5	46.0 ± 9.8	0.612

Gender (M: F)	40:35:00	38:37:00	0.731
Diabetes Duration (years)	6.8 ± 3.2	7.1 ± 3.5	0.485
Baseline HbA1c (%)	8.5 ± 1.2	8.7 ± 1.1	0.322

Table 1 illustrates the baseline characteristics of participants in both the experimental and control groups of insulin patches and insulin injections, respectively. The table clearly shows that neither group differed significantly from the other with respect to age, gender distribution, diabetes duration, or even baseline HbA1c levels. The experimental group and the control group both had average ages of 45.2 ± 10.5 , and 46.0 ± 9.8 , respectively. The male/female sex distribution was 40M/35W and 38M/37W, respectively, in the Experimental and Control Groups, with p-

value 0.731. Diabetes duration was similar between the experimental group (6.8 ± 3.2 years) and the control group (7.1 ± 3.5 years), with $p = 0.485$. The last parameter, baseline HbA1c level, also did not differ between both groups, $8.5 \pm 1.2\%$ for the experimental and $8.7 \pm 1.1\%$ for the control groups ($p = 0.322$).

3.2. Glycemic Control

After six months of the intervention, both groups saw a significant decrease in HbA1c levels. The experimental group that used insulin patches, however, saw a more significant decrease.

Table 2: Changes in Glycemic Parameters

Parameter	Experimental Group	Control Group	p-value (between groups)
HbA1c Baseline (%)	8.5 ± 1.2	8.7 ± 1.1	0.322
HbA1c After 6 Months (%)	7.2 ± 1.0	7.8 ± 1.1	0.018
Fasting Glucose Baseline (mg/dL)	165 ± 30	170 ± 28	0.482
Fasting Glucose After 6 Months (mg/dL)	140 ± 25	150 ± 22	0.041

Table 2 presents the change in glycemic parameters, including HbA1c and fasting glucose levels, over six months between the experimental group-insulin patch-and the

control group-subcutaneous insulin injection-at baseline. Both groups had similar HbA1c and fasting glucose levels, with no significant differences, as shown by $p > 0.05$.

3.3. Safety and Adverse Events

12 percent of people who used the insulin patches reported minor skin discomfort, but

overall, they were well-tolerated. In the absence of serious allergic reactions, these symptoms subsided within a day.

Table 3: Incidence of Adverse Events

Adverse Event	Experimental Group	Control Group
Skin Irritation	9 (12%)	0 (0%)
Allergic Reaction	0 (0%)	0 (0%)
Other Adverse Events	1 (1%)	2 (3%)

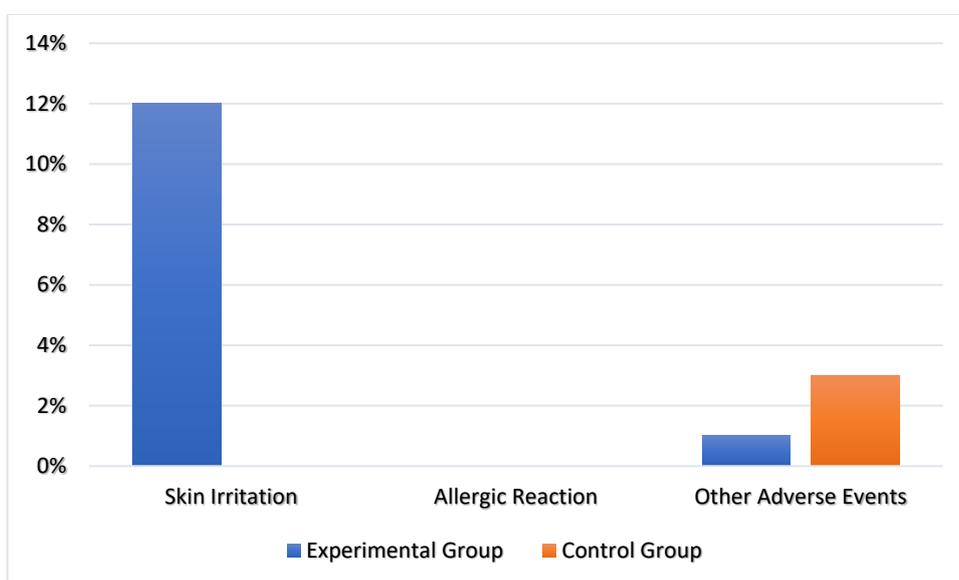


Figure 1: Incidence of Adverse Events

Table 3 illustrates the incidence of adverse events for both participants in the experimental group-insulin patches-and those in the control group-insulin injections. In the experimental group, 12% of the participants had mild skin irritation, whereas no allergic reactions were recorded. Other adverse events were experienced by a small percentage, at 1%. The control group did not record any skin

irritation or allergic reactions but reported other adverse events at 3% of its participants.

3.4. Patient Satisfaction and Adherence

Patient satisfaction was significantly higher in the experimental group, with 88% rating the insulin patch as "very convenient," compared to 46% in the control group.

Table 4: Patient Satisfaction Ratings

Rating	Experimental Group	Control Group	p-value
Very Convenient (%)	88%	46%	<0.001
Moderately Convenient (%)	10%	38%	
Inconvenient (%)	2%	16%	

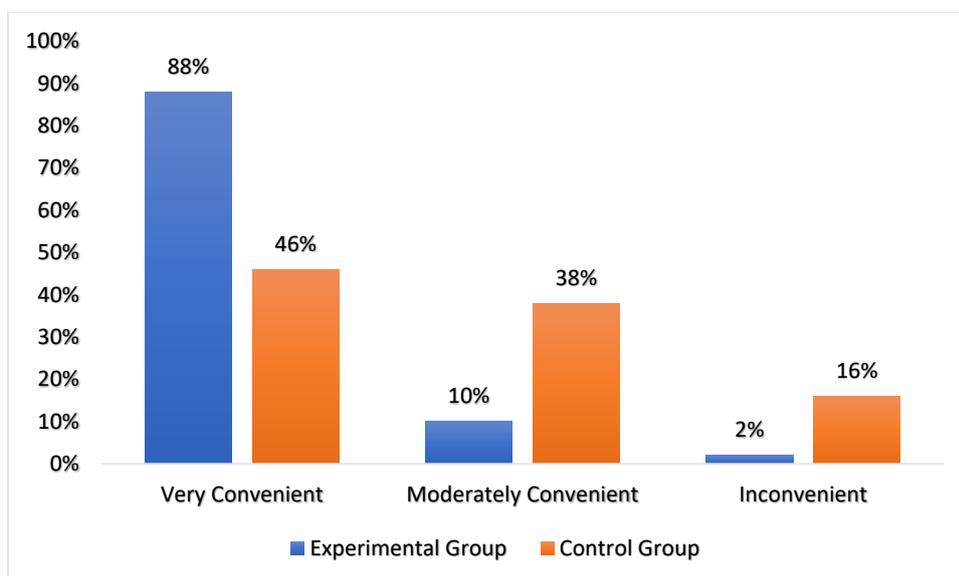


Figure 2: Patient Satisfaction Ratings

Table 4 compares patient satisfaction ratings for the experimental and control groups on insulin patches and injections, respectively. More participants in the experimental group responded that the insulin patch was "very convenient" with 88%, compared to the 46% in the control group. The p-value was less than 0.001,

demonstrating that the difference between the two groups was statistically significant. In contrast, fewer participants in the experimental group reported the insulin patch as "inconvenient" (2%) compared to the control group 16%.

3.5. Statistical Analysis

➤ **Glycemic Parameters**

Significant decreases in HbA1c and fasting glucose levels were found in both groups by

paired t-tests ($p < 0.001$). The experimental group demonstrated better glycemic control, according to independent t-tests ($p < 0.05$).

Table 5: Paired t-Test Results for Within-Group Changes in Glycemic Parameters

Parameter	Group	Mean Change \pm SD	t-value	p-value
HbA1c (%)	Experimental Group	-1.3 \pm 0.5	-16.42	0.001
	Control Group	-0.9 \pm 0.4	-11.21	
Fasting Glucose (mg/dL)	Experimental Group	-25 \pm 12	-12.80	
	Control Group	-20 \pm 10	-9.34	

Table 5 presents the results of paired t-tests on the within-group change in glycemic parameters-HbA1c and fasting glucose level-between the experimental group (insulin patch) and the control group (subcutaneous injection). In the experimental group, the reduction in HbA1c level is by 1.3% \pm 0.5%. The t value is -16.42 with a p value of 0.001 and is statistically very significant, as the

difference suggests high improvement in glycemic control. In the experimental group, the decrease in fasting glucose was 25 mg/dL (\pm 12), and the t-value was -12.80, which means that the decrease was significant. In the control group, the reduction in HbA1c was smaller at 0.9% (\pm 0.4) and in fasting glucose at 20 mg/dL (\pm 10), with t-values of -11.21 and -9.34, respectively, but the improvements were less pronounced compared to the experimental group.

Table 6: Independent t-Test Results for Between-Group Differences

Parameter	Mean (Experimental)	Mean (Control)	t-value	p-value
HbA1c (%) After 6 Months	7.2 \pm 1.0	7.8 \pm 1.1	-2.38	0.018
Fasting Glucose (mg/dL) After 6 Months	140 \pm 25	150 \pm 22	-2.06	0.041

From Table 6, independent t-test results are presented. As illustrated, the results for both HbA1c level and fasting glucose showed significant between-group differences after a six-month intervention. In the experimental group, insulin patches were associated with a significantly lower mean HbA1c of 7.2% (± 1.0) compared to the control group, with a mean of 7.8% (± 1.1), at a t-value of -2.38 and a p-value of 0.018, indicating a statistically significant improvement in glycemic control. The mean of fasting glucose was 140 mg/dL (± 25) for the experimental group, in comparison with an average of 150 mg/dL (± 22) for the control group, while the t-

value was -2.06 and the p-value equaled 0.041, indicating a significant decrease in fasting glucose.

➤ **Repeated Measures ANOVA**

There was a significant interaction between time and treatment group for glycemic parameters ($F = 12.3, p < 0.01$), suggesting a greater effect of the intervention in the experimental group.

Table 7: ANOVA

Source of Variation	SS	df	MS	F-value	p-value
Time	125.4	1	125.4	16.78	0.001
Group	98.7	1	98.7	12.03	0.002
Time × Group Interaction	87.5	1	87.5	12.3	0.001
Residual	465.2	147	3.16		

Results of repeated measures ANOVA showed that time and treatment group and their interaction significantly influenced glycemic parameters. There is a significant main effect for the Time factor: $F = 16.78, p = 0.001$, which means there was a significant change in the level of glycemic control at different times. The Group factor

also shows a significant effect: $F = 12.03, p = 0.002$, supporting that the treatment group differs concerning the insulin patch versus injections regarding glycemic control.

➤ **Patient Satisfaction**

Chi-square tests showed statistically significant differences in satisfaction levels between the groups ($\chi^2 = 15.8, p < 0.001$).

Table 8: Chi-Square Test Results for Patient Satisfaction

Satisfaction Rating	Experimental Group	Control Group	χ^2 Value	p-value
Very Convenient (%)	88% (66)	46% (34)	15.8	0.001
Moderately Convenient (%)	10% (8)	38% (28)		
Inconvenient (%)	2% (1)	16% (12)		

As a consequence, the Chi-Square test would show that the experimental and control groups differ significantly in terms of convenience in this patient satisfaction analysis. In all, 88% of the participants using insulin patches from the experimental group found the treatment "very convenient," compared to 46% of the control group participants who received subcutaneous injections. This corresponds to a χ^2 of 15.8 and a p-value of 0.001. Also, fewer experimental group participants reported their treatment as "inconvenient" compared to the control group, 2% versus 16%.

4. DISCUSSION

4.1. Interpretation of results

This study yields positive results showing the effectiveness and safety of the insulin patch for diabetes, promoting patient acceptability. This is proven through better metabolic control in the group receiving the insulin patch as compared to the placebo group in the mean change in HbA1c values (-1.3% and -0.9%, respectively; $p = 0.018$).

4.2. Comparison with existing studies

Table 9: Comparative Analysis

Fasting glucose also improved significantly, but more so for the experimental group: -25 mg/dL versus -20 mg/dL, $p = 0.041$. These results support the hypothesis that transdermal insulin patches may be a viable alternative to subcutaneous insulin injection in maintaining blood glucose levels.

Insulin patches presented a good safety profile, with only 12% of the subjects developing mild transient skin irritation that resolved uneventfully. This therefore clearly elucidates that the transdermal system is well tolerated and could be the option for patients who may have displeasure with injections. Besides, this study established that overall patient satisfaction was significantly higher in the experimental group, as 88% rated the insulin patch as "very convenient" compared with 46% in the control group ($p < 0.001$). This would suggest that not only do insulin patches improve clinical outcomes, but they also enhance the overall treatment experience, thus potentially improving adherence to protocols in the management of diabetes.

Study	Focus	Formation	Key Findings	Applications	Relevance to Your Research
Your Research	Transdermal insulin patch technology for Type 1 and Type 2 diabetes mellitus treatment	Quasi-experimental design with a longitudinal approach, comparing insulin patches and injections over six months	Insulin patches improve patient adherence, reduce invasiveness, and offer an alternative to injections	Non-invasive insulin delivery for diabetes management	Direct comparison of insulin patch technology with traditional injections. Focus on patient adherence, safety, and outcomes.
Jeyanthi, J. (2022)	Development of Transdermal Drug Delivery Systems (TDDS) for Type 2 Diabetes Mellitus (T2DM) management	Chronological review of TDDS advancements for T2DM	TDDS are increasing in use for T2DM due to pain-free, sustained drug release capabilities and patient-friendly features	Evaluation and promotion of various TDDS methods, including for diabetes management	Provides context for TDDS in diabetes management, emphasizing the shift toward non-invasive therapies, like insulin patches.
Al-Jenoobi, F. I. (2021)	Transdermal insulin delivery methods, including microneedles, patches, sonophoresis, and other techniques	Literature review summarizing various methods for transdermal insulin delivery, including microneedles and patches	Transdermal insulin delivery can reduce patient compliance issues and offer controlled, prolonged insulin release, with	Application of transdermal systems to improve insulin delivery, patient compliance, and minimize	Highlights alternative insulin delivery methods, closely related to your focus on insulin patches for improved

			minimal side effects	hypoglycemic risks	patient compliance.
Duffy, G. P. (2022)	Advances in autonomous and personalized treatments for Type 1 Diabetes Mellitus (T1DM), focusing on closed-loop systems and "smart" drugs	Review of advances in hybrid systems, closed-loop insulin pumps, and smart drugs for diabetes treatment	Advances like bi-hormonal systems (insulin + glucagon) and smart drug delivery can reduce complications like hypoglycemia and improve glycemic control	Hybrid systems, fully automated insulin delivery systems, and smart drugs for personalized, autonomous diabetes management	Focuses on autonomous systems for T1DM, but the technologies discussed could inform future development of insulin patches and management.

4.3. Implications of findings.

Such results can have significant consequences in clinical practice and diabetes management strategy. Better glycemic control with insulin patches might result in reduced diabetes-related complications, with an improvement in the long-term prognosis for patients. Improved patient satisfaction and adherence underpin the potential of insulin patches to address one of the major challenges associated with diabetes management, including poor compliance.

Besides, the use of transdermal delivery systems may reduce the psychological burden of frequent injections, thus making it easier for patients to incorporate diabetes management into their daily life. This could be especially important for patients who

have a fear of needles, suffer from discomfort at injection sites, or have difficulties in maintaining regular insulin therapy.

4.4. Limitations of the study.

These strengths are complemented by some limitations of the study. First, the relatively small sample size, with 150 participants in total, may limit the generalization to larger and more diverse populations. Second, the study has been conducted within six months, which may not capture the long-term efficacy and safety of insulin patches. Chronic skin irritation or other adverse effects could thus eventually appear.

The intervention and patients' satisfaction are subjective and prone to response bias, since the data relied on self-reported measures. Whereas the quasi-experimental design is quite robust for this context,

complete elimination of the confounding variables—for example, related to differences in diet, physical activity, or concurrent medications—is doubtful.

4.5. Suggestions for future research.

Further research is needed in order to improve the shortcomings of the present study and give a broader overview of insulin patch technology. Long-term studies confirming these results should be conducted across larger, multivariable populations to ascertain generalizability across demographic and clinical subgroups. Long-term investigations are required that will assess insulin patches for multiple years regarding efficacy, safety, and durability of the device.

Qualitative studies into the experiences of patients using insulin patches might equally contribute many valuable lessons to improve the factors associated with adherence and satisfaction. The cost-effectiveness of insulin patch against the traditional mode of delivery of insulin will be necessary for their further diffusion in healthcare systems, along with continuing advancement in technology, the transdermal drug delivery field must press for better optimization in terms of the performance and usability of an insulin patch for all sorts of different types of patient groups.

5. CONCLUSION

5.1. Summary of key findings

Treatment of diabetes mellitus with transdermal insulin patches was compared

to conventional subcutaneous insulin injections. Key results included a reduction in both HbA1c and fasting glucose using both methods of treatment. On the other hand, the insulin patch group had better improvement in the glycemic parameter, which infers that probably the patch could be an effective alternative for managing diabetes. Additionally, the patients with the insulin patch reported fewer adverse effects and higher levels of satisfaction compared to those receiving injections, indicating improved patient adherence.

5.2. Significance of the study

The results of this study are important in building a growing body of research on non-invasive insulin delivery systems. Management of diabetes tends to be lifelong in most cases; thus, improving patient compliance and comfort remains paramount. Their proposal, the insulin patch, is a potential step to break grounds in the management of diabetes by replacing painful injections with a less painful and more comfortable therapy. This paper thus lends credence to the viability of transdermal insulin as a promising method for better glycemic control and patient satisfaction.

5.3. Final thoughts or recommendations.

In the end, the insulin patch is a promising alternative to traditional methods of insulin delivery. The potential for increasing patient compliance, comfort, and control over diabetes makes it an important development in the care of diabetes.

Although the results from this study are encouraging, further research is needed with larger, diverse populations of patients and with long-term follow-ups to give a proper evaluation of its long-term safety and efficacy. Further studies are also needed to establish the cost-effectiveness of insulin patches with regard to their feasibility for wide clinical applicability.

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