EJMI

DOI: 10.14744/ejmi.269369
EJMI 2026;10(3):369–377

Research Article

Digital Insulin Management in Type 2 Diabetes: Enhancing Treatment Adherence and Safety with Connected Pens and IDegAsp

Gökçen Güngör Semiz,[1] Berna Demir Yüksel,[1] Barış Emekdaş,[2] Mehmet Emin Arayıcı,[3] Fatma Çetinkaya,[4] Tevfik Demir[5]

[1]Department of Internal Medicine, Division of Endocrinology and Metabolism, Faculty of Medicine, Dokuz Eylul University, İzmir, Türkiye
[2]Department of İnternal Medicine, Faculty of Medicine, Bakırcay University, İzmir, Türkiye
[3]Department of Biostatistics and Medical Informatics, Faculty of Medicine, Dokuz Eylül University, İzmir, Türkiye
[4]Buca Seyfi Demirsoy Training and Research Hospital, İzmir, Türkiye
[5]Freelance physician, İzmir, Türkiye

Abstract

Objectives: Poor adherence and therapeutic inertia limit the success of insulin therapy in type 2 diabetes mellitus (T2DM). There is a lack of real-world evidence on connected pens addressing these barriers in T2DM. We investigated the clinical impact of integrating the NovoPen 6 smart pen with insulin degludec/aspart (IDegAsp) on treatment intensity, metabolic control, and hypoglycemia in a T2DM cohort.

Methods: This multicenter, retrospective observational study included 67 patients with T2DM (median age, 65 years; diabetes duration, 15 years), divided into two groups: those who added a smart pen to ongoing IDegAsp ("digital switch," n=46) and those who transitioned from conventional insulins ("combined switch," n=21). Parameters were evaluated over a median follow-up of 18 months.

Results: Smart pen integration significantly optimized treatment intensity across both groups. The "digital switch" cohort maintained stable metabolic control while significantly reducing total daily insulin doses (p=0.018). The "combined switch" group achieved a simplified transition with a significant decrease in daily injection frequency. Hypoglycemia rates did not differ between the subgroups.

Conclusion: Integrating smart insulin pens into T2DM management optimizes dosing accuracy and reduces treatment burden without increasing hypoglycemia, serving as an essential tool for overcoming clinical inertia.

Keywords: Insulin Degludec/Aspart, Smart Insulin Pen, Type 2 Diabetes Mellitus

Cite This Article: *Güngör Semiz G, Demir Yüksel B, Emekdaş B, Arayıcı ME, Çetinkaya F, Demir T. Digital Insulin Management in Type 2 Diabetes: Enhancing Treatment Adherence and Safety with Connected Pens and IDegAsp. EJMI 2026;10(3):369–377.*

Address for correspondence: Gökçen Güngör Semiz, MD, Department of Internal Medicine, Division of Endocrinology and Metabolism, Faculty of Medicine, Dokuz Eylul University, İzmir, Türkiye
Phone: +90 505 769 62 45 **E-mail:** ggungor28@hotmail.com

Submitted Date: July 24, 2026 **Accepted Date:** August 14, 2026

According to the International Diabetes Federation (IDF), the global prevalence of diabetes is projected to rise from 589 million in 2021 to 853 million by 2050, imposing an unsustainable economic burden on healthcare systems and society.[1] As a critical worldwide public health concern with a surging global prevalence, type 2 diabetes mellitus (T2DM) is a chronic inflammatory disease that frequently necessitates sequential glucose-lowering therapies, including insulin, to achieve or maintain optimal glycemic targets.[2]

Type 1 diabetes mellitus (T1DM) is an autoimmune disease caused by T-cell-mediated destruction of pancreatic beta cells, requiring lifelong exogenous insulin, which the American Diabetes Association (ADA) recommends administering via multiple daily injections (MDI) or continuous subcutaneous insulin infusion (CSII). Conversely, T2DM involves insulin resistance and progressive beta-cell dysfunction; although oral antidiabetic drugs (OADs) or non-insulin injectables are preferred as first-line therapies, disease progression often requires intensification with insulin therapy.[2] Initiating basal insulin as an add-on to OADs is widely recommended as the optimal strategy for initial treatment intensification. If prandial insulin is further required to achieve stable glycemic regulation, short-acting insulin can be introduced either as a single pre-meal injection (basal-plus regimen) or as multiple preprandial injections (basal-bolus insulin regimens/intensive insulin therapy). Although basal-plus or basal-bolus treatment regimens significantly improve both fasting and postprandial glucose regulation in T2DM, it has been widely reported that treatment adherence markedly declines as the number of daily injections increases.[3]

Consequently, patient adherence and persistence represent two critical behavioral pillars for achieving target glycemic outcomes, particularly in complex insulin regimens that present distinctive management challenges. Evidence indicates that insulin nonadherence can reach up to 44.3% among individuals with T2DM, directly contributing to compromised glycemic control and accelerated microvascular damage.[4] While adherence concerns daily protocol compliance, persistence entails maintaining therapy over the intended timeline, from initiation to discontinuation. Notably, only 1 in 5 patients who initiate basal insulin therapy remain on treatment for a full year.[5] Ultimately, both nonadherence and nonpersistence undermine glycemic stability, substantially increasing the risk of long-term diabetic complications.[6]

To mitigate these compliance-related barriers, significant advancements have been documented in insulin administration systems over the past century, evolving from conventional syringes to prefilled disposable or reusable insulin pens and ultimately to algorithm-controlled insulin pumps.[7] Recent innovations in pen technology highlight "connected" or "smart" insulin pens, which can transfer dosing data to the cloud or a smartphone application. These connected devices can retain specific insulin doses and the exact timing of injections in their internal memory, thereby bridging the gap between glucose monitoring and insulin delivery. A prominent example of this technology is the NovoPen 6 smart insulin pen system, which uses dedicated cartridges of insulin degludec/aspart (IDegAsp)—the first soluble co-formulation providing distinct basal and prandial effects in a 70:30 ratio, with a duration of action of approximately 42 hours.[8] This combination provides effective glycemic control with a low risk of hypoglycemia in patients with T2DM and has been available in Türkiye as a reimbursable smart pen system since October 2023.

A review of the current literature reveals that the clinical evaluation of smart insulin pens has predominantly focused on populations with T1DM. Furthermore, a significant portion of the existing publications in this field consists of literature reviews rather than original clinical research. Consequently, there remains a distinct scarcity of real-world data exploring the implementation of these technologies in patients with T2DM, particularly in combination with modern insulin co-formulations. To address this gap, the present study aimed to investigate the clinical impact of integrating the NovoPen 6 smart insulin pen system in a real-world T2DM cohort. Specifically, we evaluated changes in glycemic control, hypoglycemia frequency, and treatment intensity across two distinct cohorts: patients adding smart pen technology to their ongoing IDegAsp regimen ("digital switch") and those transitioning from conventional insulin therapies to an IDegAsp smart pen ("combined switch"). In this study, we investigated whether these smart pen systems could help identify dosing errors, missed insulin doses, and accidental excess doses and whether this could facilitate treatment optimization.

Methods

Study Design

We designed this research as a retrospective, longitudinal observational study. Data collection took place across three medical centers, including tertiary education and research institutions and university hospitals.

The study protocol was approved by the Non-Interventional Research Ethics Committee of Buca Seyfi Demirsoy Training and Research Hospital (decision number 2023/208, dated 27.12.2023). The study was conducted in accordance with the principles of the Declaration of Helsinki. Patients

with type 2 diabetes mellitus (T2DM) who visited the outpatient endocrinology clinics of these centers and switched to the IDegAsp smart insulin pen system (NovoPen 6) between September 2023 and September 2024 were included in the study. The reasons for the treatment alteration were suboptimal glycemic control and frequent hypoglycemic attacks. In this study, we defined "suboptimal glycemic control" as an HbA1c level above 7.5% immediately before the switch, even though the patients were already on a stable insulin regimen. We used structured inclusion and exclusion criteria to determine patient eligibility. The inclusion criteria were defined as follows: adult patients aged 18 years or older, formally diagnosed with T2DM, who were actively receiving any conventional insulin therapy—including basal, basal-bolus, premixed insulin regimens, or prefilled disposable insulin degludec/aspart—and subsequently transitioned to the IDegAsp smart insulin pen system (NovoPen 6). We applied these exclusion criteria to prevent confounding factors from skewing our results. The study excluded individuals receiving active chemotherapy, patients with severe neurocognitive issues, and those hospitalized for acute cardiovascular or infectious events at the time of transition. We also excluded pregnant or lactating women, individuals with substance abuse issues, and patients taking systemic glucocorticoids for any reason.

The NovoPen 6 smart insulin pen is a CE-marked connected device featuring built-in memory and NFC technology. It automatically records the date, time, and dosage of each injection, allowing both patients and clinicians to objectively track dosing history. In this study, we used this integrated dataset to objectively identify and quantify missed insulin degludec/aspart (IDegAsp) doses as a robust measure of treatment adherence.

Data Collection

Clinical, biochemical, and treatment-related parameters of the included patients were collected retrospectively from the hospital electronic health record systems. Metabolic and laboratory data, including glycated hemoglobin A1c (HbA1c), fasting plasma glucose (FPG), low-density lipoprotein cholesterol (LDL-C), triglycerides, and microalbuminuria values, were extracted at baseline and at corresponding follow-up intervals of 3, 6, 12, and, where available, 24 months after transition to the insulin degludec/aspart (IDegAsp) smart pen system (NovoPen 6). All follow-up laboratory investigations were conducted at the same centers where the patients' baseline evaluations had been performed. Regarding insulin regimens, the total daily number of insulin injections and the precise daily insulin doses (expressed in units) were longitudinally tracked and compared with pre-transition parameters. To evaluate the impact of the smart pen ecosystem on concomitant oral antidiabetic drugs (OADs), the total number of non-insulin OADs was recorded at baseline and at the 1-year post-transition milestone. Oral antidiabetic medications were continued in accordance with the Turkish Endocrine Metabolism Society guidelines.

Furthermore, the frequency and severity of hypoglycemic events were evaluated longitudinally according to the American Diabetes Association (ADA) criteria, which define hypoglycemia as a blood glucose level of 70 mg/dL or lower (<3.9 mmol/L).[9] These events were classified as mild hypoglycemia if they could be self-managed by the patient without third-party assistance or as severe hypoglycemia if they required external or medical intervention. All patients received structured education on hypoglycemia recognition and management from certified diabetes nurse educators, and hypoglycemic episodes occurring during the preceding 1-month period were systematically collected from verified patient self-reports documented during routine outpatient follow-up visits.

Patient Stratification

Initially, 69 patients with type 2 diabetes mellitus (T2DM) transitioning to the smart pen ecosystem were screened. Two patients who were exclusively receiving oral antidiabetic drugs (OADs) without prior insulin therapy were excluded to maintain cohort homogeneity, leaving a final analytical sample of 67 patients. To differentiate the clinical impact of connected technology from that of the pharmacological formulation, this cohort was stratified based on pre-study regimens. The first subgroup included 46 patients who were already using prefilled disposable insulin degludec/aspart (IDegAsp) pens, in whom switching to the reusable smart pen system (NovoPen 6) isolated the longitudinal impact of digital tracking on glycemic control and hypoglycemia metrics. The second subgroup consisted of 21 patients transitioning from alternative conventional regimens (basal, basal-bolus, or premixed) to the IDegAsp smart pen, reflecting a combined switch in both the pharmacological agent (insulin degludec/aspart) and the delivery device. Comparative clinical outcome evaluations were performed through separate, independent analyses for each treatment transition pathway. Furthermore, the cohorts were directly compared with each other specifically regarding changes in HbA1c levels.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics (version 30.0; IBM Corp., Armonk, NY, USA). The distribution of continuous variables was assessed for normality using the Shapiro–Wilk test together with visual inspection

of histograms. Because most continuous variables did not follow a normal distribution, continuous data are summarized as mean±standard deviation and median (minimum–maximum), and categorical data are presented as frequencies and percentages. Within-patient changes over time and before-versus-after comparisons were evaluated using the Wilcoxon signed-rank test; each follow-up time point (months 3, 6, 12, 18, and 24) was compared with the corresponding baseline value using complete paired observations. Because the number of patients with available measurements decreased over time due to variable follow-up duration, the paired sample size (n) is reported for each comparison. Between-group comparisons of patients who switched to the smart insulin pen system (NovoPen 6)—specifically, those transitioning from IDegAsp versus those transitioning from conventional insulin regimens—were performed using the Mann–Whitney U test. The within-patient change in glycated hemoglobin (ΔHbA1c) was calculated as the difference between baseline and on-treatment values, with positive values indicating a reduction. All statistical analyses were performed using two-sided tests, with p-values <0.05 considered statistically significant.

Results

Baseline Characteristics of the Study Population

A total of 67 patients were included in the research. The mean age was 63.8±9.3 years (median 65, range 20–81), and 42 patients (62.7%) were women. The median duration of diabetes was 15.0 years (range 0.5–30), and the mean body mass index was 30.4±5.0 kg/m^2. Hypertension (82.1%) and hyperlipidemia (77.6%) were the most frequent comorbidities, followed by chronic kidney disease (31.3%) and coronary artery disease (20.9%); cerebrovascular events and diabetic foot were not observed. At baseline, patients were receiving a median of 2 oral antidiabetic drugs and a median total daily insulin dose of 40 units (range 12–106), administered via a median of 2 daily injections. Regarding the study cohorts, 46 patients (68.7%) who were already on an IDegAsp regimen were switched to the smart insulin pen system, while the remaining 21 patients (31.3%) were switched from conventional insulin regimens. The median follow-up duration was 18 months (range 6–24). Treatment discontinuation occurred in only two patients, one withdrawing due to poor metabolic control and the other due to recurrent hypoglycemia (Table 1).

When comparing baseline characteristics, patients in the group transitioning from insulin degludec/aspart (IDegAsp) were significantly younger than those in the conventional regimen cohort (p=0.027). In contrast, no significant differences were observed between the groups regarding diabetes duration, body mass index (BMI), or baseline HbA1c levels. Similarly, total daily insulin doses did not differ significantly between the cohorts. Notably, the IDegAsp cohort had a significantly lower frequency of daily injections at baseline than the conventional treatment group (p=0.018) (Table 2).

Table 1. Baseline demographic and clinical characteristics of the study population (n=67)

Characteristic	n (%)	Mean±SD / Median (min–max)
Age (years)		63.8±9.3 / 65 (20–81)
Sex		
Female	42 (62.7)	
Male	25 (37.3)	
Diabetes duration (years)		15.0±6.4 / 15.0 (0.5–30)
Body mass index (kg/m^2)		30.4±5.0 / 29.4 (19.4–44.3)
Baseline antidiabetic treatment		
Number of oral antidiabetic drugs		2.0±0.8 / 2 (0–3)
Daily injection number		2.3±1.0 / 2 (1–5)
Total daily insulin dose (units)		42.7±20.8 / 40 (12–106)
Switched from IDegAsp	46 (68.7)	
Comorbidities		
Hypertension	55 (82.1)	
Hyperlipidemia	52 (77.6)	
Coronary artery disease	14 (20.9)	
Chronic kidney disease	21 (31.3)	
Heart failure	8 (11.9)	
Diabetic neuropathy	5 (7.5)	
Retinopathy	4 (6.0)	
Cerebrovascular event	0 (0.0)	
Diabetic foot	0 (0.0)	

Data are presented as n (%) for categorical variables and as mean±standard deviation and median (minimum–maximum) for continuous variables. IDegAsp, insulin degludec/insulin aspart co-formulation. Diabetes duration was available for 62 patients, body mass index for 58 patients, and number of oral antidiabetic drugs for 66 patients.

Efficacy of the Smart Insulin Pen System Across Study Cohorts

Within-group analyses revealed no statistically significant changes in HbA1c levels from baseline to the 3-, 6-, 12-, and 24-month follow-ups in either the IDegAsp or conventional therapy transition cohorts (p>0.05). Similarly, independent evaluations of both cohorts showed no significant differences in LDL, triglyceride, or microalbuminuria levels between baseline and the 12-month visit (p>0.05).

Table 2. Inter-group comparison of baseline demographic and clinical characteristics

Parameter	IDegAsp to Smart Pen (n=46)	Conventional regimens to Smart Pen (n=21)	p*
Age (years)	65 (44-74)	70.5 (53-81)	**0.027**
Diabetes Duration (years)	15 (1-30)	17.7 (0.5-30)	0.276
Baseline BMI (kg/m^2)	29.5 (20.0-44.3)	28.9 (19.4-38.0)	0.794
Baseline HbA1c (%)	8.0±1.6 / 7.75 (5.80–13.90)	7.5±1.7 / 7.30 (6.10–12.30)	0.305
Daily injection number (n)	2 (1-5)	3 (1-4)	**0.018**
Total daily insulin dose (units)	42 (12-106)	49 (14-66)	0.823

Data are presented as mean±standard deviation and median (minimum–maximum) for continuous variables. HbA1c: glycated hemoglobin; BMI: body mass index; OAD: oral antidiabetic drug. *p-value calculated by Mann–Whitney U test; p <0.05 indicates statistical significance.

Furthermore, body mass index (BMI) remained stable, with no significant changes from baseline to the end of the first year in either group. A comprehensive breakdown of the changes within both study cohorts is provided in Table 3.

Treatment Intensity and Hypoglycemia Outcomes

Following the transition to the smart pen system, the IDegAsp cohort demonstrated a statistically significant reduction in the total daily insulin dose during follow-up (p=0.018). Conversely, in the cohort transitioning from conventional insulin regimens, total daily insulin requirements did not differ significantly, whereas daily injection frequency decreased significantly (p=0.006). The number of concomitant oral antidiabetic drugs (OADs) remained stable across both groups. Furthermore, an analysis of safety outcomes revealed no significant differences in the rates of severe (major) or mild (minor) hypoglycemia between the study cohorts (Table 4).

Comparative Glycemic Efficacy by Transition Pathway

Between-group comparisons revealed no statistically significant difference in baseline HbA1c levels between the cohorts transitioning to the smart pen from either an IDegAsp or conventional insulin regimen. Furthermore, the mean changes in HbA1c from baseline (ΔHbA1c) at the 6- and 12-month follow-up milestones showed no significant differences between the two transition pathways (p>0.05). These data indicate that both pre-transition modalities yielded comparable glycemic efficacy following the initiation of the smart insulin pen system. These findings are presented in detail in Table 5.

Discussion

Insulin therapy represents an indispensable requirement in type 1 diabetes management; however, in type 2 diabetes mellitus (T2DM), it also becomes an inevitable necessity when oral antidiabetic drugs (OADs) fail to provide sufficient glycemic optimization or are clinically contraindicated. The profound long-term benefits of early, intensive glycemic control in patients with T2DM have recently been reinforced by 44-year follow-up data from the landmark UKPDS 91 study.[10] Furthermore, the American Diabetes Association (ADA) 2026 Standards of Care advocate early initiation of insulin therapy to achieve rapid metabolic stabilization, especially in patients with T2DM presenting with severe glucose toxicity or markedly elevated baseline HbA1c levels.[11] Despite established clinical frameworks, the success of insulin therapy is severely limited by poor adherence, which affects up to 50% of patients and remains a critical barrier to achieving glycemic targets. Notably, approximately one-third of these individuals omit an average of 3 insulin doses per month. This widespread nonadherence stems from regimen complexity, a high injection burden, forgetfulness, socioeconomic constraints, and fear of side effects or weight gain. Consequently, there is an urgent clinical need for novel technological tools to objectively monitor dosing behaviors and enhance patient adherence.[12]

This multicenter, longitudinal observational study provides real-world evidence on the clinical impact of transitioning to a connected smart insulin pen system (NovoPen 6) in patients with T2DM. We grouped patients according to their prior therapies to compare two specific scenarios. The "digital switch" group consisted of prior IDegAsp users, while the "combined switch" group consisted of those transitioning from conventional regimens to an IDegAsp smart pen. It is important to note that the baseline characteristics of our study population reflect a predominantly geriatric cohort, with a median age of 65 years (range 20–81) and a median diabetes duration of 15 years. Since this population is older and has a long history of the disease, these patients are particularly vulnerable to major vascular complications. Furthermore, these patients may frequently experience cognitive or memory issues as they age. It is clear that the clinical utility of connected smart insulin pen systems is particularly pronounced in this vulnerable group. The smart pen records

Table 3. Longitudinal changes in metabolic and clinical parameters stratified by treatment transition pathways

Cohort 1/parameter	n	Mean±SD	Median (min–max)	p*
HbA1c, % over time				
Baseline	46	8.0±1.6	7.75 (5.8–13.9)	Ref.
Month 3	21	8.0±1.2	8.2 (6.1–11.3)	0.821
Month 6	30	8.1±1.9	7.3 (5.6–13.7)	0.689
Month 12	30	8.0±1.6	8.1 (6.1–11.5)	0.873
Month 24	9	7.2±1.2	6.8 (6.3–10.2)	0.398
LDL-cholesterol (mg/dL)				
Baseline	43	101.9±28.2	99.0 (55.0–197.0)	Ref.
Month 12	28	94.3±23.8	93.5 (49.0–154.0)	0.569
Triglycerides (mg/dL)				
Baseline	44	166.7±77.3	143.5 (46.0–425.0)	Ref.
Month 12	28	149.0±49.6	127.0 (78.0–252.0)	0.432
Microalbuminuria (mg/g)				
Baseline	41	75.7±109.5	20.0 (2.2–460.0)	Ref.
Month 12	29	59.5±117.6	11.0 (2.0–554.0)	0.713
BMI				
Baseline	40	30.5±5.0	29.5 (20.1–44.3)	Ref.
Month 12	34	30.4±4.4	29.5 (22.1–41.2)	0.058
Cohort 2/parameter HbA1c, % over time				
Baseline	19	7.7±1.7	7.3 (6.1–12.3)	Ref.
Month 3	7	7.3±1.2	6.8 (6.2–8.7)	0.344
Month 6	9	8.1±2.0	7.4 (5.9–12.5)	0.402
Month 12	11	7.1±1.2	6.9 (5.7–9.6)	0.502
Month 24	4	7.5±1.2	7.5 (6.5–8.5)	—
LDL-cholesterol (mg/dL)				
Baseline	17	105.6±24.7	111.0 (60.0–144.0)	Ref.
Month 12	7	99.4±27.7	104.0 (66.0–139.0)	0.891
Triglycerides (mg/dL)				
Baseline	18	182.4±99.0	157.0 (53.0–416.0)	Ref.
Month 12	7	189.7±32.7	202.0 (119.0–213.0)	0.188
Microalbuminuria (mg/g)				
Baseline	19	57.5±68.6	15.0 (7.0–262.0)	Ref.
Month 12	7	70.7±106.8	20.0 (12.0–297.0)	0.875
BMI				
Baseline	18	30.1±5.3	29.0 (19.4–38.1)	Ref.
Month 12	16	31.0±5.6	31.3 (22.2–38.1)	0.283

Cohort 1 (n=46) consists of patients who switched to the smart insulin pen system from insulin degludec/aspart (IDegAsp); Cohort 2 (n=21) consists of patients who transitioned to the smart insulin pen system from conventional insulin regimens. *p-values are derived from the Wilcoxon signed-rank test versus the corresponding reference (baseline / before-switch) value using complete paired observations. HbA1c: glycated hemoglobin; BMI: body mass index; LDL: low-density lipoprotein; SD: standard deviation

insulin dosing data in real time, creating a completely objective medical history. This directly protects older patients from severe glycemic excursions by preventing them from taking a dose twice or forgetting it entirely.

Table 4. Changes in treatment intensity and hypoglycemia data over time in both cohorts

Cohort 1/parameter	n	Mean±SD	Median (min–max) / n (%) †	p*
Number of oral antidiabetic drugs				
Before switch	46	2.1±0.8	2.0 (0.0–3.0)	Ref.
Last visit	45	2.2±0.9	2.0 (0.0–3.0)	0.539
Total daily insulin dose (units)				
Before switch	46	44.2±23.2	41.0 (12.0–106.0)	Ref.
Last visit	43	38.8±20.2	36.0 (10.0–110.0)	**0.018**
Daily Injection Frequency (n)				
Before switch	46	2.0±0.9	2.0 (1.0–5.0)	Ref.
Last visit	44	2.0±0.8	2.0 (1.0–4.0)	0.889
Severe hypoglycemia (episodes/patient)				
Before switch	44	0.05±0.30	1 (2.3)	Ref.
After switch	44	0.00±0.00	0 (0.0)	0.317
Mild hypoglycemia (episodes/patient)				
Before switch	44	0.52±1.32	12 (27.3)	Ref.
After switch	44	0.45±0.95	12 (27.3)	0.942
Cohort 2/parameter				
Number of oral antidiabetic drugs				
Before switch	20	1.6±0.7	1.5 (1.0–3.0)	Ref.
Last visit	18	1.6±0.8	2.0 (0.0–3.0)	0.739
Total daily insulin dose (units)				
Before switch	21	39.6±14.0	40.0 (14.0–66.0)	Ref.
Last visit	18	36.9±13.8	37.0 (14.0–60.0)	0.193
Daily Injection Frequency (n)				
Before switch	21	2.7±1.2	3.0 (1.0–4.0)	Ref.
Last visit	18	2.2±0.7	2.0 (1.0–3.0)	**0.006**
Severe hypoglycemia (episodes/patient)				
Before switch	18	0	0	-
After switch	18	0	0	-
Mild hypoglycemia (episodes/patient)				
Before switch	18	0.50±0.51	9 (50.0)	Ref.
After switch	18	0.50±0.99	5 (27.8)	0.914

*Cohort 1 (n=46) consists of patients who switched to the smart insulin pen system from insulin degludec/aspart (IDegAsp); Cohort 2 (n=21) consists of patients who transitioned to the smart insulin pen system from conventional insulin regimens.
*p-values are derived from the Wilcoxon signed-rank test versus the corresponding reference (baseline / before-switch) value using complete paired observations; tests were not computed when fewer than five paired observations were available (shown as "—").
†For hypoglycemia, this column reports the number (percentage) of patients with ≥1 episode; for all other parameters it reports median (minimum–maximum). The number of patients with available measurements (n) decreases over time owing to variable follow-up duration.
SD, standard deviation

Our most important clinical finding concerned treatment intensity. The smart pens helped patients in both groups optimize their daily insulin regimens without compromising glycemic control or increasing the risk of hypoglycemia. In particular, patients already receiving IDegAsp maintained stable metabolic control with reduced daily insulin doses. This is likely a consequence of digital feedback, which has been shown to mitigate clinical inertia and "catch-up" dosing by uncovering previously unnoticed missed injections. Patients who transitioned from conven-

Table 5. Comparison of glycemic control between patients switched from insulin degludec/aspart (IDegAsp); and from conventional insulin regimens

Parameter	Switched from IDegAsp (n)	Switched from conventional Tx (n)	p†
HbA1c at baseline (%)	7.75 (5.80–13.90) (46)	7.30 (6.10–12.30) (19)	0.305
HbA1c at month 6 (%)	7.30 (5.60–13.70) (30)	7.40 (5.90–12.50) (9)	0.947
HbA1c at month 12 (%)	8.10 (6.10–11.50) (30)	6.90 (5.70–9.60) (11)	0.102
ΔHbA1c, baseline → month 6 (%)	0.10 (-2.40–2.00) (30)	-0.20 (-1.20–1.90) (9)	0.790
ΔHbA1c, baseline → month 12 (%)	0.05 (-4.90–4.70) (30)	0.30 (-1.60–3.80) (11)	0.659

†: p values from the Mann–Whitney U test; values are median (minimum–maximum), (n). ΔHbA1c is the within-patient change from baseline (positive values indicate a reduction). Baseline HbA1c did not differ between groups; on-treatment HbA1c and ΔHbA1c at months 6 and 12 also showed no significant between-group differences. IDegAsp: insulin degludec/insulin aspart co-formulation; HbA1c: glycated hemoglobin; Tx: treatment.

tional regimens experienced a significant decrease in the frequency of insulin injections. This was not surprising, given that switching to a co-formulated mixture such as IDegAsp streamlines the daily treatment process. The stability of hypoglycemic events in both subgroups emphasizes the safety and reliability of the smart pen.

Our findings, based on real-world observations, align with the clinical improvements reported in recent randomized controlled trials (RCTs). In a crossover trial of patients with uncontrolled T2DM, smart insulin pen caps that provide reminders and digital feedback significantly improved treatment adherence and glycemic metrics.[12] In addition, a multicenter RCT in patients with T1DM showed that the use of connected insulin pen caps resulted in a substantially higher time in range (TIR) than in masked controls.[13] Our study did not include randomization or CGM-derived metrics, but we observed improvements in treatment intensity, as reflected by lower daily insulin doses and less frequent injections. These findings are similar to those of other studies in which patients adhered more closely to treatment and insulin dosing was more accurate. However, our findings regarding hypoglycemia differ from the existing literature. While RCTs frequently report a decrease in hypoglycemia rates, we observed that hypoglycemia remained stable in our cohort. This difference is likely explained by the retrospective design of our study and reliance on patient-reported logs, which inherently limit the detection of asymptomatic hypoglycemic events compared with the objective data obtained from the CGM systems used in those trials.[12,13]

Several limitations must be considered when interpreting our outcomes. First, the modest sample size may have restricted the statistical power to detect subtle changes in hypoglycemia rates. Second, because continuous glucose monitoring (CGM) was unavailable, we relied on patient-reported logs, which are prone to recall bias and often fail to capture asymptomatic or nocturnal hypoglycemic events. Finally, due to the retrospective nature of our data collection, incomplete laboratory datasets were observed at some follow-up intervals. Ultimately, larger prospective studies using standardized CGM data are needed to fully understand how smart pens affect hypoglycemia and long-term glycemic control.

Recent literature indicates that smart pens have the potential to transform diabetes management. They replace the traditional reliance on patient memory with a clear, data-driven treatment strategy.[7,14,15] Our findings clearly reflect this change. The devices revealed missed doses and reduced clinical inertia, allowing patients receiving IDegAsp to use less insulin and providing patients transitioning from conventional regimens with a much simpler injection schedule. These results demonstrate the importance of connected pens as a routine component of care for patients treated with insulin. They help eliminate dosing errors that contribute to "therapeutic inertia," enabling the establishment of safe, personalized treatment plans.

Conclusion

In conclusion, our findings show that smart insulin pens simplify T2DM management and improve dosing accuracy, which is particularly important for older patients with a long history of diabetes. These devices track missed doses, prevent accidental double dosing, and simplify complex insulin regimens. They provide a practical means of overcoming therapeutic inertia while maintaining a low risk of hypoglycemia. Future prospective studies should incorporate CGM data to determine more precisely how these pens affect hypoglycemic events. This will be the next step in integrating digital insulin metrics into clinical practice.

Disclosure

Ethics Committee Approval: This study was approved by The Non-Interventional Research Ethics Committee of Buca Seyfi Demirsoy Training and Research Hospital (Approval Number: 2023/208 Approval Date: 27.12.2023)

Informed Consent: Written informed consents were obtained from patients who participated in this study.

Conflict of Interest: The authors declare that there is no conflict of interest.

Use of AI for Writing Assistance: The authors declared that artificial intelligence was not used in the study.

Financial Disclosure: The authors declared that this study received no financial support.

Authorship Contributions: Concept – TD; Design – TD, GGS; Supervision – TD ; Materials – GGS, BDY, FÇ, BE; Data Collection and/or Processing – GGS, BDY, B.E, FÇ; Analysis and/or Interpretation – MEA; Literature Review – GGS; Writing – GGS; Critical Review – TD, MEA.

Peer-review: Externally peer-reviewed.

References

1. Magliano DJ, Boyko EJ; Diabetes Atlas 11th edition scientific committee. Diabetes Atlas. 11th ed. Brussels (Belgium): International Diabetes Federation; 2025.
2. American Diabetes Association Professional Practice Committee for Diabetes*. 9. Pharmacologic Approaches to Glycemic Treatment: Standards of Care in Diabetes-2026. Diabetes Care 2026;49(Suppl 1):S183–S215. [CrossRef]
3. Home P, Riddle M, Cefalu WT, Bailey CJ, Bretzel RG, Del Prato S, et al. Insulin therapy in people with type 2 diabetes: opportunities and challenges? Diabetes Care 2014;37(6):1499–508. [CrossRef]
4. Cramer JA, Roy A, Burrell A, Fairchild CJ, Fuldeore MJ, Ollendorf DA, et al. Medication compliance and persistence: terminology and definitions. Value Health 2008;11(1):44–7. [CrossRef]
5. Perez-Nieves M, Kabul S, Desai U, Ivanova JI, Kirson NY, Cummings AK, et al. Basal insulin persistence, associated factors, and outcomes after treatment initiation among people with type 2 diabetes mellitus in the US. Curr Med Res Opin 2016;32(4):669–80. [CrossRef]
6. Idris I, Gulati K, Perez-Nieves M, Hadjiyianni I, Cao D, Tahbaz A, et al. Associated factors that influenced persistence with basal analog insulin therapy among people with type 2 diabetes: An exploratory analysis from a UK real-world sample. Prim Care Diabetes 2019;13(2):106–12. [CrossRef]
7. Heinemann L, Sieber J, Kulzer B. Connected pens or smart pens: technology needs context. J Diabetes Sci Technol 2026;20(1):184–92. [CrossRef]
8. Haahr H, Fita EG, Heise T. A review of insulin degludec/insulin aspart: pharmacokinetic and pharmacodynamic properties and their implications in clinical use. Clin Pharmacokinet 2017;56(4):339–54. [CrossRef]
9. American Diabetes Association Professional Practice Committee. 2. Classification and Diagnosis of Diabetes: Standards of Medical Care in Diabetes—2022. Diabetes Care 2022;45(Suppl 1):S17–S38. [CrossRef]
10. Adler AI, Coleman RL, Leal J, Whiteley WN, Clarke P, Holman RR. Post-trial monitoring of a randomised controlled trial of intensive glycaemic control in type 2 diabetes extended from 10 years to 24 years (UKPDS 91). Lancet 2024;404(10448):145–55. [CrossRef]
11. American Diabetes Association Professional Practice Committee for Diabetes. Standards of care in diabetes—2026. Diabetes Care 2026;49(Suppl 1):S1–S324.
12. Galindo RJ, Ramos C, Cardona S, Vellanki P, Davis GM, Oladejo O, et al. Efficacy of a smart insulin pen cap for the management of patients with uncontrolled type 2 diabetes: a randomized cross-over trial. J Diabetes Sci Technol 2023;17(1):201–7. [CrossRef]
13. Gomez-Peralta F, Abreu C, Fernández-Rubio E, Cotovad L, Pujante P, Gaztambide S, et al. Efficacy of a connected insulin pen cap in people with noncontrolled type 1 diabetes: a multicenter randomized clinical trial. Diabetes Care 2023;46(1):206–8. [CrossRef]
14. Lingen K, Pikounis T, Bellini N, Isaacs D. Advantages and disadvantages of connected insulin pens in diabetes management. Endocr Connect 2023;12(11):e230108. [CrossRef]
15. Giorgino F, Bonfanti R, Castaldo F, Irace C, Laurenzi A, Maffeis C, et al. The utility of smart multiple daily injection systems in intensive insulin-treated people with diabetes: an italian expert consensus. J Diabetes Sci Technol 2026;20(4):1450–9. [CrossRef]