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Optimizing Diabetes Management: Insights from a Prospective Study

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Abstract

Introduction: According to the results of a large international observational study, IDMPS (The International Diabetes Management Practices Study), the achievement of therapeutic objectives in terms of glycemic control (HbA1c < 7%]), LDL cholesterol (LDLc < 2.6 mmol/l) and blood pressure (BP < 130/80 mmHg) among diabetics remains sub-optimal. The main objective of this study was to assess the quality of care provided to type II and type I diabetics, in terms of glycemic control and the management of the various associated cardiovascular risk factors, in our department. Secondly, this study aimed to identify predictive factors for achieving optimal metabolic control, with the ultimate goal of improving the management and outcomes of diabetic patients. **Materials and Methods:** This prospective, descriptive, and analytical study was performed at the Endocrinology Department of Hassan II University Hospital, Fez, from January 2020 to December 2022, and included patients with type 1 and type 2 diabetes receiving follow-up in a specialized diabetology consultation. The primary endpoint was glycemic control, assessed using patient-level mean HbA1c over the two-year follow-up, while the secondary endpoints included weight loss, blood pressure control, and lipid control, represented by the averages of BMI, blood pressure, and LDL-C levels collected during patient follow-up. **Results**: After two years of follow-up, good metabolic control—defined as the simultaneous achievement of the three therapeutic targets (glycemic control, blood pressure control, and lipid control)—was attained by 42.8% of patients with Type 2 Diabetes (T2DM) and 39.8% of those with Type 1 Diabetes (T1DM). Achieving good metabolic control was significantly associated with a reduction in cardiovascular events (p = 0.013; OR = 0.22; 95% CI [0.19 - 0.28]) and microvascular complications (p = 0.001; OR = 0.31; 95% CI [0.26 - 0.43]). In multivariate logistic regression analysis, several factors were independently associated with the achievement of optimal meta-

bolic control. These included High socioeconomic status (OR = 0.72, 95% CI [0.35 - 0.97]), weight loss of 5- 10% from baseline body weight (OR = 0.76, 95% CI [0.54 - 0.83]), number of education sessions > 6 (OR = 0.59, 95% CI [0.26 - 0.97]), therapeutic adherence (OR = 0.79, 95% CI [0.46 - 0.98]), and self-monitoring of blood glucose > 4/day (OR = 0.41, 95% CI [0.11 - 0.83]). **Conclusion:** Good metabolic control is the cornerstone of any strategy aimed at reducing the risk of diabetes-related complications. Nevertheless, the practical implementation of recommendations for the management of people with diabetes remains a real challenge for the various healthcare systems around the world. Our study shows an improvement in the metabolic control of diabetics during follow-up.

Keywords

Diabetes Management, Cardiovascular Risk Factors, Therapeutic Objectives, Metabolic Control, Complications Prevention

1. Introduction

Good metabolic control is crucial for reducing diabetes-related complications. However, the practical application of management guidelines for diabetics remains a significant challenge for healthcare systems worldwide. Many studies have repeatedly shown sub-optimal control among diabetic patients. In developing countries, glycemic control has remained poor and is worsening over the past 12 years, as evidenced by real-world data from the international IDMPS study involving over 66,000 individuals with type 2 diabetes [1]. This decline persists despite numerous advancements in diabetes management, including the introduction of new medications that enhance diabetes control and clinical outcomes.

According to the results of a large international observational study, the IDMPS (The International Diabetes Management Practices Study), therapeutic targets for glycemic control (HbA1c < 7%), LDL cholesterol (LDLc < 2.6 mmol/l) and blood pressure (BP < 130/80 mmHg) were achieved in only 25% of participants with type 1 diabetes and 36% with type 2 diabetes [1]. These findings are consistent with data from other large cohort studies, such as the NHANES (National Health and Nutrition Examination Survey) in the United States, which similarly reported that a minority of individuals with diabetes achieve all three recommended cardiometabolic targets [2]. The UK National Diabetes Audit also revealed suboptimal target attainment, with fewer than 40% of patients with type 2 diabetes achieving combined targets for glycemia, lipid control, and blood pressure [3]. Such trends underscore the persistent global challenge in optimizing diabetes management and suggest that despite the availability of effective pharmacologic therapies and clinical guidelines, a significant proportion of patients remain at elevated risk for cardiovascular and microvascular complications [4] [5].

These results can be explained by a number of constraints. Patient-related bar-

riers to initiation, titration, and adherence of insulin therapy include fear of hypoglycemia and weight gain, psychological resistance or anxiety about injections, insufficient education about insulin regimens, and suboptimal communication between physicians and patients, which contribute to therapeutic inertia and dose omission [6]-[8].

While the IDMPS study provides robust statistical strength through its multicenter approach and large cohort, it lacks long-term follow-up due to its cross-sectional design. In response, our study seeks to highlight the significance of long-term diabetes monitoring over a two-year period, emphasizing personalized care for patients. By considering each individual's unique characteristics—such as the type of diabetes, comorbidities, lifestyle habits, and personal preferences—the goal is to enhance treatment adherence, prevent complications, and promote better disease management. The primary objective of our study was to assess the management of type 1 and type 2 diabetics under the care of the endocrinology, diabetology, metabolic diseases, and nutrition department at the Hassan II University Hospital, focusing on glycemic control and management of associated cardiovascular risk factors, including weight loss, blood pressure control, smoking cessation, and LDL cholesterol target achievement. The secondary objective was to identify predictive factors for achieving optimal metabolic control, ultimately aiming to improve the management and outcomes of diabetic patients.

2. Materials and Methods

2.1. Study Design and Participants

A prospective descriptive and analytical study was conducted in the Department of Diabetology, Endocrinology, Metabolic Diseases, and Nutrition at Hassan II University Hospital in Fez. Patient inclusion took place over a continuous 12-month period from January to December 2020, and all eligible patients attending the department during this period were consecutively enrolled and followed for two years, until December 2022. A flow diagram detailing patient selection and follow-up is presented in **Figure 1**.

2.2. Sample Size Justification

The primary objective of this study was to evaluate the quality of care provided to patients with type 1 and type 2 diabetes followed at our department. To ensure a comprehensive assessment of real-world practice, all eligible patients were included, thereby constituting an exhaustive sample of the population managed in our center during the study period. As the study aimed to describe routine care in this specific clinical setting, a prior sample size calculation was not performed. However, a post-hoc power analysis was conducted to evaluate the statistical robustness of the findings.

2.3. Inclusion/Exclusion Criteria

Patients aged ≥ 18 years with a confirmed diagnosis of type 1 or type 2 diabetes

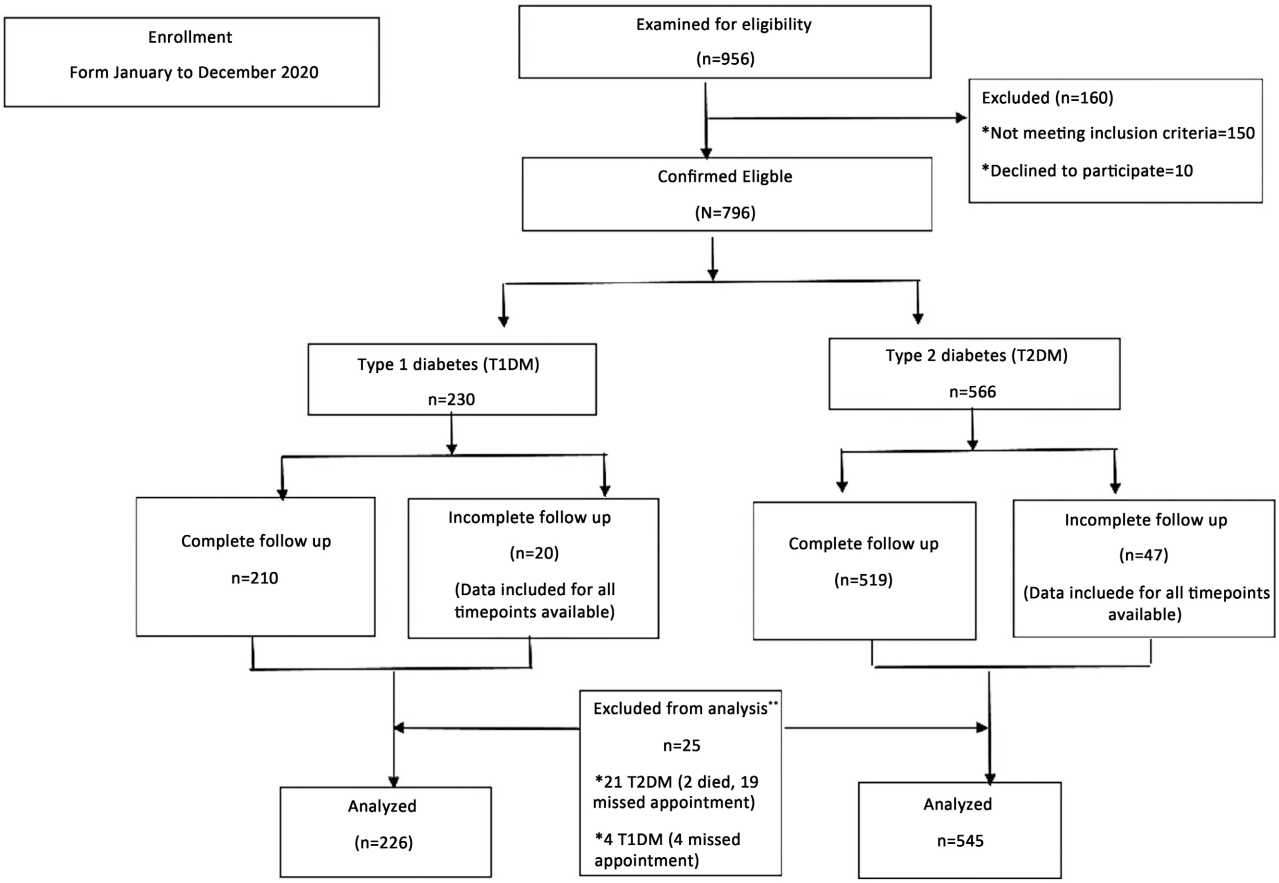
according to ADA criteria, followed in the Department of Endocrinology and Diabetology at Hassan II University Hospital during the study period (January-December 2020), were consecutively included. The study population was divided into two groups:

1) G1: Patients with type 2 diabetes.

2) G2: Patients with type 1 diabetes.

Patients with gestational diabetes, pregnancy, or secondary diabetes, were excluded.

Additionally, participants who did not attend any post-inclusion follow-up visits were excluded from the analysis.



Note: **: participants with no follow-up visits were excluded from the analysis.

Figure 1. Participant flow diagram.

2.4. Data Collection

We studied various variables:

Socio-demographic data: age, sex, marital status, level of education, professional activity and socio-economic level.

Clinical data: Body Mass Index (BMI), Waist Circumference (WC), Blood Pressure (BP), and complete somatic examination.

Biological and radiological data: Hemoglobin A1c (HbA1c), lipid profile, de-

generative, and autoimmunity workup, echocardiography, arterial Doppler ultrasound of the lower limbs and supra-aortic trunks.

All Patients were assessed at 3 months and then every 6 months for 2 years. Participants with incomplete follow-up were retained in the analysis, and all available time points were used.

2.5. Assessment Criteria

The primary endpoint was glycemic control, assessed using patient-level mean HbA1c over the two-year follow-up. Secondary endpoints included weight, blood pressure, and lipid control, evaluated using the patient-level average values of Body Mass Index (BMI), blood pressure, and Low-Density Lipoprotein Cholesterol (LDL-C) derived from all available measurements collected during follow-up. These individual mean values were subsequently compared with guideline-recommended targets to determine the proportion of patients achieving glycemic and cardiometabolic control.

Glycemic targets were defined according to ADA 2021 guidelines and were individualized based on patient's characteristics, including age, duration of diabetes, comorbidities, and risk of hypoglycemia. Cardiovascular risk stratification and LDL-C targets were defined according to ESC 2021 guidelines. The blood pressure target was defined as BP< 130/80 mmHg according to the ESC/ESH 2021 guidelines.

2.6. HbA1c Measurement

HbA1C was determined by HPLC (High Performance Liquid Chromatography) followed by mass spectrometry or capillary electrophoresis.

2.7. Assessment of Microvascular and Macrovascular

Microvascular complications:

Diabetic retinopathy was screened by ophthalmologists using ophthalmoscopy (fundus examination). Diabetic kidney disease was evaluated in all participants by measuring serum creatinine, calculating the estimated Glomerular Filtration Rate (eGFR) using the CKD-EPI equation, and determining the Urine Albumin-to-Creatinine Ratio (UACR). Diabetic neuropathy was assessed clinically through a standardized neurological examination, including the Diabetic Neuropathy Assessment (DNA) score and the 10-g monofilament test.

Macrovascular complications:

Cardiovascular evaluation included clinical assessment and complementary investigations. Peripheral Arterial Disease (PAD) screening was performed using the Ankle-Brachial Index (ABI), with lower limb arterial Doppler ultrasound conducted when indicated. Cardiac assessment comprised a standard Electrocardiogram (ECG), Transthoracic Echocardiography (TTE), and supra-aortic trunk Doppler ultrasound. Exercise stress testing was performed in selected patients based on clinical indications.

2.8. Ethical Issues

The Patients were informed of the voluntary and anonymous nature of the study, and were free to refuse. Consent was required from all patients.

2.9. Scores and Questionnaires

Perceived Stress Scale: (PSS10): Exposure to psychological stress was assessed using the 10-item Perceived Stress Scale (PSS-10), translated into Moroccan Arabic and previously validated in a nationwide population-based study [9]. Items were rated on a 5-point Likert scale ranging from 0 ("never") to 4 ("very often"), yielding a total score between 0 and 40, with higher scores reflecting greater perceived stress.

Questionnaires with more than 20% missing items were excluded, while mean imputation was applied when only one or two items were missing, in accordance with standard psychometric recommendations.

2.10. Definitions

1) Moderate hypoglycemia:

Level 1: Blood glucose levels from 54 to 70 mg/dL.

Level 2: Blood glucose levels < 54 mg/dl.

2) Severe hypoglycemia:

Hypoglycemia requires the assistance of a third party.

2.11. Data Analysis

Quantitative variables were expressed as mean standard deviation or median and interquartile range depending on the type of distribution of the variable.

Qualitative variables were expressed as numbers and percentages.

The comparison between the two groups of T1DM and T2DM was performed using either the Student's t-test or the Mann-Whitney U test, depending on the distribution of the variable.

Factors predictive of good diabetes control were identified in two stages. First, the quantitative variable HbA1c was transformed into a qualitative variable indicating optimal metabolic control (Yes/No), with poor glycemic control coded as the event (1) for the dependent variable. Variables significantly associated with good glycemic control were then identified using univariate logistic regression, and crude Odds Ratios (ORs) with their 95% confidence intervals were calculated. Subsequently a multivariate logistic regression model was performed including all variables significantly associated in the univariate analysis in order to assess the independent contribution of each factor, adjusted for the other variables included in the model. Since poor metabolic control was coded as the event (1), ORs less than 1 were considered protective factors and therefore predictors of good metabolic control.

A p-value < 0.05 was considered indicative of statistical significance.

Data were recorded in Microsoft Excel and analyzed using SPSS software, version 22.

2.12. Use of Artificial Intelligence Tools

An artificial intelligence-based language model (QuillBot) was used to assist in revising the English language of the manuscript. No AI tool was used for data analysis, interpretation of results, or generation of scientific conclusions. All content was verified by the authors.

3. Results

3.1. Study Population and Baseline Characteristics

A total of 771 patients were analyzed, with 70.6% diagnosed with type 2 diabetes and 29.4% with type 1 diabetes. A higher proportion of females was observed, with a male-to-female sex ratio of 0.65. Furthermore, the mean age of patients with type 2 diabetes was 63.10 ± 10.80 years, whereas those with type 1 diabetes were significantly younger, with a mean age of 31.18 ± 9.2 years.

In terms of socio-economic status, the majority of our patients belonged to the middle class, representing 65.3% of the total. As for their educational background, 48% were illiterate. Additionally, 30% of patients had health insurance (**Table 1**).

3.2. Initial Assessment: Clinical, Biological and Therapeutic Data

Initial clinical assessment revealed that 55.2% of patients with Type 2 Diabetes (T2DM) were obese, compared to only 3.9% of those with Type 1 Diabetes (T1DM) ($p < 0.001$). Abdominal obesity was also more prevalent in T2DM, affecting 73.3% of patients, while only 11.9% of T1DM patients were affected ($p < 0.01$).

Hypertension was present in 53.5% of T2DM patients, compared to 15.9% of T1DM patients ($p < 0.001$). Moreover, the majority of hypertensive T1DM patients had optimal blood pressure control, with 80.5% achieving this compared to just 19.3% of hypertensive T2DM patients ($p = 0.02$).

In terms of smoking habits, 10.2% of T2DM patients were non-cessation smokers, while 6.19% of T1DM patients fell into this category ($p = 0.076$). Regarding quality of life, assessed using the Perceived Stress Scale (PSS10), moderate stress was reported in 66.3% of patients, and high stress in 11.2%.

The paraclinical evaluation showed that most T2DM patients had suboptimal glycemic control, with 81% exhibiting poor control compared to 70.7% of T1DM patients ($p = 0.043$). Dyslipidemia was diagnosed in 62.3% of T2DM patients, compared to 18.1% of T1DM patients ($p < 0.001$).

Acute complications were more prevalent in patients with T1DM. Hypoglycemia occurred in 53.09% of T1DM patients, with 21.2% reporting at least one episode of severe hypoglycemia. In contrast, 26.9% of T2DM patients experienced hypoglycemia, with 9.17% having severe episodes ($p = 0.02$). Additionally, 44.24% of T1DM patients had a history of Diabetic Ketoacidosis (DKA), compared to just 6.2% of T2DM patients ($p = 0.01$). In contrast, Hyperosmolar Hyperglycemia State (HHS) was recorded in only 1.4% of T2DM patients.

Finally, degenerative complications were observed in 58.3% of T2DM patients,

compared to 43.6% of T1DM patients (p = 0.05).

In terms of diabetes treatment, 47.7% of patients with Type 2 Diabetes Mellitus (T2DM) were treated with Oral Antidiabetic Drugs (OAD) alone, 36.7% with a combination of insulin and OAD, and 15.9% with insulin alone, with a mean insulin dose of 0.58 ± 0.33 IU/kg. Only 8.2% of T2DM patients were receiving cardioprotective treatment.

In contrast, all patients with Type 1 Diabetes Mellitus (T1DM) were treated with insulin. At the initial evaluation, 93.4% of T1DM patients were managed with a basal-bolus regimen using fixed doses, as they had not previously received education on meal carbohydrate counting. The remaining 6.6% of T1DM patients were treated with a premixed insulin regimen.

Regarding hypertension treatment, 81% of hypertensive T2DM patients were on monotherapy, 16.4% on dual therapy, and 2.3% on triple therapy. In contrast, all hypertensive T1DM patients were on monotherapy, typically including an Angiotensin-Converting Enzyme inhibitor (ACE inhibitor) or an Angiotensin II Receptor Blocker (ARB).

For dyslipidemia, 65.4% of T2DM patients were on statins, compared to only 17.1% of T1DM patients (p < 0.001) (**Table 2**).

3.3. Follow Up of Diabetic Patients

After 2 years of follow-up, optimal glycemic control was achieved in 68.6% of individuals with T2DM compared to 58.8% of those with T1DM (p = 0.009), with an improvement in the average HbA1c over time in both groups (**Figure 2**). In T1DM, achieving glycemic control was associated with an increase in hypoglycemia, but this was statistically insignificant (56.6% vs 53.09%, p = 0.45). Regarding blood pressure control, 74.1% of individuals with T2DM met their blood pressure target, compared with 82.7% of those with T1DM (p = 0.011). In terms of LDL-c target attainment, 69.7% of T2DM patients reached their LDL-c goal, compared with 74.7% of T1DM patients (p = 0.08). Among patients with obesity, a weight reduction of 5% - 10% of initial body weight was observed in 68.1% of those with T2DM and 44.4% of those with T1DM, with no statistically significant difference (p = 0.15).

Overall, the composite triple therapeutic target (glycemic control, blood pressure control, and LDL-cholesterol target attainment) was achieved in 42.8% of T2DM patients and 39.8% of T1DM patients (p = 0.40).

Regarding degenerative complications, good metabolic control was associated with a reduction in cardiovascular events (p = 0.013; OR = 0.22; 95% CI [0.19 - 0.28]) and microvascular complications (p =0.001; OR = 0.31; 95% CI [0.26 - 0.43].

In terms of treatment at follow-up, 26.4% of patients with T2DM were treated with OAD alone, 57.2% with a combination of OAD and insulin, and 16.3% with insulin alone. The mean insulin dose increased from 0.58 ± 0.33 IU/kg at baseline to 0.78 ± 0.54 IU/kg at follow-up (p = 0.02).

Among patients with T1DM, although a flexible basal-bolus regimen was proposed to all patients during follow-up, only 4.4% were motivated to adopt carbo-

hydrate counting, 94.2% were managed with a fixed-dose basal-bolus regimen with doses adjusted by clinicians according to glycemia, and 1.3% with an insulin pump. The mean insulin dose increased from 0.66 ±0.25 IU/kg at baseline to 0.76 ± 0.38 IU/kg at follow-up (p = 0.01)

Regarding hypertension treatment, 35.2% of hypertensive T2DM patients were on monotherapy, including an ACE inhibitor or ARB, 54.5% on dual therapy, and 10.3% on triple therapy. In contrast, hypertensive T1DM patients were generally well-controlled on monotherapy, including a nephroprotective treatment.

In terms of dyslipidemia, 84.1% of T2DM patients were on statins, compared to 46.3% of T1DM patients (Table 3).

3.4. Metabolic Control and Determining Factors

In multivariable analysis, after adjusting for confounding factors, good metabolic control was associated with: High socioeconomic status (OR = 0.72, 95% CI [0.35 - 0.97]), weight loss of 5% - 10% from baseline body weight (OR = 0.76, 95% CI [0.54 - 0.83]), number of education sessions > 6 (OR = 0.59, 95% CI [0.26 - 0.97]), therapeutic adherence (OR = 0.79, 95% CI [0.46 - 0.98]), and self-monitoring of blood glucose > 4/day (OR =0.41, 95% CI [0.11 - 0.83]) (Table 4).

Table 1. Demographic characteristics of patients with type 1 (T1DM) and type 2 (T2DM) diabetes mellitus.

characteristics	All patients (N = 771)	T1DM (n = 226)	T2DM (n = 545)
Age [a](year)	47.14 ± 10.00	63.10 ± 10.80	31.18 ± 9.2
Sex [b](%)			
Female	470 (61)	130 (57.5)	340 (62.4)
Male	301 (39)	96 (42.5)	205 (37.6)
Socio-economic status [b](%)			
Low status	200 (26)	57 (25.3)	143 (26.2)
Middle status	504 (65.3)	129(57)	375 (68.8)
High status	67 (8.7)	40 (17.7)	27 (5)
Education level[b]			
Illiterate	370 (48)	33 (14.6)	337 (61.9)
Primary	112 (14.5)	35 (15.5)	77 (14.1)
Secondary	235 (30.5)	114 (50.5)	121 (22.2)
University	54 (7)	44 (19.4)	10 (1.8)
Healthcare coverage[b]			
Without	100 (13)	23 (10.2)	77 (14.1)
With	671 (87)	203 (89.8)	468 (85.9)
Type of coverage			
Private health insurance	78 (11.6)	18 (8.9)	60 (12.8)
Public health insurance	593 (88.4)	185 (91.1)	408 (87.2)

Note: [a]: Data expressed as mean ± standard deviation, [b]: Data expressed as frequency percentage.

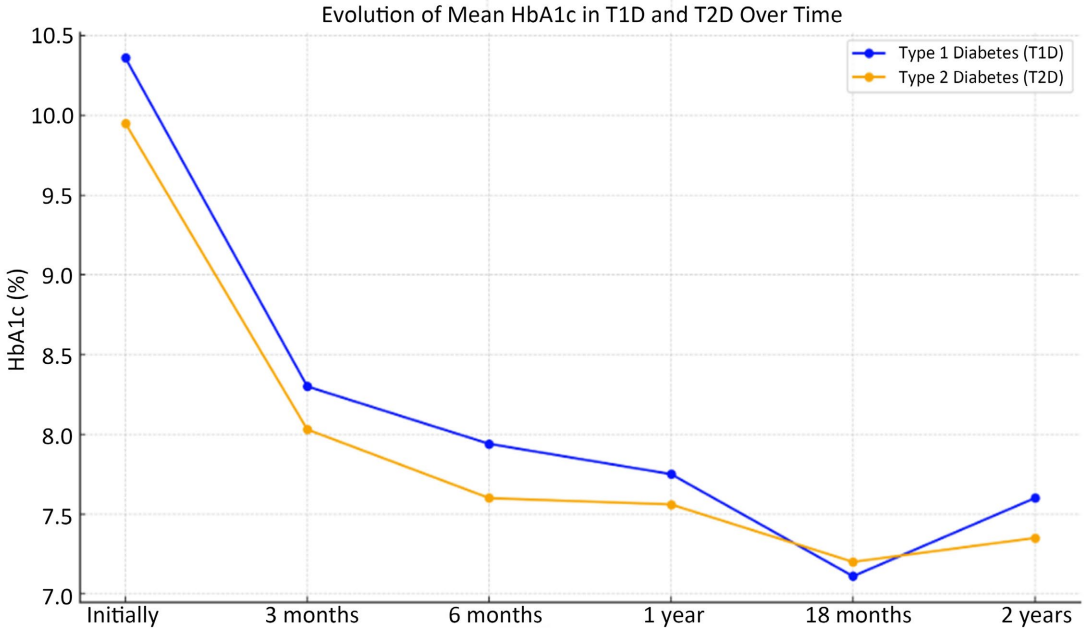
Table 2. Clinical and paraclinical features and treatment patterns in type 1 and type 2 diabetes mellitus.

Variables	T1DM (n = 226)	T2DM (n = 545)	p value
Clinical data			
*Arterial hypertension (AH) (%)[a]	36 (15.9)	292 (53.5)	<0.001
Well controlled	29 (80.5)	56 (19.3)	
Poorly controlled	7 (19.5)	236 (80.7)	
*Smoking[a]	14 (6.19)	56 (10.2)	0.076
*Weight assessment			
Average BMI (kg/m2)[b]	23.94 ± 3.01	29.06 ± 3.78	0.01
Overweight[a]	54 (23.8)	73 (32.3)	
Obesity[a]	9 (3.9)	301 (55.2)	<0.001
Average WC (cm)[b]	85.4 ± 5.44	100.16 ± 5.84	0.02
Abdominal obesity[a]	27 (11.9)	400 (73.3)	<0.01
Paraclinical data			
Glycemic control:			
*Mean HbA1c[b]	10.36% ± 1.36	9.95 ± 1.29	0.023
*HbA1c > 10% [a]	(61.9)	(61.6)	
*HbA1C: 7% - 10%[a]	(8.8)	(19.4)	
* HbA1C ≤ 7%[a]	(29.3)	(19)	
Lipid status[a]:			
* Dyslipidemia	41 (18.1)	340 (62.4)	<0.001
*LDL above target	33 (14.6)	295 (54.12)	
* HDL < 0.40 g/l (men)	18 (7.9)	81 (14.8)	
*HDL < 0.50 g/l (Women)	27 (11.9)	102 (18.7)	
*TG > 1.50 g/l	35 (15.4)	241 (44.2)	
Therapeutic management			
Diabetes treatment[a]:			
1) Oral antidiabetics	0 (0)	260 (47.7)	
2) Insulin + oral antidiabetics	0 (0)	200 (36.7)	
3) Insulin therapy	226 (100)	85 (15.6)	
OAD classes[a]:			
Metformin	0 (0)	345 (63.3)	
Sulfonylurea		100 (18.3)	
DPP-4i**		65 (11.9)	
GLP-1 RA***		30 (5.5)	
SGLT2i****		15 (2.7)	
Type of insulin[a]			0.043
Human insulin	130 (57.5)	209 (73.3)	
insulin analogue	96 (42.5)	72 (25.3)	
Coformulation	0 (0)	4 (1.4)	
Average daily insulin doses (U/kg)[b]	0.66 ± 0.25	0.58 ± 0.33	
Insulin regimen[a]			
Premixed	15 (6.6)	200 (70.2)	
Basal bolus	211 (93.4)	40 (14)	
Bed time	0 (0)	45 (15.8)	

Continued

Treatment of hypertension[a]			
Amlodipine	0 (0)	77 (26.4)	
ACEi***** or ARB******	36 (100)	160 (54.8)	
Dual therapy	0 (0)	48 (16.4)	
Triple therapy	0 (0)	7 (2.4)	<0.001
Treatment of dyslipidemia[a]			
Dietary interventions	34 (82.9)	118 (34.6)	
Dietary interventions + Statin	7 (17.1)	222 (65.4)	
Acute complications[a]:			
Hypoglycemia	122 (53.9)	147 (26.9)	0.02
DKA	100 (44.24)	34 (6.2)	0.01
Hyperglycemic Hyperosmolar Syndrome	0 (0)	8 (1.4)	0.08
Degenerative complications[a]:			
Diabetic retinopathy	46 (20.3)	153 (28.1)	0.024
Diabetic kidney disease	40 (17.6)	128 (23.4)	0.075
Diabetic neuropathy	9 (3.9)	52 (9.5)	0.008
Cardiovascular complications	8 (3.5)	186 (34.1)	<0.001
Foot ulcer	2 (0.8)	77 (14.1)	<0.001

Note: [a]: Data expressed as frequency percentage, [b]: Data expressed as mean ± standard deviation; **: DPP4 inhibitor (DPP4i), ***: GLP-1 Receptor Agonist (GLP1 RA), ****: SGLT2 inhibitor (ISGLT2i), ******: Angiotensin II Receptor Blocker(ARB), *****: Angiotensin-Converting Enzyme inhibitor (ACEi).



Note: Mean HbA1c values (expressed as %) at baseline and at each follow-up time point are plotted to illustrate changes in glycemic control over the study period. The figure demonstrates a progressive reduction in mean HbA1c values in both T1D and T2D populations.

Figure 2. Evolution of Mean HbA1c in T1D and T2D during follow-up.

Table 3. Clinical, paraclinical, and therapeutic data after 2 years of follow-up.

Variables	T1DM (n = 226)	T2DM (n = 545)	P value
Achieving objectives:			
Blood pressure [a]:			
TA <130/80 mmhg	187 (82.7)	404 (74.1)	0.024
TA ≥ 130/80 mmhg	39 (17.3)	141 (25.9)	
Weight objective [a]:			
Weight loss < 5%	5 (55.6)	96 (31.9)	0.15
Weight loss of 5% - 10%	4 (44.4)	205 (68.1)	
Total	9 (100)	301 (100)	
Glycemic objective [a]:			
HbA1C in the target range	133 (58.8)	374 (68.6)	0.031
HbA1C over the target	93 (41.2)	171 (31.4)	
HbA1C average (%)	7.6 ± 0.92	7.35 ± 1.58	
LDL-c target [a]:			
Achieved	169 (74.7)	380 (69.7)	0.14
Not achieved	57 (25.3)	165 (30.3)	
Triple objective [a]:			0.072
Achieved	90 (39.8)	233 (42.8)	
Not achieved	136 (60.2)	312 (57.2)	
Diabetes treatment[a]:	0(0)	144 (26.4)	
Oral antidiabetics	0(0)	312 (57.2)	
Insulin + oral antidiabetics	226 (100)	89 (16.3)	
Insulin therapy			
Insulin regimen[a]:			
Premixed	0(0)	169 (42.1)	0.13
Bed time	0(0)	140 (35)	
Basal bolus	223 (98.7)	92 (22.9)	
Insulin pump	3 (1.3)	0 (0)	
Average daily insulin doses (U/kg)[b]	0.76 ± 0.38	0.78 ± 0.54	
Blood glucose self-monitoring[a]			
<4 measurements/d	198 (87.6)	338 (62.1)	0.01
>4 measurements/d	24 (10.6)	7 (1.2)	
Treatment of hypertension[a]			
Monotherapy including an ARB or an ACEi	36 (100)	103 (35.2)	0.003
Dual therapy		159 (54.5)	
Triple therapy		30 (10.3)	
Treatment of dyslipidemia[a]			
Dietary interventions	22 (53.7)	54 (15.9)	0.017
Dietary interventions + Statin	19 (46.3)	286 (84.1)	
Acute complications:			
Average hypoglycemia/week[b]	1.92 ± 1.08	0.68 ± 1.17	0.021
Moderate hypoglycemia[a]	102 (45.1)	108 (19.8)	
Severe hypoglycemia[a]	18 (7.9)	11 (2)	

Continued

Degenerative complications[a]			
Diabetic retinopathy:	47 (20.8)	157 (28.8)	0.033
Stability	40 (85.1)	139 (88.5)	
Progression	7 (14.9)	18 (11.5)	0.076
Diabetic kidney disease:	44 (19.4)	135 (24.7)	
Negativation of microalbuminuria	8 (18.2)	18 (13.3)	
GFR stability	39 (88.6)	120 (88.9)	
Alteration of GFR*	5 (11.4)	15 (11.1)	
Diabetic neuropathy	9 (3.9)	55 (10)	0.018
Cardiovascular complications	8 (3.5)	198 (36.3)	0.002
Foot ulcer	2 (0.8)	82 (15)	0.016

Note: [a]: Data expressed as frequency percentage, [b]: Data expressed as mean ± standard deviation, *: GFR: Glomerular Filtration Rate.

Table 4. Determinants of good metabolic control in univariate and multivariate analysis.

	Univariable analysis		Multivariable analysis	
Variable	OR [95% CI]	p	OR [95% CI]	p
*Age	1.05 [1.03; 1.07]	<0.001	0.99 [0.72; 1.25]	0.22
*Sex Female-Male	1.03 [0.82; 1.31]	0.757	0.95 [0.72; 1.25]	0.73
*Socio-economic level High-Low	0.56 [0.24; 0.69]	0.01	0.72 [0.35; 0.97]	0.01
*Health coverage Yes-No	0.43 [0.31; 0.87]	<0.001	0.70 [0.58; 4.50]	0.12
*Education level High-Low	0.75 [0.47; 0.92]	0.01	0.59 [0.34; 2.16]	0.21
*Diabetes duration (>10Y) Yes-No	2.90 [2.57; 9.35]	0.042	1.003 [0.98; 5.83]	0.40
*Smoking cessation Yes-Non	0.69 [0.23; 0.94]	0.04	0.99 [0.54; 4.58]	0.25
*Weight loss (5% - 10%) Yes-No	0.38 [0.16; 0.43]	<0.001	0.76 [0.54; 0.83]	<0.001
*Number of education sessions (>6) Yes-No	0.43 [0.18; 0.65]	0.001	0.59 [0.26; 0.97]	0.01
*Therapeutic compliance Yes-No	0.35 [0.22; 0.56]	<0.001	0.79 [0.46; 0.98]	0.001
*Self-monitoring of blood glucose (>4/day) Yes-No	0.65 [0.16; 0.79]	0.001	0.41 [0.11; 0.83]	0.01

4. Discussion

Our prospective study (n = 771) demonstrated a marked improvement in metabolic control over time in patients with diabetes. Overall, 68.6% of individuals with Type 2 Diabetes (T2DM) and 58.8% of those with Type 1 Diabetes (T1DM) achieved their individualized HbA1c targets, reflecting significant clinical progress. This improvement was accompanied by a substantial reduction in mean HbA1c levels, from 9.95 ± 1.29% to 7.35 ± 1.58% in T2DM patients, and from 10.36 ± 1.36% to 7.6 ± 0.92% in T1DM patients. However, when considering comprehensive metabolic control—defined as simultaneous achievement of HbA1c and LDL-C targets and blood pressure <130/80 mmHg—only 42.8% of T2DM and 39.8% of T1DM patients met all three goals. These findings underscore the clinical benefit of individualized glycemic targets while highlighting the persistent challenge of achieving holistic metabolic control in routine practice. These findings represent a substantial improvement compared to previously published international data. The International Diabetes Management Practices Study (IDMPS), a large-scale study involving over 66,000 individuals with T2DM, has consistently reported suboptimal control, with fewer than 50% of participants achieving the recommended HbA1c target of < 7%, and less than 70% maintaining HbA1c levels below8% [1].

In particular, data from the fifth wave of the IDMPS, conducted across multiple countries, showed that in Morocco, only 26.8% of patients with Type 2 Diabetes (T2DM) achieved an HbA1c level below 7%. Moreover, just 6.6% of those with Type 1 Diabetes (T1DM) and 2.7% of those with T2DM met the triple therapeutic target [10]. In Algeria, during the seventh wave of the IDMPS, which included 280 diabetic patients (82 with T1DM and 198 with T2DM), 40% of T2DM and 25% of T1DM patients met the glycemic target. However, only 3.7% of T2DM patients succeeded in reaching all three treatment targets [11].

Similar patterns were observed across the African continent. According to the African cohort of the 7th IDMPS wave, just 33.1% of T2DM patients achieved an HbA1c < 7%, while only 3.1% met the full set of recommended goals (HbA1c <7%, blood pressure ≤130/80 mmHg, and LDL-C <2.6 mmol/L or 100 mg/dL) [12].

In this study, we adopted a holistic approach to diabetes management, integrating both non-pharmacological and pharmacological interventions tailored to individual patient needs. The non-pharmacological components included personalized educational programs, psychological support for patients experiencing emotional distress, smoking cessation counseling for active smokers, and individualized meal plans. On the pharmacological side, treatment optimization involved switching patients to more appropriate therapeutic regimens or adjusting insulin doses accordingly.

Regarding treatment strategies, our results revealed a diverse range of therapeutic approaches among patients with Type 2 Diabetes (T2D): 26.4% were treated with Oral Antidiabetic Drugs (OADs) alone, 57.2% received a combination of OADs and insulin, and 16.3% were managed with insulin therapy alone. A

significant increase in mean insulin dose was observed over time, rising from 0.58 ± 0.33 IU/kg to 0.78 ± 0.54 IU/kg (p = 0.02), underscoring the progressive nature of T2D and the need for treatment intensification. Among patients with Type 1 Diabetes (T1D), 97.3% were managed with multiple daily insulin injections (basal-bolus regimens), while only 2.7% used insulin pumps. Similarly, insulin requirements increased significantly from 0.66 ± 0.25 IU/kg to 0.76 ± 0.38 IU/kg (p = 0.01). When compared with data from the IDMPS 5th and 7th waves, where approximately 36% of T2D patients were on insulin [10] [12], our findings suggest a higher rate of insulin use, likely reflecting both disease progression and clinical practice differences. Notably, therapeutic intensification was associated with a modest increase in reported hypoglycemic episodes, particularly among T1D patients (53% vs. 21.7% in T2D; p = 0.02), highlighting a key barrier to optimal dose escalation.

Achieving good metabolic control was strongly associated with a significant reduction in both cardiovascular events (p = 0.013; OR = 0.22; 95% CI [0.19 - 0.28]) and microvascular complications (p = 0.001; OR = 0.31; 95% CI [0.26 - 0.43]) in this cohort. This aligns with results from major clinical trials such as the United Kingdom Prospective Diabetes Study (UKPDS) and Diabetes Control and Complications Trial (DCCT) [13] [14], which have consistently shown that intensive glycemic control reduces the risk of microvascular complications including retinopathy and nephropathy. Furthermore, the UKPDS study highlighted the benefits of tight glycemic management on macrovascular outcomes, although these effects are often influenced by other cardiovascular risk factors [13]. Contemporary meta-analyses also support the notion that sustained HbA1c reduction contributes to lower rates of both micro- and macrovascular complications, emphasizing the critical importance of metabolic control in diabetes care [15] [16].

The multivariate analysis identified several factors significantly associated with better metabolic control, including High socioeconomic status (OR = 0.72, 95% CI [0.35 - 0.97]), weight loss of 5% - 10% from baseline body weight (OR = 0.76, 95% CI [0.54 - 0.83]), number of education sessions > 6 (OR = 0.59, 95% CI [0.26 - 0.97]), therapeutic adherence (OR = 0.79, 95% CI [0.46 - 0.98]), and self-monitoring of blood glucose > 4/day (OR = 0.41, 95% CI [0.11 - 0.83]. These findings align with extensive literature highlighting the multifactorial nature of diabetes management. Socio-economic status has been consistently shown to influence diabetes outcomes, with lower socio-economic groups often experiencing poorer glycemic control due to limited access to healthcare and educational resources [17]. Structured diabetes education programs improve patient knowledge, self-care behaviors, and adherence, leading to better glycemic outcomes [18]. Weight loss improves insulin sensitivity and glycemic control, as shown by the Look AHEAD trial, which demonstrated cardiovascular and metabolic benefits following intensive lifestyle interventions [19]. Treatment adherence is a well-documented determinant of diabetes control; poor adherence is linked to worse outcomes and increased healthcare utilization [20]. Moreover, regular self-monitor-

ing of blood glucose enables timely therapeutic adjustments and is associated with improved HbA1c, particularly among insulin users [21] [22].

5. Strengths and Limitations of Our Study

The use of standardized methodologies in this prospective study enabled a comprehensive evaluation of diabetes management in populations with type 1 and type 2 diabetes. The main strengths include the large sample size and the extended duration of follow-up, which together enhance the robustness of the findings. Several limitations should be noted. The monocentric design limits the generalizability of the findings. Variability in laboratory assays may have affected biological measurements. Losses to follow-up and incomplete assessments could have led to an underestimation of complications. Finally, the lack of a cost-effectiveness analysis prevents evaluation of the economic sustainability of the observed benefits.

6. Conclusion

Our study demonstrated notable progress in glycemic and metabolic control among diabetic patients; however, significant global challenges remain. Achieving optimal diabetes outcomes is hindered by the complex, progressive nature of the disease, variability in treatment response, therapeutic inertia, and poor adherence—often due to regimen complexity, side effects, limited disease understanding, and cognitive decline. Economic barriers, including high medication costs and inadequate insurance coverage, further limit treatment access and adherence, contributing to persistent health disparities. Addressing these multifactorial challenges through personalized care, timely treatment intensification, patient education, and equitable health policies is essential for improving outcomes and reducing the global burden of diabetes.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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