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EFFECTS OF GLYCEMIC CONTROL ON REFRACTION IN DIABETIC PATIENTS / IMPACT OF BLOOD SUGAR MANAGEMENT ON VISION CHANGES IN DIABETICS/ GLYCEMIC REGULATION AND ITS EFFECTS ON REFRACTIVE ERRORS IN DIABETIC PATIENTS

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ABSTRACT:

Introduction: This study investigates the effects of glycemic control on refractive changes in diabetic patients, aiming to understand how fluctuations in blood sugar levels influence refractive errors and overall vision quality.

Materials and methods: The study included 100 participants, divided into two groups based on their glycemic control: Group A (Controlled Glycemia) and Group B (Uncontrolled Glycemia). Over a 12-month period, data on HbA1c levels, fasting blood glucose, and refractive errors were collected and analyzed.

Results: Group A, with better glycemic control, maintained stable HbA1c levels and experienced fewer significant refractive changes compared to Group B. Specifically, Group A had a lower incidence of refractive shifts of ≥0.50 diopters at all measured intervals ($p < 0.05$). Correlations between HbA1c levels and refractive changes were statistically significant, highlighting the impact of blood glucose management on refractive stability.

Conclusion: The findings underscore the importance of stringent glycemic control in preventing vision-related complications in diabetic patients. Better glycemic management can minimize biochemical perturbations in the lens, thereby stabilizing refractive errors.

Keywords: *Diabetes mellitus, glycemic control, refractive errors, hyperglycemia, myopia, hyperopia, diabetic retinopathy, HbA1c, blood glucose, vision changes*

Introduction:

Diabetes mellitus, a chronic metabolic disorder characterized by hyperglycemia, is a leading cause of various systemic complications, including those affecting the eyes. Among the myriad of ocular complications, diabetic retinopathy is the most well-known; however, diabetes can also influence the refractive status of the eye[1]. Refractive errors, such as myopia (nearsightedness) and hyperopia (farsightedness), can be significantly impacted by fluctuations in blood glucose levels. The precise relationship between glycemic control and changes in refraction remains an area of active research, with important implications for the management of vision in diabetic patients[2].

Diabetes mellitus is classified mainly into two types: Type 1 diabetes (T1D), characterized by autoimmune destruction of pancreatic β-cells leading to insulin deficiency, and Type 2 diabetes (T2D), which involves a combination of insulin resistance and relative insulin deficiency[3]. Chronic hyperglycemia, the hallmark of diabetes, leads to complications affecting various organs, including the eyes. Diabetic retinopathy, cataract formation, and glaucoma are well-

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documented ocular complications associated with diabetes[4]. However, changes in refractive status are less frequently discussed but are equally significant.

Refractive errors occur when light entering the eye is not focused correctly onto the retina, resulting in blurred vision. The major types of refractive errors include myopia, hyperopia, astigmatism, and presbyopia[5,6]. In diabetic patients, fluctuations in blood glucose levels can cause changes in the refractive index of the crystalline lens, leading to temporary or permanent shifts in refractive errors. The crystalline lens is highly sensitive to changes in blood glucose levels, and variations in glucose concentration can affect its hydration and curvature, thereby altering its refractive power.

The relationship between blood glucose levels and refractive changes in diabetic patients is complex and multifaceted. Hyperglycemia can induce myopic shifts, while rapid correction of hyperglycemia, especially in newly diagnosed patients, can lead to hyperopic shifts. This phenomenon is attributed to changes in the refractive index of the crystalline lens due to osmotic effects induced by glucose and its metabolites[7,8].

High blood glucose levels can cause osmotic swelling of the lens, altering its curvature and refractive index, leading to myopia. This swelling is caused by increased glucose concentration in the aqueous humor, which is metabolized to sorbitol via the polyol pathway. As glucose diffuses out of the lens more slowly than glucose enters, sorbitol accumulates, causing osmotic swelling and affecting the lens's refractive index. Changes in lens hydration occur due to fluctuations in glucose levels, drawing water into the lens, causing it to swell and change shape, altering its refractive power[9]. Prolonged hyperglycemia can also lead to glycation of lens proteins, resulting in structural changes that affect the lens's refractive properties and contribute to long-term refractive errors.

Several studies have demonstrated the correlation between glycemic control and refractive changes in diabetic patients. For instance, a study by Fledelius[8] (1990) observed that patients with poorly controlled diabetes exhibited significant myopic shifts, which reverted to hyperopia following stabilization of blood glucose levels. Similarly, a longitudinal study by Saito et al[6]. (2003) found that diabetic patients experienced significant refractive changes during periods of unstable glycemic control, underscoring the importance of maintaining stable blood glucose levels to prevent such fluctuations.

Justification

Understanding the impact of glycemic control on refractive errors in diabetic patients is crucial for several reasons. Refractive changes can significantly impact a patient's quality of life, affecting daily activities and overall well-being. Temporary refractive changes associated with poor glycemic control can lead to misdiagnoses and unnecessary prescription changes. Precise management of refractive errors can contribute to better glycemic control, as vision problems can hinder physical activities, medication schedules, and accurate glucose monitoring. Maintaining stable refractive status through optimal glycemic control can support overall diabetes management.

Aims and objectives:

To investigate the effects of glycemic control on refractive changes in diabetic patients, with a focus on understanding how fluctuations in blood sugar levels influence the refractive errors and overall vision quality in individuals with diabetes.

Objectives:

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1. To analyze the correlation between blood glucose levels and changes in refractive errors among diabetic patients.
2. To assess the impact of improved glycemic control on the progression or stabilization of refractive errors in diabetic patients.

Materials and methods:

Study Design and Participants

This was a longitudinal, observational study designed to evaluate the effects of glycemic control on refractive changes in diabetic patients over a 12-month period. The study included two groups of participants: Group A (Controlled Glycemia) and Group B (Uncontrolled Glycemia). Each group consisted of 50 participants, resulting in a total of 100 study participants.

Inclusion and Exclusion Criteria

Inclusion criteria:

1. Adults aged between 40 and 70 years.
2. Diagnosed with type 2 diabetes for at least 5 years.
3. Regular follow-up at the diabetes clinic.
4. No history of ocular surgery or significant ocular pathology other than diabetic retinopathy.
5. HbA1c levels below 7% for Group A and above 8% for Group B at baseline.

Exclusion criteria:

1. Presence of significant ocular diseases (e.g., glaucoma, cataract affecting vision).
2. History of refractive surgery.
3. Other systemic diseases that might affect glycemic control (e.g., Cushing's syndrome).
4. Pregnancy or lactation.

Data Collection

Data were collected at baseline, 3 months, 6 months, and 12 months. The following parameters were recorded:

1. Demographic and Baseline Characteristics: Age, gender, duration of diabetes, baseline HbA1c, and fasting blood glucose levels (Table 1).
2. Glycemic Control: HbA1c and fasting blood glucose levels were measured at each visit (Table 2).
3. Refractive Error: Refractive error, expressed as spherical equivalent, was measured using an autorefractor at each visit (Table 3).
4. Incidence of Refractive Changes: The incidence of significant refractive changes, defined as a shift of ≥0.50 diopters (D), was recorded (Table 4).

Procedures

1. Glycemic Control Assessment: HbA1c was measured using high-performance liquid chromatography, and fasting blood glucose was measured using a glucose oxidase method. These assessments were performed at baseline and every three months thereafter.
2. Refractive Error Measurement: An autorefractor was used to measure the refractive error. Measurements were taken in a standardized manner, with the mean of three readings recorded for accuracy. Spherical equivalent was calculated as the sphere value plus half of the cylindrical value.

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3. Statistical Analysis: Statistical analyses were conducted using SPSS software version 25.0. Continuous variables were expressed as mean ± standard deviation. Differences between groups were analyzed using the independent t-test for continuous variables and the chi-square test for categorical variables. The Pearson correlation coefficient was used to assess the correlation between HbA1c levels and refractive changes. A p-value of <0.05 was considered statistically significant.

Ethical Considerations

The study protocol was approved by the Institutional Review Board (IRB) of the participating medical center. Informed consent was obtained from all participants prior to enrollment. The study adhered to the principles of the Declaration of Helsinki.

Results:

Table 1: Demographic and Baseline Characteristics of Study Participants

Characteristics	Group A (Controlled Glycemia)	Group B (Uncontrolled Glycemia)	p-value
Number of participants	50	50	-
Age (years)	55.2 ± 10.1	54.8 ± 9.8	0.82
Gender (Male/Female)	28/22	27/23	0.89
Duration of Diabetes (years)	10.3 ± 6.2	11.1 ± 7.0	0.58
HbA1c (%)	6.5 ± 0.4	8.9 ± 1.2	<0.001
Fasting Blood Glucose (mg/dL)	110 ± 15	160 ± 20	<0.001

The demographic and baseline characteristics of the participants are detailed in Table 1. Both groups consisted of 50 participants each, with no significant differences in age, gender distribution, or duration of diabetes. However, there were significant differences in HbA1c levels and fasting blood glucose, with Group A maintaining lower values (HbA1c: 6.5% vs. 8.9%, fasting glucose: 110 mg/dL vs. 160 mg/dL), indicating better glycemic control ($p < 0.001$ for both).

Table 2: Changes in Glycemic Control Over Study Period

Time Point	Group A (Controlled Glycemia)	Group B (Uncontrolled Glycemia)	p-value
Baseline	6.5 ± 0.4	8.9 ± 1.2	<0.001
3 Months	6.4 ± 0.3	8.7 ± 1.1	<0.001
6 Months	6.3 ± 0.3	8.5 ± 1.0	<0.001
12 Months	6.2 ± 0.3	8.4 ± 0.9	<0.001

Table 2 presents the changes in glycemic control over the study period. Group A consistently maintained their HbA1c levels within a narrow range (6.2% to 6.5%), while Group B showed slight improvements over time but remained significantly higher (8.4% to 8.9%). The

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differences between the groups remained statistically significant throughout the study ($p < 0.001$ at all time points).

Table 3: Changes in Refractive Error (Spherical Equivalent) Over Study Period

Time Point	Group A (Controlled Glycemia)	Group B (Uncontrolled Glycemia)	p-value
Baseline	-0.50 ± 0.75 D	-0.60 ± 0.80 D	0.45
3 Months	-0.48 ± 0.70 D	-0.55 ± 0.75 D	0.60
6 Months	-0.46 ± 0.68 D	-0.50 ± 0.72 D	0.72
12 Months	-0.45 ± 0.65 D	-0.40 ± 0.70 D	0.88

In Table 3, the changes in refractive error (measured as spherical equivalent) are shown over the study period. At baseline, both groups had similar refractive errors (-0.50 D in Group A and -0.60 D in Group B, $p = 0.45$). Over time, the refractive changes in both groups were minimal and not statistically significant, with no notable differences between Group A and Group B at any time point (p-values ranging from 0.45 to 0.88).

Table 4: Incidence of Refractive Changes (≥0.50 D Shift) Over Study Period

Time Point	Group A (Controlled Glycemia)	Group B (Uncontrolled Glycemia)	p-value
3 Months	5 (10%)	15 (30%)	0.02
6 Months	3 (6%)	12 (24%)	0.01
12 Months	2 (4%)	10 (20%)	0.03

The incidence of significant refractive changes (defined as a shift of ≥0.50 D) is detailed in Table 4. Group A experienced fewer instances of such changes compared to Group B at all measured intervals. Specifically, by 3 months, 10% of Group A had significant refractive changes compared to 30% of Group B ($p = 0.02$). This trend continued, with Group A showing lower incidences at 6 months (6% vs. 24%, $p = 0.01$) and 12 months (4% vs. 20%, $p = 0.03$), indicating a higher stability of refractive error in the controlled glycemia group.

Table 5: Correlation Between Glycemic Control (HbA1c) and Change in Refractive Error

Parameter	Pearson Correlation Coefficient (r)	p-value
Baseline HbA1c vs. 3-Month Refractive Change	0.30	0.01
Baseline HbA1c vs. 6-Month Refractive Change	0.35	0.005
Baseline HbA1c vs. 12-Month Refractive Change	0.40	0.001
Change in HbA1c vs. 3-Month Refractive Change	0.28	0.02
Change in HbA1c vs. 6-Month Refractive Change	0.32	0.01

Change in HbA1c vs. 12-Month Refractive Change	0.38	0.003

Table 5 explores the correlation between glycemic control (HbA1c) and changes in refractive error. The baseline HbA1c levels showed a positive correlation with refractive changes at 3 months (r = 0.30, p = 0.01), 6 months (r = 0.35, p = 0.005), and 12 months (r = 0.40, p = 0.001). Similarly, changes in HbA1c over the study period were also positively correlated with refractive changes, with correlation coefficients of 0.28 (p = 0.02) at 3 months, 0.32 (p = 0.01) at 6 months, and 0.38 (p = 0.003) at 12 months. These findings suggest that better glycemic control is associated with fewer and smaller refractive changes over time.

Discussion:

This study examines the impact of glycemic control on refractive changes in diabetic patients, contributing to a nuanced understanding of how blood sugar regulation affects vision. The results highlight significant correlations between glycemic control, measured by HbA1c levels, and the stability of refractive errors over time. These findings are in line with and expand upon previous research, providing further evidence that tight glycemic management can mitigate vision-related complications in diabetic patients.

The study comprised two groups: those with controlled glycemia (Group A) and those with uncontrolled glycemia (Group B). The demographic and baseline characteristics of the groups were similar, ensuring comparability. The primary outcomes demonstrated that:

- Group A maintained significantly lower HbA1c levels and fasting blood glucose compared to Group B throughout the study period.
- There was no significant difference in refractive errors between the groups at baseline and over time; however, Group A exhibited fewer instances of significant refractive changes (≥0.50 D shift) compared to Group B.
- A positive correlation existed between baseline HbA1c levels and refractive changes at 3, 6, and 12 months, as well as between changes in HbA1c over the study period and refractive changes.

1. Glycemic Control and Refractive Changes:

Previous studies have demonstrated that fluctuations in blood glucose levels can lead to transient changes in lens hydration, affecting refractive status. This study corroborates the findings of Okamoto et al[10]. (2000), who observed that hyperglycemia-induced osmotic changes in the lens can alter its curvature, leading to refractive shifts. The current study extends these findings by showing that sustained glycemic control not only reduces these fluctuations but also results in fewer significant refractive changes over a longer period.

2. Long-term Impact of Glycemic Regulation:

Fong et al[11]. (1999) highlighted that chronic hyperglycemia contributes to diabetic retinopathy, which can indirectly affect refractive errors through macular edema and other structural changes in the eye. The present study's long-term follow-up and consistent measurement intervals strengthen the argument that maintaining HbA1c within a target range can minimize these structural alterations, thus stabilizing refractive errors.

3. Statistical Correlations and Clinical Significance:

The correlation between HbA1c levels and refractive changes, as reported in this study, aligns with the work of Kastelan et al[12]. (2007), who found similar associations in a shorter study period. The present study's extended duration and robust sample size provide more compelling evidence of the clinical significance of glycemic control in preventing vision-related issues. Moreover, the statistical significance of these correlations ($p < 0.05$ across various time points) underscores the importance of sustained glycemic management.

The physiological mechanisms connecting glycemic control and refractive stability are multifaceted. Hyperglycemia can lead to biochemical changes in the lens, such as increased sorbitol accumulation through the polyol pathway, resulting in osmotic stress and lens swelling[13] (Brownlee, 2005). This osmotic effect causes transient myopia or hyperopia, depending on the direction of lens hydration changes. Our study's findings support the hypothesis that better glycemic control reduces such biochemical perturbations, thereby stabilizing refractive error.

Additionally, the role of advanced glycation end products (AGEs) in lens stiffness and transparency cannot be overlooked[14] (Varun et al., 2002). AGEs accumulate in diabetic patients with poor glycemic control, leading to lens opacification and altered refractive indices. The lower incidence of significant refractive changes in Group A suggests that minimizing AGEs through controlled glycemia can preserve lens elasticity and transparency.

The clinical implications of these findings are substantial. For healthcare providers, emphasizing the importance of glycemic control is crucial not only for preventing systemic complications of diabetes but also for maintaining ocular health. Regular monitoring of HbA1c and fasting blood glucose should be a cornerstone of diabetes management protocols, particularly for patients presenting with refractive changes.

Optometrists and ophthalmologists should consider the patient's glycemic status when evaluating unexplained refractive shifts. Our study supports the integration of glycemic control assessment into routine eye examinations for diabetic patients. Early identification and intervention can prevent the progression of refractive errors and improve overall visual outcomes.

Limitations:

Despite its strengths, the study has limitations that warrant consideration. The sample size, although adequate, might benefit from further expansion to enhance the generalizability of the findings. Additionally, while the study duration covered one year, longer follow-ups would provide more insight into the chronic effects of glycemic control on refractive stability.

Conclusion:

This study reinforces the critical role of glycemic control in managing refractive stability in diabetic patients. Consistent and controlled glycemia, reflected in stable HbA1c levels, correlates with fewer and less significant refractive changes over time. These findings underscore the importance of stringent blood sugar management as a preventive strategy against vision-related complications in diabetes. As the prevalence of diabetes continues to rise globally, integrating these insights into clinical practice can improve the quality of life for millions of individuals.

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