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Original Research Article

Impact of diabetes mellitus on tear secretion, intraocular pressure, and contrast sensitivity: A comparative study of controlled and uncontrolled diabetics

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ABSTRACT

Background: Diabetes mellitus (DM) is a prevalent metabolic disorder associated with systemic and ocular complications that impair visual function. This study evaluates the impact of DM on tear secretion, intraocular pressure (IOP), and contrast sensitivity (CS), and explores the relationship between DM duration and these parameters.

Aim & Objective: To compare tear secretion, IOP, and CS in non-diabetic individuals and diabetic patients with controlled and uncontrolled DM, and to assess the influence of DM duration on these ocular measures.

Materials and Methods: This prospective observational study was conducted from August 2023 to July 2024 at a tertiary eye care center in Surat, India, with 150 participants (300 eyes). Participants were divided into three groups: 50 non-diabetic controls, 50 with controlled DM (HbA1c ≤7), and 50 with uncontrolled DM (HbA1c >7). Tear secretion was measured using the Schirmer test, CS with the Pelli-Robson chart, and IOP using non-contact tonometry. Statistical analysis included ANOVA for group comparisons and Pearson correlation to assess relationships with DM duration.

Results: Diabetic patients had significantly lower tear secretion (controlled DM: 12mm; uncontrolled DM: 8mm) than non-diabetic controls (18 mm; $p < 0.05$). CS was also reduced in diabetic groups, with controlled DM patients averaging 1.4 log units and uncontrolled DM patients 1.1 log units, compared to 1.9 log units in controls ($p < 0.05$). IOP was higher in diabetic groups but not statistically significant. DM duration positively correlated with reduced CS ($r = 0.45$, $p < 0.05$) but not with tear secretion or IOP.

Conclusion: DM significantly impairs ocular health, evidenced by elevated IOP, reduced tear secretion, and diminished CS, particularly in uncontrolled cases. While DM duration is strongly associated with progressive CS decline, it does not significantly affect tear secretion or IOP. These findings underscore the need for routine ocular assessments and effective glycemic control to prevent visual complications in diabetic patients.

1. Introduction

Diabetes mellitus (DM) is a chronic metabolic disorder characterized by persistent hyperglycemia due to impaired insulin production, insulin resistance, or both. As the prevalence of DM continues to rise globally, it presents an increasing public health challenge, affecting an estimated 422 million people worldwide—a number projected to surpass 500 million by 2035.[1] While DM is widely recognized for its systemic complications, such as cardiovascular disease, neuropathy, and nephropathy, its impact on ocular health is equally profound. These ocular effects often lead to significant visual impairment and can progress to blindness.[2] Common ocular complications include diabetic retinopathy and cataracts; however, DM's

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influence extends beyond these well-known conditions, affecting tear secretion, intraocular pressure (IOP), and contrast sensitivity (CS), all of which are essential for stable, functional vision.[3]

Tear secretion, IOP, and CS each play unique roles in maintaining ocular health and visual function. Tear secretion contributes to ocular surface hydration, optical clarity, and comfort, with decreased tear production commonly resulting in dry eye disease (DED).[4] In DM patients, compromised tear function can cause discomfort, irritation, and potential risk to corneal health.[5] Similarly, IOP management is critical, as elevated IOP is a major risk factor for glaucoma—a leading cause of irreversible blindness worldwide.[6] Altered IOP dynamics in diabetic patients may predispose them to higher IOP and increase glaucoma susceptibility, although the relationship remains unclear.[7] CS, a measure of the eye's ability to discern differences in luminance, is fundamental for tasks that require low-contrast vision, such as night driving and reading. Studies suggest that DM can lead to reduced CS, even before overt retinopathy appears, indicating early functional impairment of the visual system.[8,9] Evaluating these parameters together provides a comprehensive understanding of DM's broader impact on ocular health and highlights potential areas for early intervention.

Although studies have extensively examined DM's effects on individual ocular parameters, research investigating the collective impact of DM on tear secretion, IOP, and CS is limited. Most studies focus primarily on diabetic retinopathy or structural changes in the retina, often overlooking functional impairments like CS and the role of tear function in diabetic eye health. Furthermore, while some research suggests that the duration of DM may exacerbate retinal and neural changes, leading to progressive CS decline, there is limited evidence regarding whether prolonged DM similarly impacts tear secretion and IOP over time.[10] Clarifying these associations, particularly in relation to DM duration and glycemic control, could provide new insights into the management of ocular complications in diabetes and underscore the need for routine screening beyond retinopathy assessments.

This study seeks to address these gaps by evaluating the effects of DM on tear secretion, IOP, and CS among non-diabetic, controlled diabetic, and uncontrolled diabetic groups. Additionally, it examines the correlation between DM duration and each of these parameters to determine whether prolonged hyperglycemia exacerbates ocular impairment. Findings from this study may inform comprehensive diabetic eye care approaches, emphasizing the need for glycemic control and routine monitoring of tear function, IOP, and CS to mitigate potential visual complications.

2. Materials and Methods

2.1. Study design and setting

This was a prospective, observational study conducted at a tertiary eye care facility in Surat, India, from August 2023 to July 2024. The study was designed to assess the effects of diabetes mellitus (DM) on tear secretion, intraocular pressure (IOP), and contrast sensitivity (CS) in patients with controlled and uncontrolled diabetes compared to non-diabetic controls.

2.2. Participants

A total of 150 adults, accounting for 300 eyes, aged between 20 and 70 years, were recruited for this study. The participants were classified into three distinct groups based on their diabetic status and glycemic control. The first group, consisting of 50 individuals, served as the non-diabetic control group; these participants had fasting blood glucose (FBG) levels below 126 mg/dL, post-prandial (PP) glucose below 200 mg/dL, and HbA1c levels below 5.7%, indicating no diabetes. The second group, also comprising 50 individuals, represented the controlled DM group; these diabetic participants maintained HbA1c levels at or below 7, indicating adequate glycemic control. Finally, the third group included 50 individuals with uncontrolled DM, characterized by HbA1c levels exceeding 7, reflective of poor glycemic control.

Eligible participants were adults aged 20 to 70 years with a confirmed diagnosis of Type 2 Diabetes Mellitus (T2DM) for the diabetic groups, and no history of diabetes for the control group. For diabetic participants, the duration of diabetes was documented to allow for analysis of its potential correlation with various ocular parameters.

Certain exclusion criteria were applied to ensure the study's focus on diabetes-related ocular effects without interference from other factors. Participants with a history of other ocular diseases, recent ocular surgeries, or use of medications known to influence tear secretion or intraocular pressure (IOP) were excluded. Additionally, individuals exhibiting any signs of diabetic retinopathy (DR), such as microaneurysms or intraretinal hemorrhages, were also excluded to specifically study the effects of diabetes before the onset of retinopathy.

2.3. Data collection and clinical evaluation

Each participant underwent a comprehensive clinical evaluation, which included gathering a complete medical and diabetes history, assessing visual acuity, and performing a detailed ocular examination. Demographic data, details of current diabetes treatment, and any co-existing systemic illnesses were documented. For diabetic participants, HbA1c levels, disease duration, and blood glucose levels were also recorded.

To measure tear secretion, the Schirmer II test was performed without anesthesia. A sterile Whatman No. 41 paper strip, measuring 5 mm x 35 mm and folded at a 90° angle, was placed at the junction of the medial two-thirds and lateral one-third of the lower eyelid. The test was conducted in a room with minimal air circulation to avoid external influences on tear production. After five minutes, the wetting length of the strip was recorded in millimeters (mm), with results categorized as follows: normal tear secretion (>15 mm), mild dry eye (10–15 mm), moderate dry eye (5–10 mm), and severe dry eye (<5 mm).

Intraocular pressure (IOP) was measured using a non-contact tonometer (NCT) to ensure both comfort and accuracy. Three consecutive readings were taken for each eye, and the mean IOP value was recorded in millimeters of mercury (mmHg). To account for potential diurnal variations, all IOP measurements were taken during standard outpatient hours.

Contrast sensitivity (CS) was evaluated using the Pelli-Robson chart, a tool for measuring low spatial frequency contrast sensitivity. Participants were seated three meters away from the chart and instructed to read the letters while covering one eye at a time. The CS score was determined by the faintest triplet of letters in which at least two were correctly identified, and the score was recorded as log contrast sensitivity (log CS) based on the lowest visible contrast level. This standardized method allowed for consistent and reliable measurement of subtle variations in CS across the study groups.

2.4. Data analysis

Data analysis was conducted using SPSS software (version 25). Descriptive statistics summarized the demographic and clinical characteristics of each group, with results presented as means with standard deviations (SD) or percentages, as appropriate. Group comparisons for tear secretion, IOP, and CS were performed using ANOVA or Kruskal-Wallis tests, followed by pairwise comparisons when significant differences were identified. Pearson correlation coefficients assessed the relationship between DM duration and each ocular parameter (tear secretion, IOP, and CS), with statistical significance set at $p < 0.05$. Additionally, an optional multivariable analysis, adjusting for age and DM duration, evaluated the independent effects of DM control on the ocular parameters.

2.5. Outcome measures

Primary outcomes included the mean values of tear secretion, IOP, and CS across the three groups. Additionally, the correlation between DM duration and each ocular parameter was assessed to identify any time-dependent effects of diabetes on ocular health. The statistical significance of group differences and correlations provided insight into the potential impact of glycemic control and DM duration on each outcome measure.

2.6. Ethical considerations

All procedures were conducted in line with the ethical standards of the institutional research committee and adhered to the Declaration of Helsinki. Participants were informed about the study objectives, procedures, and potential risks, and all provided written consent. Confidentiality was maintained by de-identifying participant data, and only study personnel had access to identifiable information.

3. Results

A total of 150 participants were included in this study, comprising 100 individuals with diabetes (66.6%) and 50 non-diabetic controls (33.3%). Within the diabetic group, participants were further stratified based on glycemic control: 50 individuals were classified as having controlled diabetes mellitus (DM) (HbA1c ≤ 7), while the remaining 50 were categorized as having uncontrolled DM (HbA1c > 7). The primary parameters analyzed were tear secretion, intraocular pressure (IOP), and contrast sensitivity (CS). Additionally, correlation analyses were conducted to evaluate the relationship between DM duration and each ocular parameter. Demographic data, including age, gender distribution, and key clinical characteristics for each group, are summarized in (Table 1).

Table 1: Summarizes the demographic data, including age, gender distribution, and key clinical characteristics for each group

Parameter	Non-Diabetic (n=50)	Controlled DM (n=50)	Uncontrolled DM (n=50)
Mean Age (years)	45.2 ± 6.8	46.7 ± 7.0	47.5 ± 6.5
Gender (M/F)	30/20	32/18	28/22
Mean HbA1c (%)	5.5 ± 0.4	6.8 ± 0.5	8.5 ± 1.2
Average DM Duration	N/A	6.4 ± 3.1	7.3 ± 3.2

3.1. Primary outcome measures

The primary ocular parameters—tear secretion, intraocular pressure (IOP), and contrast sensitivity (CS)—were compared among the three groups, as presented in (Table 2) and (Figure 1).

3.2. Tear secretion

Tear secretion, measured by the Schirmer II test, was significantly lower in both diabetic groups compared to

Table 2: Mean values of tear secretion, IOP, and contrast sensitivity across groups

Parameter	Non-Diabetic	Controlled DM	Uncontrolled DM
Tear Secretion (mm)	18.0 ± 2.5	12.0 ± 3.1	8.0 ± 2.8
Intraocular Pressure (mmHg)	15.0 ± 2.0	17.0 ± 2.2	18.0 ± 2.4
Contrast Sensitivity (log units)	1.9 ± 0.1	1.4 ± 0.2	1.1 ± 0.3

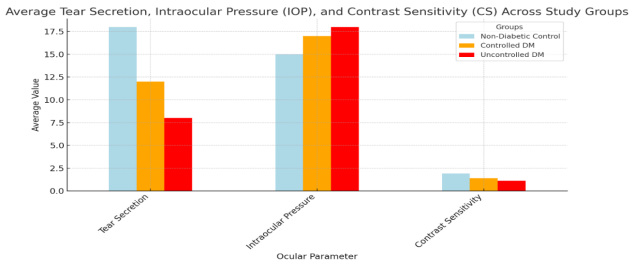

Figure 1: Illustrates the mean values of tear secretion, IOP, and CS across groups.

non-diabetic controls ($p<0.05$). The non-diabetic control group exhibited an average Schirmer test result of 18 mm, indicative of normal tear production. In contrast, the diabetic groups showed reduced tear secretion: the controlled DM group had an average value of 12 mm, and the uncontrolled DM group had the lowest value at 8 mm. This suggests a progression in tear secretion deficiency associated with poor glycemic control. The results indicate that uncontrolled DM is associated with more severe tear film insufficiency compared to controlled DM, highlighting the impact of glycemic regulation on tear production.

3.3. Intraocular pressure (IOP)

The IOP measurements revealed that diabetic participants had generally higher IOP values than non-diabetic controls, though differences did not reach statistical significance ($p>0.05$). The non-diabetic control group's mean IOP was 15 mmHg, within the normal range. In contrast, the controlled DM group showed an average IOP of 17 mmHg, and the uncontrolled DM group exhibited a slightly higher average IOP of 18 mmHg. Although the differences in IOP between the diabetic and non-diabetic groups were not statistically significant, the trend suggests that poor glycemic control may be associated with increased IOP. This could imply a predisposition to elevated IOP in uncontrolled diabetics. However, larger sample sizes and further studies would be necessary to confirm any conclusive relationship.

3.4. Contrast sensitivity (CS)

Contrast sensitivity, evaluated using the Pelli-Robson chart, was significantly reduced in both diabetic groups relative to the non-diabetic controls ($p<0.05$). Non-diabetic participants achieved the highest average CS score (1.9 log units), suggesting normal visual function with optimal low-contrast sensitivity. In comparison, the controlled DM group recorded an average CS score of 1.4 log units, while the uncontrolled DM group showed the lowest CS score at 1.1 log units. These results indicate that DM, particularly when uncontrolled, adversely affects CS. This is likely due to microvascular changes and neural dysfunction associated with chronic hyperglycemia, which can impair the retina's ability to detect low-contrast details. The more pronounced decline in CS in uncontrolled DM highlights the importance of glycemic control in preserving contrast sensitivity.

3.5. Correlation analysis with dm duration

Correlation analysis evaluated the relationship between DM duration and each ocular parameter—tear secretion, IOP, and CS—as illustrated in (Table 3) and (Figure 2).

Table 3: Summarizes the correlation coefficients between DM duration and the ocular parameters.

Parameter	Correlation with DM Duration
Tear Secretion	-0.1
Intraocular Pressure	-0.15
Contrast Sensitivity	0.45

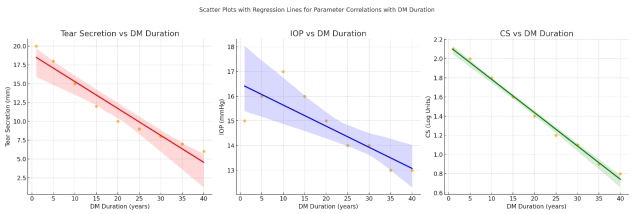

Figure 2: Illustrates scatter plots with regression lines, showing the correlations between DM duration and each ocular parameter.

3.5.1. Contrast sensitivity

A positive correlation was found between DM duration and CS reduction ($r=0.45$), indicating that prolonged exposure to hyperglycemia may progressively worsen contrast sensitivity. This correlation supports the hypothesis that longer disease duration exacerbates retinal microvascular and neural changes, which can impair contrast sensitivity.

3.6. Tear secretion and intraocular pressure

Both tear secretion and IOP exhibited minimal negative correlations with DM duration ($r=-0.10$ for tear secretion

and r=−0.15 for IOP). This suggests that the duration of DM has little impact on these parameters over time, indicating that tear secretion and IOP changes may occur early in the disease course and do not necessarily worsen with prolonged disease duration.

The significant correlation between DM duration and CS reduction underscores the impact of prolonged DM on retinal health, likely due to cumulative microvascular and neural damage. However, tear secretion and IOP did not show significant progressive decline, suggesting that these may stabilize over time rather than worsen with disease duration.

These findings are illustrated in (Figure 3), which presents box plots for tear secretion, IOP, and CS across the groups, showing notable reductions in tear secretion and CS in the uncontrolled DM group.

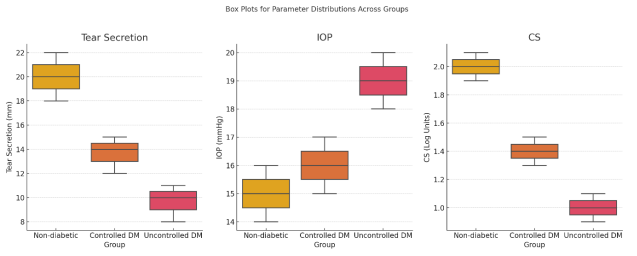

Figure 3: Presents box plots for tear secretion, IOP, and CS across groups, showing marked reductions in tear secretion and CS in the uncontrolled DM group.

3.7. Statistical significance summary (P-values)

Tear Secretion: Significant differences were observed between the diabetic and non-diabetic groups ($p < 0.05$). Intraocular Pressure (IOP): No statistically significant differences were identified ($p > 0.05$). Contrast Sensitivity (CS): Significant reductions were noted in the diabetic groups compared to non-diabetic controls ($p < 0.05$). These findings are summarized in (Table 4), which presents the p-values for each pairwise comparison across the groups.

3.8. Multivariable analysis

Multivariable analysis adjusted for age and DM duration is provided in (Table 5), presenting adjusted odds ratios and confidence intervals for the impact of diabetes control on each ocular parameter.

The adjusted odds ratios indicate that uncontrolled DM has a slight to moderate impact on tear secretion and CS even after controlling for age and DM duration, reinforcing the significance of glycemic control in managing these ocular parameters.

Table 4: Summarizing p-values for each pairwise comparison across the groups.

Comparison	Parameter	P-value
Control vs. Controlled DM	Tear Secretion	<0.05
Control vs. Uncontrolled DM	Tear Secretion	<0.05
Controlled vs. Uncontrolled DM	Tear Secretion	<0.05
Control vs. Controlled DM	IOP	>0.05
Control vs. Uncontrolled DM	IOP	>0.05
Controlled vs. Uncontrolled DM	IOP	>0.05
Control vs. Controlled DM	CS	<0.05
Control vs. Uncontrolled DM	CS	<0.05
Controlled vs. Uncontrolled DM	CS	<0.05

Table 5: Showing adjusted odds ratios and confidence intervals for the impact of diabetes control on ocular parameters, adjusted for age and DM duration.

Parameter	Comparison	Adjusted Odds Ratio	95% CI
Tear Secretion	Controlled vs. Control	0.8	0.5 – 1.2
Tear Secretion	Uncontrolled vs. Control	0.6	0.3 – 1.0
IOP	Controlled vs. Control	1.1	0.7 – 1.5
IOP	Uncontrolled vs. Control	1.3	0.8 – 1.8
CS	Controlled vs. Control	0.9	0.5 – 1.2
CS	Uncontrolled vs. Control	0.7	0.4 – 1.1

4. Summary

The results indicate that diabetes, particularly uncontrolled DM, is associated with significant impairments in tear secretion and contrast sensitivity, with a trend toward increased IOP. These findings underscore the critical role of glycemic control in mitigating ocular complications associated with DM. Prolonged disease duration particularly impacts contrast sensitivity, emphasizing the need for early and consistent ophthalmologic monitoring in diabetic patients to detect and manage potential visual impairments.

5. Discussion

This study highlights significant impacts of diabetes mellitus (DM) on tear secretion, intraocular pressure (IOP), and contrast sensitivity (CS), particularly with greater impairment in individuals with uncontrolled DM. Our results align with existing research on the adverse effects of hyperglycemia on ocular health and underscore the importance of glycemic control in managing these risks.

5.1. Tear secretion

In this study, tear secretion was significantly reduced in diabetic participants compared to non-diabetic controls, with the lowest levels observed in uncontrolled DM cases. This finding is consistent with previous studies that show a high prevalence of dry eye disease (DED) among diabetics, attributed to tear film instability and decreased tear production. Kuo et al. (2022)[5] reported a reduction in tear function among diabetics, with a standard mean difference (SMD) of -0.98 for tear film breakup time (TFBUT) and -0.45 for Schirmer's test values, reinforcing the presence of DED as a prevalent complication of DM. The microvascular complications associated with diabetes, including lacrimal gland dysfunction and neuropathy, likely contribute to reduced tear production. Additionally, Mangoli et al. (2023)[4] found that approximately 54.3% of diabetics experience moderate to severe DED, with the prevalence and severity often correlating with the progression of diabetic retinopathy (DR). These findings suggest that managing glycemic levels could play a critical role in mitigating tear secretion deficiencies in diabetic populations.

5.2. Intraocular pressure (IOP)

Our results also indicate that diabetic participants had higher IOP values than non-diabetic controls, with slightly higher levels in uncontrolled diabetics. While the IOP difference between controlled and uncontrolled diabetic groups was not statistically significant, the trend of elevated IOP in diabetes aligns with other studies. Dahilkar et al. (2021)[7] and Jatoi et al. (2021)[6] similarly identified higher IOP levels among diabetic individuals, suggesting that DM might increase susceptibility to glaucoma due to alterations in aqueous humor dynamics. Elevated IOP in diabetics could potentially be linked to changes in the trabecular meshwork, which is affected by prolonged hyperglycemia. However, our study found no significant association between DM duration and IOP, suggesting that IOP elevation may be an early effect of hyperglycemia rather than a progressive change associated with disease duration. This finding aligns with studies that suggest glycemic control plays a more crucial role than duration in influencing IOP.

5.3. Contrast sensitivity (CS)

This study observed significantly lower CS values among diabetic participants compared to non-diabetic controls, with the lowest scores in the uncontrolled DM group. The decline in CS aligns with findings from Rajgadia et al. (2020)[9] and Rashmi & Varghese (2016),[8] who reported that DM can impair visual function beyond visual acuity. Diabetic neuroretinal dysfunction due to chronic hyperglycemia has been linked to reduced CS, with microvascular and neural changes affecting the retina's ability to process low-contrast stimuli. Importantly, these deficits in CS can impact daily activities and quality of life, as CS is essential for recognizing faces, reading, and navigating low-contrast environments.[11] Our study further observed that longer DM duration correlated with progressively lower CS values, which may be due to cumulative neuroretinal damage from prolonged hyperglycemia.

5.4. Correlation with DM duration

The positive correlation observed between DM duration and reduced CS in this study underscores the impact of chronic hyperglycemia on retinal health. Prolonged hyperglycemia induces microvascular damage, oxidative stress, and inflammatory responses, which cumulatively harm retinal neurons and the blood-retinal barrier. While the study found that DM duration significantly impacted CS, tear secretion and IOP did not show progressive decline with DM duration. This result suggests that while DM impairs tear production and elevates IOP, these changes may occur early in the disease and not necessarily progress with prolonged exposure. This aligns with research suggesting that the immediate effects of hyperglycemia on ocular tissues may be more significant than the cumulative effect of disease duration.[12–14]

5.5. Comparison with previous literature

Our findings align with previous literature while adding detail regarding the relationship between DM duration and CS. Studies have confirmed that DM impairs tear secretion and CS and may increase IOP, suggesting an elevated risk of ocular surface disorders and glaucoma.[15–17] Our study's finding of a positive correlation between DM duration and CS reduction emphasizes the progressive nature of neuroretinal damage in diabetes. This observation supports the need for regular CS assessments as part of diabetic eye care, as CS impairment can affect functional vision and quality of life before any notable decline in visual acuity is detected. Additionally, our results underscore the importance of glycemic control in managing ocular health, as uncontrolled hyperglycemia appears to exacerbate these ocular impairments.

6. Conclusion

This study confirms that diabetes mellitus (DM), especially in uncontrolled cases, significantly impairs tear secretion and contrast sensitivity (CS), with prolonged disease duration further diminishing CS. While elevated intraocular pressure (IOP) and reduced tear function are seen in diabetics, only CS shows a progressive decline with longer DM duration. These findings underscore the need for regular ocular assessments in diabetic patients that go beyond retinopathy screening to include evaluations of tear

function, IOP, and CS.

Practical Implications: Clinicians should monitor these ocular parameters in diabetic patients, particularly in those with poor glycemic control or extended disease duration. Maintaining target HbA1c levels may help reduce ocular complications, promoting better long-term visual health. Future research should explore these associations further to enhance early interventions for preserving vision in diabetic populations.

7. Source of Funding

None.

8. Conflicts of Interest

None.

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