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Micronucleus Evaluation Of Cell Phone Radiation-Induced Genotoxicity In Oral Mucosa: A Comparative Study In Healthy, Diabetic, And Anemic Subjects

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ABSTRACT

Background: *The global increase in mobile phone usage has raised public health concerns regarding prolonged exposure to electromagnetic radiation and its potential genotoxic effects. The oral mucosa, due to its close contact with mobile devices during calls, may be especially vulnerable. Conditions such as type 2 diabetes mellitus and iron deficiency anemia are already associated with increased oxidative stress and DNA damage, yet their interaction with mobile radiation remains poorly understood. The micronucleus (MN) assay serves as a reliable, non-invasive biomarker for identifying DNA damage in exfoliated buccal cells.*

Aim and Objectives: *This study aimed to evaluate DNA damage by assessing the frequency of micronuclei in the buccal cells of three groups—healthy individuals, diabetic patients, and those with iron deficiency anemia—each using mobile phones for approximately 2 ± 1.5 hours daily. The objective was to compare MN frequency across the groups.*

Methods: *A total of 180 participants aged 25–45 were categorized into three equal groups: Group I (healthy), Group II (diabetic), and Group III (anemic). Buccal cell smears were collected from the side predominantly used during phone calls, followed by Papanicolaou staining and evaluation under a light microscope using the criteria by Tolbert et al. Statistical analysis was performed using ANOVA and Spearman's correlation coefficient.*

Results: *The frequency of cells with micronuclei was significantly higher among diabetic (51.4%) and anemic subjects (37.8%) compared to healthy individuals (12%) ($p < 0.001$). Diabetics showed a very strong positive correlation between MN frequency and HbA1c levels ($r = 0.999$, $p < 0.001$), while anemics exhibited a strong negative correlation between MN frequency and serum ferritin ($r = -0.626$, $p < 0.001$). Healthy subjects demonstrated a moderate positive correlation between mobile phone usage duration and MN frequency ($r = 0.646$, $p < 0.001$).*

Conclusion: *The study highlights a significant increase in DNA damage among diabetic and anemic individuals compared to healthy controls, suggesting that underlying systemic conditions amplify susceptibility to genotoxic effects. These findings underscore the need for careful monitoring of mobile radiation exposure, especially in individuals with chronic diseases.*

INTRODUCTION

With over three billion individuals globally using mobile phones, prolonged exposure to potentially carcinogenic electromagnetic radiation has emerged as a significant health concern. Nearly 90% of all human cancers are carcinomas, primarily originating from epithelial tissues due to their high turnover rate and frequent exposure to environmental stressors, including physical agents like radiation. In this study, the epithelial lining of the oral cavity was examined, as it lies in close proximity to mobile devices during regular phone use and may be more susceptible to radiation-induced alterations.

Among various biomarkers for detecting genotoxicity, the micronucleus (MN) assay in exfoliated oral epithelial cells is well-established. Initially introduced by Stick in 1983, this method identifies micronuclei—small extranuclear chromatin bodies that form from acentric chromosomal fragments or entire chromosomes that fail to integrate into the daughter nuclei during mitosis. Their presence indicates both structural and numerical chromosomal aberrations and serves as a reliable early indicator of carcinogenic changes.

Research suggests that systemic conditions and nutritional deficiencies may influence the development of

micronuclei. Diseases such as type 2 diabetes mellitus (DM) and iron deficiency anemia (IDA) are known to increase the generation of reactive oxygen species, thereby contributing to genomic instability. When individuals with these conditions are also exposed to mobile phone radiation, the genotoxic risk may be compounded. The objective of the present study was to investigate and compare the extent of DNA damage— reflected by the frequency of micronuclei—in healthy individuals and those with DM or IDA, all of whom are regular mobile phone users.

MATERIALS AND METHODS

Participant Selection

This study was conducted following ethical approval from the Institutional Ethics Committee (Approval No. IEC/P-267/2023). Participants were selected from the outpatient population at a dental hospital, including individuals previously diagnosed with type 2 diabetes mellitus or iron deficiency anemia. Detailed histories were gathered through structured questionnaires. A total of 180 participants meeting the inclusion criteria were enrolled and categorized into three groups:

- **Group I:** Healthy controls (n = 60)
- **Group II:** Diabetic patients (n = 60)
- **Group III:** Patients with iron deficiency anemia (n = 60)

Inclusion Criteria

- Aged between 25–45 years
- Regular users of mobile phones for voice calls (without using hands-free devices)
- Diagnosed diabetics with HbA1c ≥ 6.4%
- Diagnosed anemics with serum ferritin < 30 µg/dL

Exclusion Criteria

- History of radiotherapy
- Tobacco or alcohol use
- Presence of other systemic conditions or recent viral infections
- Occupational exposure to radiation
- Clinically visible oral mucosal lesions

Sample Collection and Slide Preparation

Participants were queried about mobile phone use, particularly the average duration and preferred side of use. Buccal mucosal scrapings were collected from the dominant side of the oral cavity using a sterile wooden spatula. Smears were immediately fixed onto glass slides, air-dried, and stained using rapid Papanicolaou (PAP) technique. Slides were then mounted with DPX and examined under a binocular microscope at 400× magnification.A total of 500 exfoliated epithelial cells were assessed per participant using the morphological criteria established by Tolbert et al. for identifying micronuclei.

Micronucleus Identification Criteria (Tolbert et al.)

- Smooth, round shape with a clear membrane
- Similar staining intensity to the primary nucleus
- Located in the cytoplasm, sized between 1/3 and 1/16 of the main nucleus
- Same focal plane and texture as the nucleus

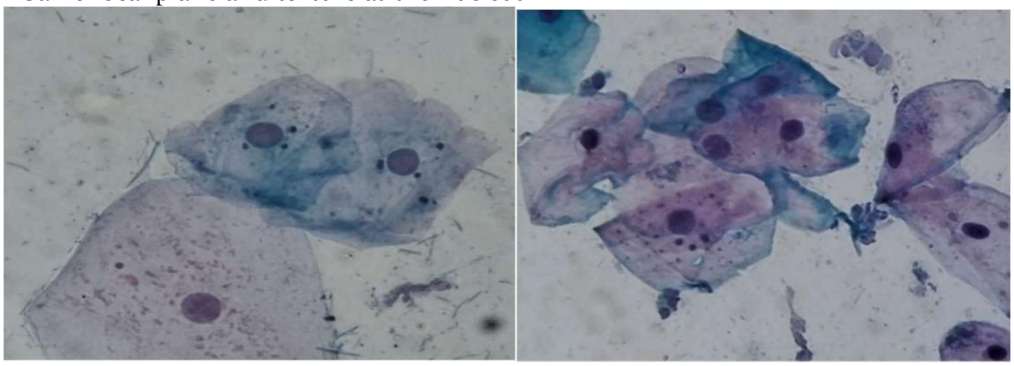

Figure 1: Buccal epithelial cell with visible micronucleus (400X, PAP stained)

Table 1: Demographic Characteristics Among Study Groups

Parameter	Group 1 (Healthy) (N=60)	Group 2 (Diabetic) (N=60)	Group 3 (Iron Deficiency Anemia)(N=60)	P-value
Age (years), Mean ± SD	28.62 ± 3.9	38.70 ± 3.4	33.17 ± 4.2	< 0.001*
Gender, n (%)				0.539
Male	28 (46.7%)	30 (50%)	24 (40%)	
Female	32 (53.3%)	30 (50%)	36 (60%)	

*** p-value below 0.05 indicated a statistically significant**

Note: The diabetic group had the highest mean age, followed by the anemic group, with healthy individuals being the youngest. Gender distribution did not differ significantly between groups.

RESULTS

The analysis revealed significant differences in both cell phone usage and genotoxic markers across the study groups.

Table 2: Comparison of Mobile Phone Use and Micronucleus Parameters Among Groups

Parameter	Group 1	Group 2	Group 3	P-value
Duration of cell phone usage (hours), Mean ± SD	**1.8 ± 0.9**	**2.3 ± 0.8**	**1.8 ± 0.8**	**< 0.001***
Average number of cells containing micronucleus, Mean ± SD	**68.53 ± 32.14**	**257.58 ± 78.11**	**189.07 ± 49.48**	**< 0.001***
Frequency of micronucleus containing cells, % (range)	**12% (4 – 30%)**	**51.4% (24 – 82.4%)**	**37.8% (24 – 78%)**	**< 0.001***

***p-value below 0.05 indicated a statistically significant Interpretation:**

The diabetic group exhibited the highest number of buccal cells with micronuclei, followed by the anemic group. Healthy individuals showed the lowest MN frequency. The data indicate significantly elevated genotoxicity in participants with chronic health conditions compared to healthy controls ($p < 0.001$).

Table 3: Correlation Between Cell Phone Use and Micronucleus Frequency (Spearman Coefficient)

Variables Compared	Group 1	Group 2	Group 3
Duration of cell phone use vs Frequency of micronucleus-containing cells	r = 0.646 [95% CI: 0.463 – 0. P < 0.001*	r = 0.231 [95% CI: -0.032 – 0. P = 0.076	r = 0.058 [95% CI: -0.207 – 0. P = 0.062
Frequency of micronucleus-containing cells vs HbA1c levels	-	r = 0.999 [95% CI: 0.999 – 1.00] P < 0.001*	-
Frequency of micronucleus-containing cells vs Ferritin levels	-	-	r = -0.626 [95% CI: -0.762 – - 0. P < 0.001*

Note: Spearman's correlation coefficient (r) used to measure correlation. P-value < 0.05 considered statistically significant.

Interpretation:

- **Healthy participants** showed a moderate positive correlation between mobile phone usage and MN frequency, suggesting radiation-induced genotoxicity ($p < 0.001$).
- **Diabetics** had a near-perfect positive correlation between HbA1c levels and MN frequency, indicating a strong association between poor glycemic control and DNA damage.
- **Anemic individuals** demonstrated a significant negative correlation between serum ferritin levels and MN frequency, pointing to iron deficiency as a contributing factor to chromosomal instability.

DISCUSSION

The possible link between mobile phone use and cancer development remains a widely debated topic. Although extensive research, including in vivo and epidemiological studies, has been conducted, conclusive evidence is still lacking. The oral cavity, being within close range of mobile device radiation, is a key site for early genotoxic changes, particularly in epithelial tissue. The buccal micronucleus (MN) assay is a well- validated, non-invasive method that can detect chromosomal instability, apoptosis, and DNA damage. In this study, a significant relationship was observed between mobile phone use and increased MN frequency in healthy individuals ($r = 0.646$, $p < 0.001$), indicating that even in the absence of systemic illness, electromagnetic radiation may lead to DNA alterations. These findings align with previous studies. For instance, Hintzsche and Stopper (2010) reported a higher MN frequency among heavy mobile phone users. Similarly, Yadav and Sharma (2008) used buccal micronucleus cytome (BMNcyt) assay and observed increased MN counts, albeit not statistically significant. Kesari et al. (2014) reported elevated micronucleus levels, apoptosis rates, and caspase-3 activity in a mouse model subjected to daily mobile radiation exposure for 60 days. Our results further underscore the heightened susceptibility of individuals with chronic conditions such as diabetes and anemia to DNA damage. Diabetic patients exhibited significantly higher MN frequency, consistent with prior research by Martínez-Pérez et al. (2007), who found similar genotoxic trends in type 2 diabetes mellitus. Shaik et al. (2010) also noted an increased micronucleus frequency in diabetic patients under glimepiride and pioglitazone treatment. Zuniga-Gonzalez et al. (2007) and Elisabeth Müllner (2014) supported these findings, indicating a doubling of MN frequency in diabetic populations. Biswas et al. (2017) similarly demonstrated increased DNA damage in diabetic individuals using buccal MN assays, with a clear link between hyperglycemia and genotoxicity. These trends are consistent with our observed strong correlation ($r = 0.999$) between HbA1c levels and MN frequency. The study also explored DNA damage in individuals with iron deficiency anemia. Higher MN frequency in this group corroborates findings from previous literature. Surrallés et al. (1997) demonstrated that iron deficiency impairs DNA repair mechanisms due to the diminished activity of DNA repair enzymes, making cells more vulnerable to oxidative damage. Ganguly et al. (2018) observed similar trends in peripheral blood lymphocytes of anemic patients. Iron, as a cofactor in numerous enzymatic reactions, plays a critical role in maintaining DNA stability. Interestingly, mobile phone use did not significantly correlate with MN frequency in diabetic or anemic groups. This suggests that intrinsic factors like oxidative stress, metabolic imbalance, and impaired cellular repair mechanisms play a more dominant role in genomic instability than external environmental exposures in these populations.

CONCLUSION

This study revealed that individuals with type 2 diabetes mellitus and iron deficiency anemia exhibit significantly higher frequencies of buccal cells containing micronuclei compared to healthy individuals. This suggests elevated genomic instability likely driven by oxidative stress and impaired cellular repair mechanisms. The strong associations with glycemic control and iron levels further support the role of chronic metabolic disturbances in enhancing DNA damage. While mobile phone radiation alone was found to be genotoxic in healthy participants, its effects were overshadowed in patients with pre-existing conditions. These findings underscore the utility of the buccal micronucleus assay as an effective, non-invasive screening tool for early detection of DNA damage, particularly in high-risk individuals. Incorporating such methods into routine clinical assessments could aid in the prevention or early intervention of conditions associated with genomic instability, including cancer.

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