Original Article

A Cross-Sectional and Histological Analysis to Understand the Cytological Effects of Cell Phone Radiation on Buccal Mucosa of Children

Voleti Sri Srujana Aravinda, Chaitanya Ram Kandregula, Radhika Muppa[1], M. Madhavi Krishna, B. S. Nikitha, Malathi Yenni

Department of Paediatric and Preventive Dentistry, Anil Neerukonda Institute of Dental Sciences, Visakhapatnam, [1]Department of Paediatric and Preventive Dentistry, Dr Sudha and Nageswararao Siddartha Dental College, Vijayawada, Andhra Pradesh, India

ABSTRACT

Context: The ongoing pandemic has affected all the spheres of life and one of the severely affected avenues is the education of a child. The online education has seen an upward curve since the start of COVID-19 pandemic. Schools globally have adopted online class tutorials as the main method to impart education and directly increasing the screen time for a child. **Aim:** The aim of the present study was to evaluate the cytological effects of prolonged mobile phone usage on the buccal mucosa of children. **Settings and Design:** Stratified sampling was used for the selection of subjects for the study. After a questionnaire regarding the usage of a mobile phone was distributed among the parents of children. Among them, 90 children were selected on the basis of pattern and frequency of mobile phone usage in the child. **Materials and Methodology:** The children were divided into three groups based on the per day hours of viewing of mobile phone, i.e., Group 1: Usage of 1–2 h a day, Group 2: Usage of 3–6 h a day, and Group 3: Usage of >6 h a day. The time frame taken into consideration was 1 year after the pandemic started. This was specifically to understand the impact of the online education. Swab was obtained by using the conventional ice-cream stick method from the buccal mucosa. **Statistical Analysis:** The samples were subjected to histological and microscopical analysis to observe for cytological changes. One-way ANOVA was used to determine the statistical significance if any. **Results:** The results obtained clearly showed that Group 3 (>6 h usage per day) showed the highest number of cellular and chromosomal aberrations which was significant. **Conclusion:** The results indicated that impact due to the prolonged screen time on the buccal mucosa is significant. A direct proportionality was seen between the apoptotic changes and chromosomal aberrations and the number of daily hour usage.

KEYWORDS: Apoptotic cells, buccal mucosa cells, children, electromagnetic radiation, exfoliated buccal epithelial cells

Address for correspondence:
Dr. Voleti Sri Srujana Aravinda,
Anil Neerukonda Institute of Dental Sciences, Visakhapatnam, Andhra Pradesh, India.
E-mail: srujanaaravinda1@gmail.com

Access this article online

Quick response code

Website: www.jisppd.com

DOI: 10.4103/jisppd.jisppd_28_22

Introduction

The first mobile phone was demonstrated by John f Mitchell and martin cooper of Motorola in 1973. Today an average person touches their mobile phone for an unreal 2617 times per day and on an average one spends

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: WKHLRPMedknow_reprints@wolterskluwer.com

How to cite this article: Srujana Aravinda VS, Kandregula CR, Muppa R, Krishna MM, Nikitha BS, Yenni M. A cross-sectional and histological analysis to understand the cytological effects of cell phone radiation on buccal mucosa of children. J Indian Soc Pedod Prev Dent 2022;40:74-80.

Submitted: 20-Jan-2022 **Revised:** 14-Mar-2022
Accepted: 15-Mar-2022 **Published:** 14-Apr-2022

800 h on mobile phone in a year. The last 10 years have been labeled as the "decade of the smartphone."[1]

Due to the ongoing pandemic, the usage of virtual reality has increased even more thus increasing screen time. The education system and schools globally were quick to adopt this as the mode of choice for imparting education as physical distancing and contactless mode became vital. The classes for children were held in a web-supported communication application such as zoom and webex. This indirectly increased the screen time and usage of mobile phone in children.[1]

The principle behind the working of a smartphone depends on radiofrequency electromagnetic waves (RF-EMW). Smartphones use microwaves as a frequency range between 300 MHz to 300 GHz.[2]

The rate at which radiation emitted by smartphones is absorbed by the human body is known as Specific Absorption Rate (SAR). It is a standardized unit that measures the impact of RF-EMW on the human body. It is expressed as Watt/kg. The Federal Communication Commission has limited the maximum legal SAR of any hand-held cell device to 1.6 W/kg.[3]

According to the WHO, Over the last few decades, the increased use of cell phones has led individuals to get exposed to electromagnetic radiation raising questions regarding health effects, especially its long-term effects.[4] Hence, WHO Research Agenda for radiofrequency radiation identified EMR effects has high priority research need.

Many *in vitro* studies have reported evidence of radiation having genotoxic effects, such as Micronucleus Assay; Chromosomal aberrations, DNA strand breaks.[5-7] In addition, in 2011 International Agency for Research on Cancer concluded that radiofrequency radiations should be registered as a possible carcinogen (Group 2B) for humans.[8,9]

A study done by Desai *et al.* (2009) had suggested that long-term exposure to mobile phone radiation initiates uncontrolled cell proliferation due to accumulated DNA damage and also that exposure to radiofrequency electromagnetic. Waves decreases the Protein Kinase C activity which may be linked to carcinogenesis.[10]

In a recent study conducted in 113 individuals within the age group of 19–84 with a phone usage of 0–15 h, observations showed that DNA damage was detected in buccal cells in patients with extended exposure to cell phone radiation. The authors concluded that mobile phone users may have a greater propensity toward malignancy and cytotoxicity.[10]

The buccal smear analysis is a cost-effective, minimally invasive method for studying chromosomal instability, apoptosis, and the regenerative potential of buccal mucosa cells. In the present day, it is widely used in epidemiological studies for evaluating the effect of nutrition, lifestyle factors, nuclear changes, and cell death.[11]

Apart from overall health effects, the effect of these radio frequencies on the oral cavity is a prime concern. In addition, the proximity of the oral tissues to a hand-held mobile phone and the susceptible nature of these structures to environmental changes make them an area of concern. Even though the data existing so far is inconclusive, the scientific evidence indicates some biological effects and possible adverse health effects that merit additional research.[12]

Existing literature suggests that effects of mobile phone usage are in direction proportionality to the time of its use. A range of symptoms has been reported varying from burning sensation, tingling of the skin on the head and extremities, fatigue, sleeping disorders, vertigo, mental distraction, increased reaction time, diminished memory, headaches, weakness, and palpations to digestive system disturbances.[12]

The present histological study is to better understand the cytotoxic effects of radiation on buccal mucosa in children and thereby establish a cause-effect relationship.

Materials and Methodology

The Ethical approval to conduct the study was obtained from the Institutional Ethical Committee. Initially, a basic questionnaire regarding the pattern and frequency of mobile usage by the child was prepared and distributed among the parents visiting the department of pedodontics, Anil Neerukonda Institute of Dental Sciences, Visakhapatnam. Questions which elicited the same response and questions which have been found difficult to answer by the parents were removed and a final questionnaire was prepared. The questionnaire was validated by two different examiners. The validated comprehensive questionnaire was then distributed to the parents/guardians. The information included the type of mobile phone, daily frequency of online classes, usage period in 24 h, brand in use, age, class, diet, and systemic disease (if any).

Patients were categorized, based on exposure to mobile phone electromagnetic radiation assessed through a questionnaire, into three groups: Group 1: Usage of 1–2 h a day, Group 2: Age-matched healthy individuals and a usage of 3–6 h a day and Group 3: Usage of >6 h a day making a total sample 90 children with 30 children in each group [Table 1].

Inclusion criteria include (1) Children aged between 4 and 14 years are included, (2) Children with no systemic disorders, (3) Children not under any medication, (4) parents owning a smartphone with

SAR of 1.6 w/kg averaged over a mass of 1 g body tissue. The specific value is the threshold value set by international commission on nonionizing radiation protection and institute of electrical and electronics engineers (IEEE),[13] (5) children who had been using smartphones for a minimum of 1 year.

Exclusion criteria were (1) Children with soft tissue lesions in the oral cavity, (2) Children who are on long-term medication, (3) Children/parents who were not willing to be a part of the study.

After allocating the child into a specific group based on a questionnaire clinical examination of oral cavity was performed to detect the presence of any soft tissue lesions. The buccal mucosa samples were collected as per the ethical guidelines and with prior consent from the parent. After a thorough pre rinsing with water, swab was obtained using a sterile ice-cream sticks from the inner walls of cheeks (buccal mucosa). Slide preparation was done as per the standard protocol.[12] Slides were stained with Giemsa, air-dried, and observed under the microscope at 10 × and 40 × magnifications for cellular changes in buccal mucosa.

A brief understanding of cross-section of normal buccal mucosa of healthy individuals is necessary to understand the various cell types which can be observed in the buccal smear [Figures 1 and 2].

Normal basal cells

Have a larger nucleus-to-cytoplasm ratio with a uniformly stained nucleus. They are smaller in size, oval in shape. Apart from the nucleus, no DNA-containing structures are observed in these cells.[14]

Micronucleated cells

Micronucleated cells are categorized by the presence of both a main nucleus and one or more smaller nuclear structures called micronuclei. The micronuclei are round/oval in shape and their diameter should range between 1/3 and 1/16 of the main nucleus. The presence of these cells is indicative of chromosome loss or fragmentation occurring during earlier nuclear division.[15]

Cells with nuclear buds

Contain nuclei with a sharp constriction at one end of the nucleus indicative of a budding process, i.e., elimination of nuclear material by budding. These were referred to as "broken egg" cells. The mechanism of nuclear bud (NB) formation is not identified but it may be due to the DNA repair.[16]

Binucleated cells

Binucleated cells are cells with two main nuclei. The nuclei are very close and may touch each other and usually have the same morphology as seen in normal cells. The significance of these cells is unidentified, but they are probably due to failed cytokinesis.[17]

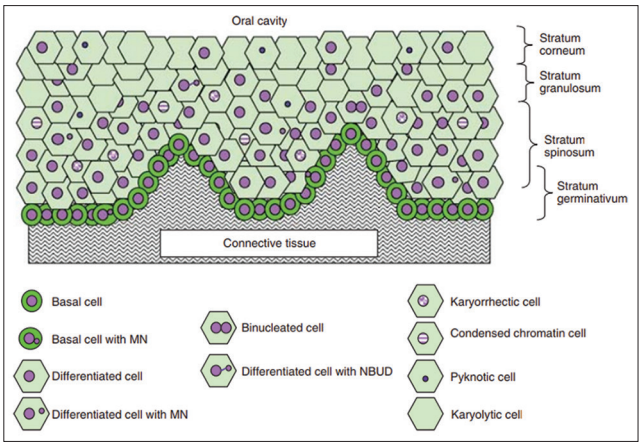


Figure 1: The mucosa of healthy individuals illustrating the different cell layers and possible spatial relationships of the various cell types[11]

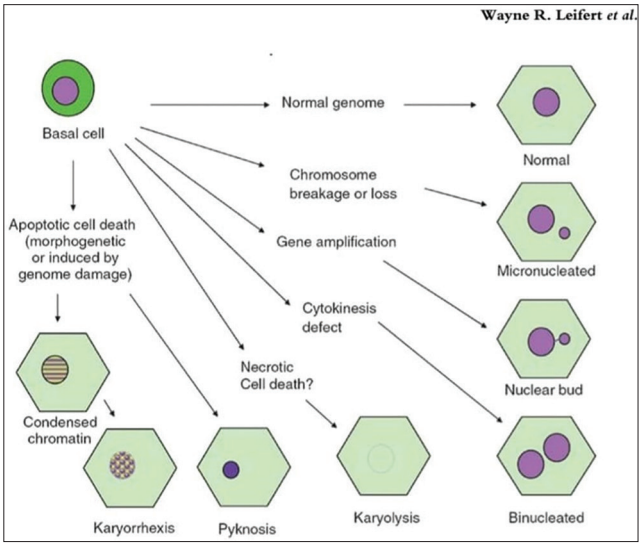


Figure 2: Diagrammatic representation of the various cell types scored in the buccal mucosa smear[11]

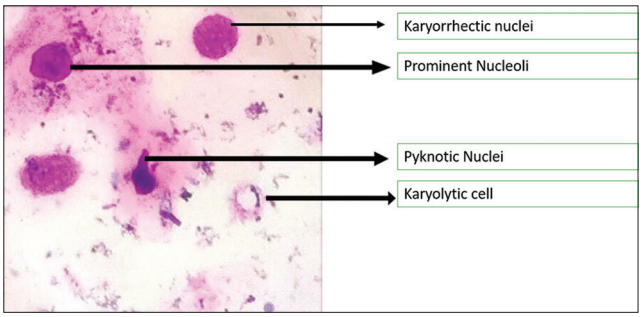


Figure 3: Showing karyorrhectic, pyknotic nuclei, prominent nucleoli and karyolytic cell

Condensed chromatin

Condensed chromatin shows a roughly striated pattern in which the aggregated chromatin is stained intensely.

In these cells, it is apparent that chromatin is aggregating in some regions of the nucleus while being lost in other areas. These cells may be under early stages of apoptosis, although this has not been shown conclusively.[18]

Karyorrhectic cells

Karyorrhectic cells have nuclei that are categorized by more extensive nuclear chromatin aggregation than condensed chromatin cells (CC). They have a speckled nuclear pattern indicative of nuclear fragmentation leading to the disintegration of the nucleus. These cells may be under a late stage of apoptosis.[19]

Pyknotic cells

Pyknotic cells are characterized by a shrunken nucleus, with a nuclear material that is uniformly stained. The biological significance is that these cells may be undergoing a unique form of cell death.[20]

Karyolytic cells

Karyolytic cells are cells with nucleus depleted of DNA. These cells do not have nucleus and represent a very late stage in the cell death process.[20]

The observed cells in this study included Normal cells, Micro nucleated cells (MN), Binucleated cells (BN), Pyknotic cells (PC), NB, Karyorrhectic cells (KR), CC, and Karyolytic cells (KL) [Figures 3-7].

Statistical analysis

The results were recorded and analyzed using ANOVA followed by *post hoc* test with statistical analysis with SPSS software version 21 (South Asia Pvt.Ltd, Delhi NCR, India) to ascertain any statistical significance between the three groups.

Results

The scoring criteria for the different cell types and nuclear anomalies are mainly intended for categorizing buccal cells into groups that distinguish between "normal" cells and cells that are considered "abnormal" on the basis of cytological and nuclear features, which are indicative of DNA damage, cytokinetic failure, or cell death. These criteria are summarized in Figure 8.

The results showed a substantial increase in the MN, NB, PC, KR, CC, and KL in Group-3 compared to Group-2 and Group-1. In addition, the exposed individuals showed a significant increase in the number of cell anomalies (MN, BN, NB, PC, CC, KR, and KL) compared to less exposed individuals. Apoptotic changes were more in Group-2 whereas nuclear and chromosomal alterations were more in Group-3 with higher exposure.

The mean frequencies of different cell types such as Micro nucleated, Binucleated, Nuclear budding (NB), pyknotic, karyorrhectic (KR), Condensed chromatin, and karyolytic cells (KL) in this study is shown in Table 2 and Graphs 1, 2.

Discussion

The cytotoxic and genotoxic effects of radiation RF-EMW emitted from a mobile phone have been listed by the WHO as research of top priority.

Previously, studies have been reported on RF-EMW radiations on Peripheral blood lymphocytes[21] and Hematological parameters in serum samples.[22] In addition, Agarwal *et al*. showed harmful effects of cell phone radiation.[23] Experimentally, nonthermal

Table 1: Characteristics of the sample population

Group name	Age (years), mean±SD	Number of males	Number of females	Sample size
Group A	7.3±1.15	14	16	30
Group B	7.9±1.22	15	15	30
Group C	7.88±1.44	16	14	30

SD=Standard deviation

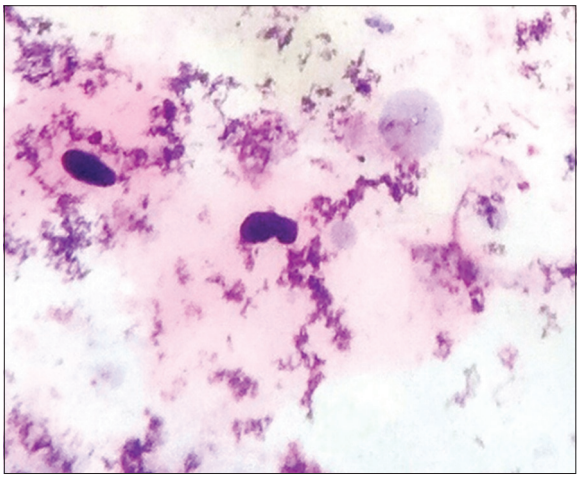


Figure 4: Buccal epithelial cells with budding nucleus

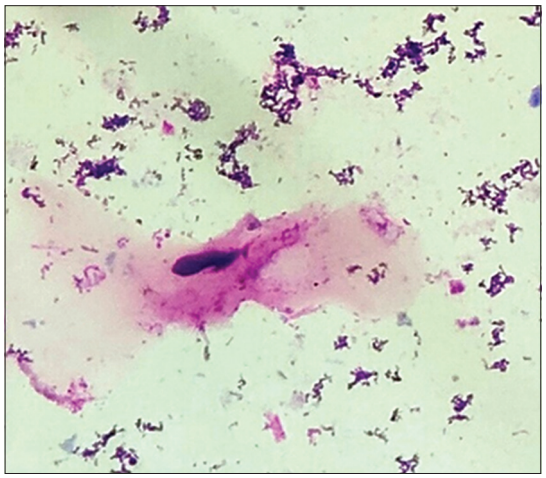


Figure 5: Budding nucleus with altered cytoplasmic and cell wall characteristics

Table 2: Interpretation of buccal mucosa cells in three study groups

Cell types	Mean			*P*	Indicative of
	Group 1	Group 2	Group 3		
Micro nucleated cells	0.4667	3.1000	6.9333	<0.001*	Chromosomal breakage
Binucleated cells	6.70	6.9333	7.50	<0.05	Cytokinesis defect
Nuclear bud	0.2667	1.8333	3.1000	<0.001*	Gene amplification
Pyknotic cells	0.4667	5.6667	6.9000	<0.001*	Apoptosis
Karyorrhectic cells	7.5000	60.0667	83.2333	<0.001*	Apoptosis
Condensed chromatin	11.7667	73.5333	80.3667	<0.001*	Apoptosis
Karyolytic cells	6.7000	60.2667	79.4000	<0.001*	Apoptosis

**P*<0.001 significance

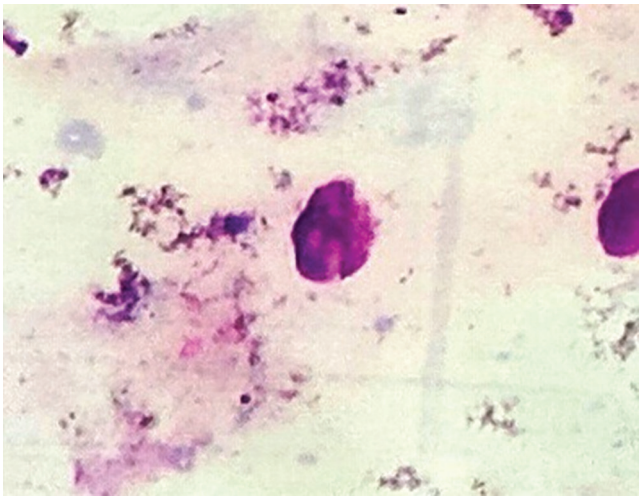


Figure 6: Chromatin condensation

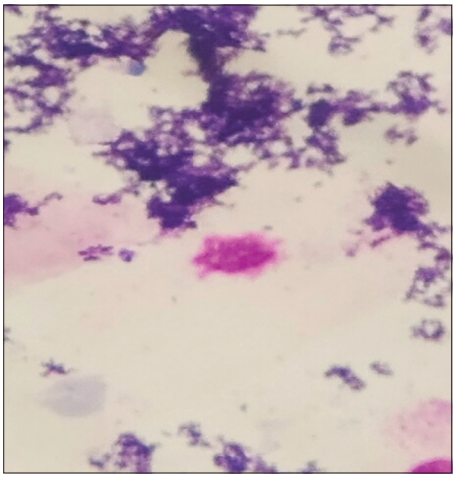
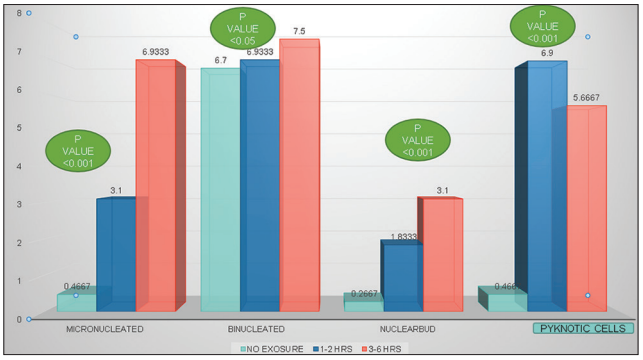


Figure 7: Karyorrhectic nuclei

Buccal cell type	Morphological features
Basal	Large nucleus: cytoplasm ratio relative to differentiated cell Smaller and more oval than differentiated cells Uniformly stained nucleus Darker green cytoplasm relative to differentiated cell when viewed under transmitted light
Differentiated	Smaller nuclear: cytoplasmic ratio More angular and flatter than basal cells Uniformly stained round nucleus
Micronucleated	Contains both main nucleus and micronucleus Micronuclei are round or oval with similar stain intensity as main nucleus Micronuclei usually have 1/3–1/16 diameter of main nucleus Micronuclei must be located in cellular cytoplasm Scored in basal and differentiated cells only
Nuclear bud	Main nucleus has a sharp constriction forming a bud Bud is attached to main nucleus Bud has similar staining intensity as main nucleus Bud diameter can be quarter to half nuclear diameter
Binucleated	Cells contain two main nuclei Nuclei are of similar size and staining intensity
Condensed chromatin	Nucleus shows areas of aggregated chromatin Distinct areas of nucleus are more intensely stained Nucleus exhibits striated pattern
Karyorrhectic	Nucleus has extensive aggregated chromatin Nuclear fragmentation may be evident
Pyknotic	Cell has small shrunken nucleus Nucleus is uniformly and intensely stained Nucleus diameter is 1/3–2/3 diameter of normal nucleus
Karyolytic	Nucleus is depleted of DNA Nucleus is not stained by Feulgen

Figure 8: Criteria for classification of cell types based on morphological features of cells[11]



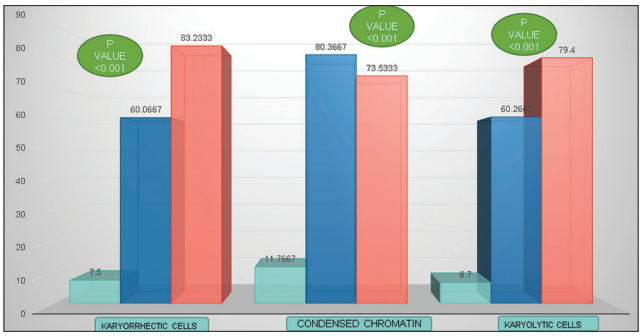
Graph 1: Mean frequencies of micro nucleated, binucleated cells, nuclear budding and pyknotic cells

DNA breakage in human fibroblasts and rat granulosa cells due to radiation from a mobile phone was also reported.[7]

Studies regarding the effects of cell phone radiation on Buccal cells have shown significant results with various parameters such as micronuclei;[10,24] BN, MN, KR, and KL.[25] A systematic review regarding the effect of cell phone radiation on buccal mucosa cells stated that mobile phone radiation has a detrimental effect on buccal mucosa with the potential to cause buccal cell anomalies.[26]

In the present study, all types of cytologic variations of the buccal mucosa were reported for the first time in children. This is a direct *in vivo* study on the effect of cell phone radiations on buccal mucosa cells.

While the observations in our study concurred with Yadav and Sharma, (2008) another study done by



Graph 2: Mean frequencies of karyorrhectic cells, condensed chromatin and karyolytic cells

Hintzsche and Stopper (2010)[10] did not find significant results in their study of MN frequency in buccal mucosa cells of mobile phone users.

The reason for the formation of the BN is unknown, but they probably indicate failed cytokinesis following the nuclear division in the basal cell layer.[11] The NB (NBUD) is suggested to be a biomarker of genotoxic events and chromosomal instability.[27] The cells with a small shrunken nucleus and a high density of nuclear material with intense uniform stain were identified as PC.[28] KR was identified with an appearance of nuclear chromatin aggregation (compared to CC). Cells with condensed chromatin, karyorrhectic, pyknotic, and KL represent degenerating cells (Apoptotic).[16]

Microscopically, in our observations, since the NBUD, PC, condensed cells, and KR were observed significantly more in the highly exposed samples, it can be concluded that these cells were degenerating and were at early or late stages of apoptosis due to the RF-EMW effects. The cells devoid of DNA and appear to have no nuclei were identified as KL. This feature probably indicates a late stage of cell death. In our study, KL was found with higher frequency in exposed individuals. The association between the above-mentioned biomarkers with many health hazards has been proved to be successful means to analyze cytotoxicity and genetic defects.[16]

Buccal cell MN has been identified as a useful biomarker that correlates with oral cancer.[29] Hence, the frequency of MN in Buccal mucosa cells can be used as a biomarker for genotoxic and carcinogenic agents, and the highly significant MN cells in our study can have profound implications.

Some studies have shown that even at low levels, RF-EMW can cause damage to cell tissue and DNA. It has been linked to brain tumors,[30] cancer, disturbed immune function, chronic allergic response, inflammatory responses,[22] headache, anxiety, stress, chronic fatigue syndrome, and depression.[31]

Similarly, Daroit *et al*. also concluded that, despite a significant rise in cell anomalies, the electromagnetic radiation emitted by cell phones among frequent users is within acceptable physiological limits.[12] However, they also suggested further studies investigating the harmful effects of cell phone radiation to draw a firm conclusion and there is increasing public concern regarding its health risks.[29]

Such an increase can have long-term effects, including risk for the development of oral carcinoma in the cell phone users after prolonged exposure.[12] since the usage of cell phones has increased in the past few years in children, any long-term effects are still unknown and a quality area for research in a longitudinal sense.

Even though extensive studies have been done to understand the effects of cell phone radiation on the oral cavity, the sample population was primarily adults. Literature is very scarce on the impact of emitted radiations on the tissues of oral cavities in children. The present study is unique in that it concentrated on the actual cytological changes which might occur on the young tissues which are sensitive to electromagnetic radiation due to prolonged usage.

Conclusion

The results of our study showed a highly significant increase in buccal cell anomalies with increased exposure to cell phone radiations.

The abnormal cells observed in the buccal mucosa are used as an endpoint to detect cytotoxic damage in exposed individuals. In addition, this information can be helpful as an early warning of the potential risk of genetic damage.

The pandemic has transformed the way our children perceive education. Newer tools for passing on information have become additive to the existing physical classroom didactic methods. In the last two decades, mobile phone usage has increased manifold. What is alarming is that it has become vital in our child's day-to-day activities. The use seems to be on an average of more than a quarter a day. The problem needs to be answered in a swift mode. Counseling and awareness of cell phone usage by children becomes necessary to protect them against the damaging effects of RF-EMW radiation.

Further studies on this subject should provide an evidence-based insight even into Geno cytotoxic changes associated with radiation emitted by smartphones.

Acknowledgement

Dr. B. Venu Naidu, Department of Oral and Maxillofacial Pathology, Anil Neerukonda Institute of dental Sciences – for histopathological interpretation of the sample.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

References

1. Daniel Dudley. The Evolution of Mobile Phones 1973 – 2019. Available from: https://Flauntdigital.com. [Last accessed on 2022 Feb 19].
2. Baan R, Grosse Y, Lauby-Secretan B, El Ghissassi F, Bouvard V, Benbrahim-Tallaa L, *et al*. Carcinogenicity of radiofrequency electromagnetic fields. Lancet Oncol 2011;12:624-6.
3. Hintzsche H, Stopper H. Micronucleus frequency in buccal mucosa cells of mobile phone users. Toxicol Lett 2010;193:124-30.
4. Hamada AL, Agarwal A, Singh A. Cell phones and their impact on male fertility: Fact or fiction. TORSJ 2011;5:125-37.
5. van Deventer E, van Rongen E, Saunders R. WHO research agenda for radiofrequency fields. Bioelectromagnetics. 2011;32:417-21.
6. Koyama S, Nakahara T, Wake K, Taki M, Isozumi Y, Miyakoshi J. Effects of high frequency electromagnetic fields on micronucleus formation in CHO-K1 cells. Mutat Res 2003;541:81-9.
7. Garaj-Vrhovac V, Horvat D, Koren Z. The relationship between colony-forming ability, chromosome aberrations and incidence of micronuclei in V79 Chinese hamster cells exposed to microwave radiation. Mutat Res 1991;263:143-9.
8. Diem E, Schwarz C, Adlkofer F, Jahn O, Rüdiger H. Non-thermal DNA breakage by mobile-phone radiation (1800 MHz) in human fibroblasts and in transformed GFSH-R17 rat granulosa cells ***in vitro***. Mutat Res 2005;583:178-83.
9. Fenech M, Holland N, Chang WP, Zeiger E, Bonassi S. The HUman MicroNucleus Project – An international collaborative study on the use of the micronucleus technique for measuring DNA damage in humans. Mutat Res 1999;428:271-83.
10. Desai NR, Kesari KK, Agarwal A. Pathophysiology of cell phone radiation: Oxidative stress and carcinogenesis with focus on male reproductive system. Reprod Biol Endocrinol 2009;7:114.
11. Thomas P, Holland N, Bolognesi C, Kirsch-Volders M, Bonassi S, Zeiger E, *et al*. Buccal micronucleus cytome assay. Nat Protoc 2009;4:825-37.
12. Daroit NB, Visioli F, Magnusson AS, Vieira GR, Rados PV. Cell phone radiation effects on cytogenetic abnormalities of oral mucosal cells. Braz Oral Res 2015;29:1-8.
13. Lee AK, Hong SE, Taki M, Wake K, Do Choi H. Comparison of Different SAR Limits in SAM Phantom for Mobile Phone Exposure. In2018 Asia-Pacific Microwave Conference (APMC) 2018 :687-9.
14. Bonassi S, Coskun E, Ceppi M, Lando C, Bolognesi C, Burgaz S, *et al*. The HUman MicroNucleus project on eXfoLiated buccal cells (HUMN (XL)): The role of life-style, host factors, occupational exposures, health status, and assay protocol. Mutat Res 2011;728:88-97.
15. Squier CA, Kremer MJ. Biology of oral mucosa and esophagus. J Natl Cancer Inst Monogr 2001;29:7-15.
16. Holland N, Bolognesi C, Kirsch-Volders M, Bonassi S, Zeiger E, Knasmueller S, *et al*. The micronucleus assay in human buccal cells as a tool for biomonitoring DNA damage: The HUMN project perspective on current status and knowledge gaps. Mutat Res 2008;659:93-108.
17. Shi Q, King RW. Chromosome nondisjunction yields tetraploid rather than aneuploid cells in human cell lines. Nature 2005;437:1038-42.
18. Frankfurt OS, Krishan A. Identification of apoptotic cells by formamide-induced dna denaturation in condensed chromatin. J Histochem Cytochem 2001;49:369-78.
19. Wyllie AH. Cell Death: A New Classification Separating Apoptosis from Necrosis. London: Chapman and Hall Ltd; 1981. p. 9-34.
20. Tolbert PE, Shy CM, Allen JW. Micronuclei and other nuclear anomalies in buccal smears: A field test in snuff users. Am J Epidemiol 1991;134:840-50.
21. Bisht KS, Pickard WF, Meltz ML, Roti Roti JL, Moros EG. Chromosome damage and micronucleus formation in human blood lymphocytes exposed *in vitro* to radiofrequency radiation at a cellular telephone frequency (847.74 MHz, CDMA). Radiation research. 2001;156:430-2.
22. Jelodar G, Nziff S, Nuhravesh M. Effect of electromagnetic field generated by BTS on hematological parameters and cellular composition of bone marrow in rat. Comp Clin Pathol 2011;20:551-5.
23. Agarwal A, Desai NR, Makker K, Varghese A, Mouradi R, Sabanegh E, *et al*. Effects of radiofrequency electromagnetic waves (RF-EMW) from cellular phones on human ejaculated semen: An *in vitro* pilot study. Fertil Steril 2009;92:1318-25.
24. Yadav AS, Sharma MK. Increased frequency of micronucleated exfoliated cells among humans exposed *in vivo* to mobile telephone radiations. Mutat Res 2008;650:175-80.
25. Rajkokila K. Buccal cytome assay – A non-invasive screening method for evaluation of radiation exposure in computer and cell phone users. IJCR 2011;33:039-46.
26. Revanth MP, Aparna S, Madankumar PD. Effects of mobile phone radiation on buccal mucosal cells: A systematic review. Electromagn Biol Med 2020;39:273-81.
27. Fenech M, Kirsch-Volders M, Natarajan AT, Surralles J, Crott JW, Parry J, *et al*. Molecular mechanisms of micronucleus, nucleoplasmic bridge and nuclear bud formation in mammalian and human cells. Mutagenesis 2011;26:125-32.
28. Tolbert PE, Shy CM, Allen JW. Micronuclei and other nuclear anomalies in buccal smears: Methods development. Mutat Res 1992;271:69-77.
29. Prihoda TJ. Genetic damage in human cells exposed to non-ionizing radiofrequency fields: a meta-analysis of the data from 88 publications (1990–2011). Mutation Research/Genetic Toxicology and Environmental Mutagenesis. 2012;749:1-6.
30. Hardell L, Carlberg M, Söderqvist F, Mild KH, Morgan LL. Long-term use of cellular phones and brain tumours: Increased risk associated with use for>or=10 years. Occup Environ Med 2007;64:626-32.
31. Johansson O. Disturbance of the immune system by electromagnetic fields – A potentially underlying cause for cellular damage and tissue repair reduction which could lead to disease and impairment. Pathophysiology 2009;16:157-77.