Is radio-frequency radiation emitted by mobile phones, a cause for concern? A dentist’s review

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Abstract

This review summarizes and interprets the biological effects of radio-frequency radiations emitted by mobile phones on the oral cavity and its constituents namely, buccal mucosal cells, saliva - its constituents and flow rate and salivary (parotid) glands. The emphasis of this review is on the changes - degenerative, cancerous or otherwise brought about in the individuals using mobile phones regularly. Most of the studies done to establish a definitive causal relationship between radio-frequency (RF) radiation and changes in oral tissues and saliva rely on the information given by the subjects which may not be accurate. Tissues closest to phone antenna are the sites of maximum exposure to RF energy, making oral cavity a target site. Thus, it is recommended to explore various changes taking place in the oral tissues with mobile phone use. Most of these effects may take years or decades before expressing themselves. Current studies lack both long-term users as well as outcomes. At present, overall the use of mobile phones has not shown any significant health hazard and the associations found in terms of changes taking place in cells and salivary constituents need to be substantiated by further strong evidence-based long-term studies.

Effects of RF Radiations on the Biological Systems

In contrast to X-ray energy, RF energy is non-ionizing because the energy of the quanta is insufficient to knock electrons from atoms. Therefore, the dominant mechanism by which RF energy affects biological systems is by heating, although a variety of
non-thermal mechanisms of interaction have been demonstrated as well, some of which include electrically induced forces on cells and electropropotion, but these mechanisms invariably require high exposure levels to produce observable effects.\(^5\)

Radio-frequency waves carry energy, and it is natural that they will cause some effect in the tissues they pass through. To measure this value of energy exchange in biological tissues a value named specific absorption rate (SAR) is calculated, which is the amount of energy absorbed per unit time per unit mass of tissue, and is expressed in W/kg. The SAR limit set by the International Commission on Non-Ionizing Radiation Protection is 2.0 W/kg. The value being averaged over 10 g of body tissue.\(^6\) SAR is measured by holding the phone in the position it is held in while making calls. The SAR value is determined in the region having the highest absorption rate in the entire head, often taken as closest to phone’s antenna.\(^6\)

Various countries have set maximum SAR levels for RF energy given out by cell phones. In the United States phones in market have SAR levels at or below 1.6 W/kg measured over the volume containing a mass of 1 gram of tissue that is absorbing the most signal, according to the Federal Communications Commission requirement. Whereas, in the European Union the European Committee for Electrotechnical Standardization specify SAR limits within the European Union, following International Electrotechnical Commission standards. The SAR limit is 2 W/kg averaged over 10 g of tissue absorbing the most signal. India switched to the US limits for mobile handsets in 2012. Unlike in the US, India will carry out random compliance tests, run by a government based Telecommunication Engineering Center SAR Laboratory, on handsets and 10% of towers. It is made compulsory for all handsets to have hands free mode.\(^6\)

The electromagnetic fields produced by mobile phones fall under the category of possibly carcinogenic to humans (Group 2B) as classified by the International Agency for Research on Cancer. This is employed when a causal association is considered credible, but when chance, bias or confounding cannot be ruled out with reasonable confidence.\(^7\) RF radiation caused effects on human health can be broadly classified into short-term and long-term effects. The principal interaction between RF energy and the human body is heating effect on body tissues, which constitutes short-term effects. Most of this energy is absorbed by the superficial tissues mainly skin, thus the brain and other organs of the body are minimally affected. Long-term effects include changes in genetic material which have led to concerns regarding increased rates of cancer in mobile phone users. The international pooled analysis of data gathered from 13 participating countries found no increased risk of glioma or meningioma with mobile phone use of more than 10 years.\(^5\) Similarly, there is no increased risk in rates of malignant or benign parotid gland tumors due to exposure to RF electromagnetic fields from mobile phones.\(^6\)

Effects induced may be thermal and non-thermal. Thermal effects inflict damage in tissues where the body is unable to dissipate the excessive heat, for example, eyes and the testes, mainly due to the relative lack of blood flow.\(^5\) The non-thermal effects are manifested due to passage of electrically shaking eddy currents formed from absorption of electromagnetic waves (EMW), which cause disruption of cell membrane integrity leading to endothelial dysfunction and alterations in the blood-brain barrier, cellular signal transduction effects, immune system effects and nervous system excitability defects.\(^10\) Fluctuations in electroencephalograph pattern, sleep pattern, and neuroendocrine functions have been observed with increased cell phone handling, along with decreased cognitive function and melatonin secretion. Cell phone exposure has also been shown to increase resting blood pressure and elevate heart rate. EMW radiation may alter Leydig and Sertoli cell function, leading to decreased testosterone secretion which may lead to altered cell proliferation. Frequent cell phone users also describe a difficulty concentrating, increased fatigue, and frequent headaches, coupled with a burning sensation near the ear and tingling or numbness of exposed tissue.\(^15\)

Head and neck region is in the closest proximity to the cell phone while in conversation. So the organs and tissues lying in this area are naturally at the greatest risk to any damage the RF waves may incur. Therefore, studies relating to oral tissues and associated structures are reviewed in this article, with the purpose of identifying any serious complications or adverse health effects that may be caused by the usage of mobile phones.

**Oral mucosa and mobile phone**

Oral mucosa is an ideal tissue to study genetic damage caused by mobile phones due to a number of reasons. First of all the close proximity of this tissue to the positioning of the gadget during telephonic conversations increases chances of its exposure more than that of any other tissue. Then, the wide known fact that 90% of human cancers are carcinomas indicates that epithelial tissue is most susceptible to genetic changes. Such changes may be either due to high proliferation rate of epithelial cells or simply due to the fact that these cells are exposed the most to all kinds of chemical, physical and radiation insults. Last but not the least, oral mucosal cells especially those belonging to the buccal mucosa are easy to harvest without any invasive procedures. The collection of buccal cells is arguably the least invasive method available for measuring DNA damage in humans, especially in comparison to obtaining blood samples for lymphocyte and erythrocyte assays or tissue biopsies.\(^16\)

The fundamental reason of developmental and degenerative diseases can be attributed to genomic damage. Diseases caused by or associated with genetics can be diagnosed, monitored and/or treated if there are reliable biomarkers. Such tools should be relevant and minimally invasive.\(^18\)

Yadav and Sharma in 2008, designed a study which investigated if mobile phone radiations lead to any in vivo effects on the micronucleus frequency in exfoliated cells, in the people exposed to them. They found a slight increase in mean frequency of karyorrhexis, broken egg and binucleated cells in the exposed subjects, but the difference was not found statistically significant. The duration of exposure and MN and total micronuclei
frequency showed a positive correlation in initial years of exposure. But slight decrease in the frequency of micronucleated cells and total micronuclei was observed for subjects exposed to more than 4 years.\(^{[17]}\)

Contradictory results were obtained by Hintzsche and Stopper in a similar study in 2010, which was designed to investigate the effect of mobile phone use on genomic instability of the human oral cavity’s mucosa cells. This study did not show any statistically significant changes in micronucleus frequency depending on age, gender, body-mass index and smoking status. Micronucleus frequency was not changed between headset users and non-users. There was no difference between people who used the phone for less than five, five–nine, or ten and more years.\(^{[18]}\)

Similar results were obtained by Ros-Llor et al. in 2012, who evaluated cytokinetic and genetic defects, proliferative potential, and cell death parameters occurring due to RF waves emitted by mobile phones in asymptomatic young population. They recorded no statistically significant changes with respect to age, gender, body mass index, or smoking status. The side of face on which cell phone was placed most of the times and the other side which served as control, were compared, along with the duration of exposure in years to mobile phone radiation, both yielded no significant differences. Thus, in relation to any of the study parameters no significant genotoxic effects due to exposure to RF could be observed.\(^{[2]}\)

### Saliva and mobile phone

Human saliva plays an important role in preserving oral homeostasis as the first defensive line against microbial invasion which protects oral mucosa mechanically and immunologically.\(^{[19,20]}\) The largest of salivary glands is the parotid gland which is located behind the ramus of the mandible and in front of the ear, close to skin surface and secretes a mainly serous saliva. They are in close proximity to the mobile phones during the phone usage. Human saliva may also serve as a biomarker for oxidative stress, which has been implicated as a mechanism of potential health effects that may result from exposure to radiofrequency electromagnetic radiation.\(^{[21]}\)

In 2010, Goldwein and Aframian, conducted an innovative study which evaluated physiologic changes in the parotid glands on mobile phone usage. The heavy user group demonstrated a significant high salivary flow rate, blood flow rate and increased volume of the parotid glands on the dominant side.\(^{[22]}\) A similar study in 2012, by Bhargava et al. focused on functional and volume related changes occurring in the parotid glands on mobile phone usage. The heavy user group demonstrated a significant high salivary flow rate, blood flow rate and increased volume of the parotid glands on the dominant side.\(^{[23]}\)

A study conducted in 2013, by Hamzany et al., focused on various salivary components and oxidative stress indices, between users of mobile phones and nonusers. They obtained significant, profound increase in salivary malondialdehyde (MDA) and carbonyl levels as well as a significant increase of the salivary flow rate in mobile-phone users as opposed to those who do not use mobile phones. Even though, the study had several limitations and confounding factors, in conclusion, mobile phone users suffered from considerable oxidative stress on proximal tissues, as was seen in parotid saliva. This oxidative stress might increase the risk of an individual in developing cancer.\(^{[24]}\)

In contrast, a study published in 2014 by Khadra et al., and Khalid et al. investigated whether or not low-intensity radio frequency electromagnetic field exposure associated with cell phone use can influence the antioxidant capacity and the oxidative stress as well as protein concentration in saliva. Saliva was tested for 8-oxo-7,8-dihydro-2’-deoxyguanosine (8-oxoG) and MDA, which are commonly used oxidative stress biomarkers. To analyze antioxidant capacity of the saliva, oxygen radical absorption capacity (ORAC) and the hydroxyl radical averting capacity assays were carried out. There was no significant effect of number of hours of cell phone use on the levels of 8-OxodG and MDA or on the oxygen and hydroxyl radicals averting capacities. This indicates that there is no relationship between exposure to RF radiation and changes in the salivary oxidant/antioxidant profile.\(^{[25]}\)

Contradictory results were observed by Arbabi-Kalati et al. in 2014, who measured the total antioxidant capacity of saliva by ferric reducing ability of plasma method and found that speaking on the mobile phone for over an hour will decrease total antioxidant capacity of saliva and salivary IgA levels more than for those speaking <20 min.\(^{[26]}\)

Khadra et al., in 2014, studied biochemical markers like superoxide dismutase (SOD), albumin, amylase, uric acid and cytochrome C in the saliva of young men. They found a significant increase in the activity of SOD but a significant decrease in that of amylase in the saliva after using mobile phones. The increases in the activity of cytochrome C and the concentrations of albumin and uric acid were not significant. A true correlation was observed between the salivary antioxidant biomarkers and the number of calling minutes, rather than the number of calls.\(^{[27]}\) Contradictory results were obtained by de Souza et al., in 2015, who compared total protein concentration, pS3, p21, reactive oxygen species, glutathione, heat shock proteins, IgA and salivary flow rate of either side parotid. They found no significant alterations in any of the parameters.\(^{[28]}\)

These findings lead to the conclusion that mobile phone usage may lead to increased oxidative stress which in turn may lead to oncogenesis, especially in younger generation.\(^{[29]}\) Hence, excessive and unchecked use of these gadgets should be controlled.

### Salivary glands and mobile phone

The majority of salivary gland tumors (about 80%) arise in the parotid glands. The submandibular glands account for 10-15%
of tumors, and the remaining tumors develop in the sublingual or minor salivary glands. Approximately, 80% of parotid gland tumors and approximately half of the submandibular gland and minor salivary gland tumors are benign.[28]

A case-control study by Auvinen et al. on cellular phone use and cancer was published in 2002, conducted on subjects who were diagnosed cases of brain tumor and salivary gland cancer. This study reported a weak association between gliomas and analog cellular phones although overall their use was not associated with brain tumors or salivary gland cancers.[29] Similar results were found in Sweden by Hardell et al., in 2004, on assessing cases from six regional cancer registries for association between the risk for salivary gland tumors development and use of cellular or cordless telephones. Overall no significantly increased risk was found. Similar results were found for different salivary glands localizations. As only few subjects reported a long-term usage of more than 10 years, so this study did not make conclusions for long-term heavy use.[30]

A Nationwide Cohort study in Danish population, published in 2006, investigated cancer risk among Danish cellular telephone users with a follow-up period of up to 21 years. No associated increased risk for brain tumors, acoustic neuromas, salivary gland tumors, eye tumors, or leukemias was detected.[31]

Lönn et al. conducted two population-based case-control studies, one in Denmark, and one in Sweden, to test the hypothesis that there is an increased risk of parotid gland tumors with long-term mobile phone use. Risk estimate for both benign and malignant tumors did not increase, irrespective of the type of handset and degree of use. Authors concluded that the data do not support the hypothesis.[32] This study is part of the Interphone Study which is a collaborative study conducted in 13 countries and includes intracranial tumors and for some countries parotid gland tumors and controls, and is collaborated by the International Agency for Research on Cancer.[8]

Sadetzki et al. in 2007 published another nationwide case-control study which assessed the association between mobile phones and parotid gland tumors. Results suggest a relation between long-term and heavy cellular phone use and parotid gland tumors. This association was seen in analyses restricted to regular users, analyses of laterality of phone use, and analyses of area of the main use.[33]

Duan et al. conducted a similar study as a hospital-based case-control study. No significant association was found between the frequency of cell phone use and epithelial parotid gland malignancy, but the results did suggest a possible dose–response relationship.[34] To evaluate the increased risk of parotid tumors Söderqvist et al. in 2012, conducted a case–control study, assessing 69 patients with salivary gland tumors and 262 randomly recruited controls. Results were found to be against there being an increased risk for parotid gland tumors as far as less usage hours and short-term use of mobile phones were concerned.[35]

A different kind of study performed by Acar et al., in 2009, investigated the possible thermal effects of microwaves from mobile phones on the facial nerve (FN) and surrounding soft tissue. They concluded radio-frequency radiations emitted from a mobile phone can cause temporary FN dysfunction that can be due to temporary temperature increase in the soft tissue around the FN.[36]

The above-mentioned studies cover the effects of radio-frequency radiation on various tissues and components in and around the oral cavity. A summary of these is given in Table 1.[2,8,17,18,21-27,29-34]

### Conclusion

While the existing evidence provides little or no indication that mobile phone handsets and base stations have carcinogenic potential, this evidence is not sufficient to rule out the possibility of any connection.[3] This evidence is not conclusive given the relatively short follow-up time of the studies, which is insufficient to cover the slow and chronic tissue changes and gene alterations. This review clearly shows that there are a number of tissues and tissue parameters that can be affected by radio-frequency radiations from mobile devices and hence can be studied. Further, we also conclude

| Table 1: Summary of studies on ill-effects of RF radiation on oral tissues and paraoral structures |
|---------------------------------|----------------------------------|----------------------------------|----------------------------------|
| Tissues/components under study  | Exfoliated oral mucosal (buccal) cells | Salivary gland tumors | Salivary oxidative stress markers, protein content, flow rate, and salivary gland volume |
| Factors determined              | Micronucleus frequency | Risk estimates for benign and/or malignant tumors | 8-Oxod G |
|                                 | Binucleated cells          |                                   | MDA   |
|                                 | Proliferative potential of basal cells |                                   | ORAC  |
|                                 | Cell death parameters      |                                   | HORAC |
|                                 |                                 |                                   | Salivary calcium, phosphate, magnesium, albumin, amylase and total protein |
|                                 |                                 |                                   | Salivary Ig A |
|                                 |                                 |                                   | Unstimulated parotid saliva |
|                                 |                                 |                                   | Stimulated parotid saliva |
|                                 |                                 |                                   | Parotid gland volume |
| Conclusions                     | According to most studies, no statistically significant changes were recorded in oral mucosal cells | Short-term usage could not be associated with an increased risk of developing salivary gland tumors | Most studies demonstrated a significant increase in salivary flow rate and volume of salivary glands as well as an increase in oxidative stress |

that there are not enough studies in this field especially those concerning the oral cavity and related structures, even though, these are the closest and most susceptible to any such effects, if they occur. The results from the studies so far are highly contradictory, and no author has come to a definitive conclusion. Thus, further large-scale and long-term follow-up studies are required to validate the findings till date and to lift the shadow of the doubt that still lingers with the use of hand-held mobile phones.

References

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