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REVIEW ARTICLE



## Effects of mobile phone radiation on buccal mucosal cells: A systematic review

M. P. Revanth , S. Aparna , and Parangimalai Diwakar Madankumar 

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### ABSTRACT

The worldwide increased use of mobile phone in recent years has raised many questions on whether their use is safe to user who is exposed to electromagnetic radiation. The aim of the review is to find out the effect of mobile phone emitted radiations on buccal mucosal cells. To identify suitable literature, an electronic search was performed using PubMed, Trip database, Cochrane, Google Scholar and EBSCO host database. The search was focused on the effect of mobile phone radiation on buccal cells. Among the literature available in English, the screening of the related titles and abstracts was done, and only those articles were selected for full-text reading that fulfilled the inclusion and exclusion criteria. The initial literature search resulted in 23 articles out of which only 7 articles fulfilled the criteria were included in this systematic review. The Studies showed that mobile phone-emitted radiations have adverse effects on buccal mucosal cells such as the formation of micronuclei and broken egg which was considered as bio-markers of genotoxicity.

### ARTICLE HISTORY

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### KEYWORDS

Mobile phone;  
electromagnetic radiation;  
buccal mucosa

### Introduction

In this emerging era of the modern world, the use of mobile phones has enormously increased in the recent years. By the end of 2018, around 5.1 billion people in the world subscribed to mobile services, accounting for 67% of the global population. A total of 1 billion new subscribers have been added in the four years since 2013 which represents an average annual growth rate of 5%. An average annual growth rate of 1.9% has been predicted between 2018 and 2025 which will bring the total number of mobile subscribers to 5.8 billion (71% of the worldwide population) (Banerjee et al. 2016).

As of today's scenario, mobile phones are used at an enormous number by all the age groups. Particularly, the age group of 25–34 is found to have the highest mobile phone usage rate of 62% (Davey and Davey 2014). According to Dagli et al. (2015), it has been noted that an average person spends 90 min a day on their phone which is used not only for having conversations but also for accessing internet, pictures and videos (Dagli et al. 2015).

The rapid worldwide increase in cell phone users has raised health concerns about potential risks associated with exposure to electromagnetic radiation (EMR) produced by this technology (Daroit et al. 2015). Mobile phones emit EMR in the microwave range 300 MHz and 300 GHz (Dagli et al. 2015).

The rate at which the EMR is absorbed by human bodies is called as specific absorption rate (SAR). It is a standardized unit that measures the impact of radio-frequency electromagnetic waves on the human body and it is expressed as Watt/Kg. The FCC (Federal Communication Commission) has limited the maximum legal SAR of any handheld cell device to 1.6 Watt/kg (Shaikh et al. 2016).

According to the International Agency for Research on Cancer, the mobile radiations are classified as Group-2B – possibly carcinogenic radiations, i.e. there “could be some risk” of carcinogenicity (IARC, 2011). This leads to the concern of possible adverse health effects on mobile phone users from exposure to EMR.

Studies done in 2010 by interphone study group have reported causal relationships between exposure to EMR and increased risk of acoustic neuroma, glioma, meningioma, infertility, deafness, and metabolic changes in brain tissue (de Oliveira et al. 2017).

In a study conducted by Zaghloul and Banna (2019), to assess the potential health hazards of whole-body exposures to smartphones among 770 Egyptians, 51.9% of them suffered from a headache, 57.5% of volunteers encountered with eye fatigue or strain, followed by ear pain of 19.9%. Body weight changes occurred in 44.3% of participants and depression in 45.3% of participants, sleep

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disturbance, social problems, and musculoskeletal disorders also were reported (Zaghloul and Banna 2019).

The possible oral cell changes like DNA damage (micronuclei (MN) and/or nuclear buds), cytokinetic defects (binucleated cells), proliferative potential (frequency of basal cells), and/or cell death (condensed chromatin, karyorrhexis, pyknotic and karyolytic cells) have been related to a high risk of cancer, aging and to the carcinogenic process, with increased genetic instability. These biomarkers can be tested in exfoliated cells, especially in oral mucosal cells (Ros-Llor et al. 2012).

Since oral mucosa is the tissue that is present in the closest vicinity of the area of a mobile phone while in use, it has chances to show possible genotoxic changes by the mobile phone radiation. Some authors like Daroit et al. (2015), Banerjee et al. (2016) have confirmed the genotoxicity of mobile radiation on oral mucosa, but authors like Ros-Llor et al. (2012), Hintzsche H and Stopper H et al. (2010) have apparently denied the genotoxic effect. Effects of EMR on biological systems remain controversial and have been subject of debate for a long time not only within the scientific community but also within the general public (Hintzsche and Stopper et al. 2009). Decades of research have also yielded contradictory results.

Hence, this systematic review was done to find out the effect of EMR emitted by mobile phone on the buccal mucosal region, as this region is close to mobile phone when in use.

## Materials and methods

Systematic review was undertaken using objectives and transparent methods as per the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) Guidelines, to identify, evaluate and summarize all relevant research findings. The protocol for systematic Review was registered first with PROSPERO (International prospective register of Systematic review). Acknowledgement ID: 151877

### Eligibility criteria

The PECO analysis of the articles searched was set as shown below:

PECO analysis:

**Population:** High Talk-time Mobile phone Users

**Exposure:** Electromagnetic Radiation

**Comparison:** Low Talk-Time Mobile phone Users

**Outcome:** Buccal Mucosal Cell Changes (Histopathologically).

## Inclusion and exclusion criteria

### Inclusion criteria

- (1) Studies that had assessed the buccal mucosal cell changes histopathologically were included.
- (2) Studies that had a sample of the population with age group between 18 and 40 years.
- (3) Cross-sectional, cohort and comparative studies were only included.
- (4) Studies done in the past 10 years were included. Since the usage of mobile phone has been drastically increased in the last decade, the review was limited only to 10 years.
- (5) Studies that was written in English language were only included.

### Exclusion criteria

- (1) Studies that included other than buccal mucosal cell changes due to mobile radiation.
- (2) Qualitative studies, reviews, expert opinion, systematic reviews, meta-analysis and case studies/series.
- (3) Studies that required translation to English language.

### Search strategy

A broad search of the literature done in PubMed, Trip database, Cochrane, Google Scholar, EBSCO host database was performed from the year January 2009 to January 2019. The keywords searched were buccal mucosa, mobile phones, electromagnetic radiation. The search strategy included the combination of the following terms: mobile phone, electromagnetic radiation and buccal mucosa, mobile phone and buccal mucosa, electromagnetic radiation and buccal mucosa, mobile radiation and buccal mucosa. The MESH terms used in PubMed were cell phone, electromagnetic radiation and mouth mucosa. Hand searches of the articles were conducted to ensure additional relevant references but no relevant had been found. The references of all the full-text articles were searched to select the relevant articles. The search patterns of various databases are given in Table 1.

The remaining studies were sorted out on the basis of their title and abstract. Finally, those studies in which the abstract fulfilled all the inclusion criteria were selected for full-text reading. In those cases in which a study met the eligibility criteria, but the information in the abstract was insufficient, full texts of the articles were also obtained. Further literature search was performed based on the references of the selected articles.

**Table 1.** Search patterns of various databases.

| Database       | Search pattern                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| PUBMED         | ((“cell phone”[MeSH Terms] OR (“cell”[All Fields] AND “phone”[All Fields]) OR “cell phone”[All Fields] OR (“mobile”[All Fields] AND “phone”[All Fields]) OR “mobile phone”[All Fields]) AND (“electromagnetic radiation”[MeSH Terms] OR (“electromagnetic”[All Fields] AND “radiation”[All Fields]) OR “electromagnetic radiation”[All Fields]) AND (“mouth mucosa”[MeSH Terms] OR (“mouth”[All Fields] AND “mucosa”[All Fields]) OR “mouth mucosa”[All Fields] OR (“buccal”[All Fields] AND “mucosa”[All Fields]) OR “buccal mucosa”[All Fields])) |
| TRIPDATABASE   | Mobile phone, Mobile Radiation, Buccal mucosa                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| EBSCO          | Mobile Phone, Electromagnetic Radiation, Buccal Mucosa                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Google Scholar | Mobile Phone, Electromagnetic Radiation, Buccal Mucosa                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| COCHRANE       | Mobile Phone, Electromagnetic Radiation, Buccal Mucosa                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

### Data extraction

The data extraction from the final seven articles was done using a data extraction form. It includes the first author name, year of publication of the article, aim of the study, objectives of the study, study design, study summary, results and outcome (Table 2).

### Quality assessment of the included studies

The final analysis included six cross-sectional studies and one cohort study. The methodological quality of the selected articles was assessed using the modified Newcastle-Ottawa Scale for cross-sectional studies and Newcastle-Ottawa Scale for cohort studies (Table 3). For cross-sectional studies, the quality score was based on five items of the following categories: group selection, outcome and exposure. A study can be awarded a maximum of one star for each numbered item within the Selection and Exposure categories. A maximum of two stars can be given for Comparability. The higher the score, the better the quality of the study. The studies with points 9–7 are Good Studies, 5–6 points are Satisfactory Studies, and 0 to 4 are Unsatisfactory Studies. Further, these scores have been categorized into high, unclear and low risk of bias using Review Manager Software version 5.3. (Figure 1).

The results of the assessment are tabulated in Table 3 as shown.

## Results

### Search results

The search generated a total of 23 articles based on the title from five different electronic database: PUBMED, TRIPDATABASE, EBSCO, COCHRANE and GOOGLE SCHOLAR.

PUBMED produced 5 articles, TRIPDATABASE produced 1 article, EBSCO produced 5 articles, Google Scholar produced 12 articles and no articles were found in COCHRANE. The full texts of 23 articles were obtained for further review. Among the obtained articles

11 articles were eliminated due to duplication, 2 articles eliminated after abstract reading and 2 articles eliminated after full-text reading. Finally, on the basis of inclusion and exclusion criteria, seven articles were selected for the review using PRISMA flowchart (Figure 2).

The inter-examiner bias was eliminated. The first two authors analysed the studies. The discrepancies between the first two authors were resolved by the consensus from the third author. Good inter reliability (kappa value = 0.8) was obtained.

### Types of population

The study population consisted of both male and female mobile users of age group, ranging from 18 to 40 years.

### Outcome

The studies included in the review identified the biomarkers for DNA damage, cytokinetic defects, proliferative potential and cell death in the oral mucosal cells of the mobile phone users and compared the duration of exposure to mobile phone radiation in the exposed oral mucosa.

Studies done by Banerjee et al. (2016), Gandhi et al. (2015), Souza et al. (2014), and Vanishree et al. (2018) showed a highly significant increase in buccal cell anomalies including MN and broken egg cell after exposure to cell phone radiations.

However, studies by Hintzsche and Stopper (2010), Ros-Llor et al. (2012), and de Oliveira et al. (2017) showed no relationship between MN frequency and duration of mobile phone use.

Meta-analysis was performed, only 3 out of 7 studies were eligible for meta-analysis but found to have higher heterogeneity.

## Discussion

The rapid growth in the number of cell phone users has raised questions about possible biological effects of the

Table 2. Data extraction table.

| Sl. no | Author                              | Study design          | Aim of study                                                                                                                                       | Stain used                                                                                   | Study summary                                                                                                                                                                                                                                                                                                                        | Outcome & Result                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|--------|-------------------------------------|-----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1      | Hintzsche and Stopper et al. (2009) | cross-sectional study | Investigated the effect of mobile phone use on genomic instability of mucosal cells of the human's oral cavity                                     | Anti- $\alpha$ -tubulin-antibody solution and chromomycin A3 (DNA SPECIFIC)                  | The study subjects consist of 131 individuals. N = 13 Individuals who did not use mobile phones at all, N = 85 individual using the mobile phone for 3 hour/week N = 33 individuals using the mobile phone for more than 3 hour/week                                                                                                 | Frequencies of fragmented nuclei per 1000 cells depending on mobile phone use shows, where t is time, $t = 0$ (n = 13) $0.38 (\pm 0.19)$ $0 < t \leq 3$ (n = 85) $0.31 (\pm 0.07)$ $3 < t \leq 6$ (n = 18) $0.08 (\pm 0.06)$ $6 < t \leq 9$ (n = 12) $0.04 (\pm 0.04)$ $9 < t \leq 12$ (n = 2) $0.00 (\pm 0.00)$ $12 < t \leq 15$ (n = 1) $0.00$<br>The result obtained proved that there was no significant increase of micronuclei due to mobile phone use.<br>DNA damage(micronuclei) in Buccal mucosa exposed (n = 50) is = $1.38 \pm 1.38$ . and Buccal mucosa no exposed (n = 50) = $1.46 \pm 1.32$ . No significant changes were recorded in subjects in relation to their age, gender, body mass index, or smoking status. |
| 2      | Ros-Llor et al. (2012)              | Cohort                | Effect of mobile phones on micronucleus frequency in human exfoliated oral mucosal cells was studied.                                              | DAPI stain (DNA SPECIFIC STAIN)                                                              | Cell samples both from right and left cheek mucosa, from each subject were collected. Cells were screened for nuclear abnormalities, especially micronucleus.                                                                                                                                                                        | It was found that the number of broken egg (structures that may be associated with gene amplification) was significantly greater in the individuals in group I ( $p < .05$ ).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 3      | Souza et al. (2014)                 | Cross-sectional study | To evaluate the genotoxic and cytotoxic potential of the exposure, by means of the micronucleus test on exfoliated cells from the oral epithelium. | Periodic acid-Schiff reagent and counterstained with 1% fast green (NON- SPECIFIC DNA STAIN) | The sample of 45 individuals, distributed into 3 groups of 15 individuals according to the amount of time in hours per week (t) that they spent using mobile phones:<br>Group I: more than 5 h ( $t > 5$ h);<br>Group II: more than 1 h and up to and including 5 h ( $> 1\text{ h} \leq 5$ h); Group III: 1 h or less ( $t < 1$ h). | There was a significant increase in the mean micronuclei count in group II ( $1.52 \pm 1.176$ ) in comparison to the group I ( $0.77 \pm 0.815$ ). In group II, the micronuclei count in the side of mobile phone use was found to be significantly elevated ( $1.52 \pm 1.176$ ) in comparison to the opposite side ( $0.90 \pm 0.3992$ ).                                                                                                                                                                                                                                                                                                                                                                                        |
| 4      | Banerjee et al. (2016)              | Cross-sectional study | To explore the effects of mobile phone radiation on the MN frequency in oral mucosal cells                                                         | Acridine Orange staining solutions (DNA SPECIFIC STAIN)                                      | A total of 300 male of age group 20–30 (150 high mobile users and 150 low mobile users). The low mobile phone users (Group I), used mobile phone since less than five years and less than three hours a week. The high mobile phone users (Group II), used mobile since more than five years and more than 10 hours a week.          | Subjects were sub-divided into quartiles of exposure in min/day, with the following observations for MN frequency, from the first to the fourth quartile:<br>first (n = 22), $1.54 (\pm 1.30)$ ;<br>second (n = 21), $2.19 (\pm 1.78)$ ;<br>third (n = 21), $2.23 (\pm 1.83)$ ;<br>fourth (n = 22), $2.13 (\pm 1.67)$ .<br>This study concluded that RF-EMF at our observed exposure levels do not induce the formation of MN in exfoliated buccal cells.                                                                                                                                                                                                                                                                          |
| 5      | de Oliveira et al. (2017)           | Cross-sectional study | To test whether mobile phone-associated EMF exposure affects the MN frequency in exfoliated buccal cells                                           | Feulgen's reaction (DNA SPECIFIC STAIN)                                                      | Buccal cell smears from the left and right inner cheeks of healthy mobile phone users, aged 18–30 (n = 86) were collected. Mean history of mobile phone use in years was $11.4 (\pm 2.36)$ ; range 4–18, with a mean duration of daily calls in minutes of $21.8 (\pm 18.66)$ ; range 2–112.                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |

Table 2. (Continued).

| Sl. no | Author                  | Study design          | Aim of study                                                                                                                                                                                                  | Strain used                                            | Study summary                                                                                                                                                        | Outcome & Result                                                                                                                                                                                                                                                                        |
|--------|-------------------------|-----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 6      | Gandhi G et al. (2015)  | cross-sectional study | To assess DNA damage, cell-proliferation and cell-death in healthy mobile phone users using mobile phones for 3–5 y and the non-mobile phone users according to the buccal micronucleus cytome (BMCyt) assay. | (not mentioned)                                        | Healthy mobile phone users (n = 25) using mobile phones for 3–5 y and the non-mobile phone users (n = 25) according to the buccal micronucleus cytome (BMCyt) assay. | The results of the study reveal a highly significant ( $p = .000$ ) increase in chromosomal damage, as evidenced by the frequency of micronucleated cells and cells with nuclear buds in mobile phone users. For Mobile phone users (n = 25) Micronucleated cells = $0.820 \pm 0.940$ . |
| 7.     | Vanishree et al. (2018) | Cross-sectional study | To evaluate the frequency of micronuclei (MN) in the buccal exfoliated cells of mobile phone users and comparison of MN frequency between high and low mobile phone users.                                    | Papanicolaou nuclear staining (NON-SPECIFIC DNA STAIN) | Group A – Low mobile phone users, used since or <5 years and <4–5 h a week.<br>Group B – High mobile phone users, used more than 5 years and more than 10 h a week.  | Control group (n = 25) = $0.060 \pm 0.03$ .<br>There was a significant increase in the mean MN count in Group B ( $1.58 \pm 0.57$ ) in comparison to the Group A ( $1.26 \pm 0.28$ ).                                                                                                   |

radiation emitted and there has been growing concern about the possible adverse health effects due to exposure to radiofrequency radiations from the mobile phones (Daroit et al. 2015).

In spite of an extensive increase in mobile phones within last few years, very little is known about the effect of long-term exposure that is experienced by people using mobile phone or living near mobile phone base stations. In the past, several investigations have been conducted in order to evaluate the possible biological effects resulting from human exposure to mobile phone radiations (Yadav and Sharma 2008).

Earlier researchers believed that the electromagnetic field of low frequency could not cause alterations in human cells, based on the hypothesis that low electromagnetic field could not generate a sufficient amount of heat to increase the tissue temperature, not causing damage at the DNA level (Yadav and Sharma 2008). However, the most widely accepted mechanism of interaction between radiofrequency radiation and biological systems is based on tissue heating that occurs when tissue or total body temperature increases for more than 1°C overloading cell thermoregulatory capacity leading to increased reactive oxygen species (ROS) that play a role in the biological effects leading to DNA damage, so the increase in the count of the MN in an individual can also be related with the localized hyperthermia (Dasdag et al. 2017; Souza et al. 2014).

MN count in the exfoliated cells can be used as a marker for an abnormal cell cycle as results of aberrant mitosis when the whole chromosome or chromatid fragment fails to reach the spindle pole. It is one of the best indicators of mitotic interference and chromosomal mutations or breakage. The MN index is preferably used for mass screening as it is rapid, simple, sensitive and cost-effective (Tolbert et al. 1992).

Daroit NB et al. studied cytogenic abnormalities of oral mucosal cells due to exposure to cell phone-emitted EMR. They found that individuals using cell phone for more than 60 min/week for 8 years had increased nuclear abnormalities. The lower lip had a higher amount of binucleated cells and broken eggs (structures associated with gene amplification) (Daroit et al. 2015). The reason for this may be that these sites are near to the cell phone, a source of EMR and also exposed to solar radiations. Similar results were obtained by Souza L da C et al., in which the number of broken eggs (structures that may be associated with gene amplification) was significantly greater in the individuals with high mobile phone use for more than 5 h (Souza et al. 2014).

Another study conducted by Shaikh et al., in the year 2016, was done to evaluate the cytotoxicity in cell phone

**Table 3.** Quality assessment of cross-sectional studies included.

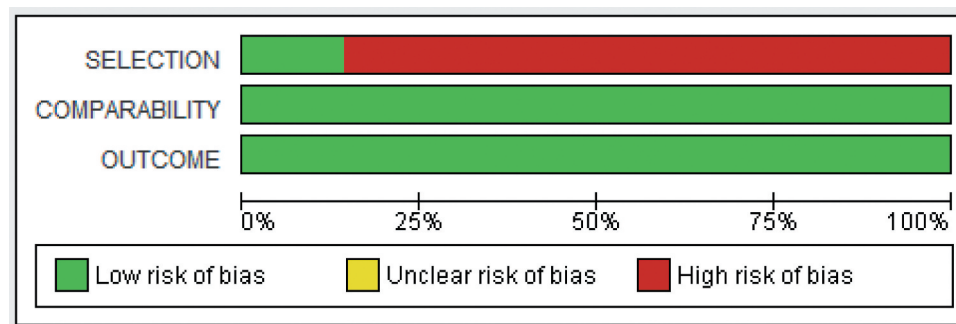
|                           | Selection 1)<br>a/b = 1<br>c/d = 0 | Selection 2)<br>a = 1<br>b = 0 | Selection 3)<br>a/b = 1<br>c = 0 | Selection 4)<br>a = 1<br>b/c = 0 | Comparability 1)<br>a = 1<br>b = 1 | Exposure 1)<br>a/b = 1<br>c/d = 0 | Exposure 2)<br>a = 1<br>b = 0 | Score |
|---------------------------|------------------------------------|--------------------------------|----------------------------------|----------------------------------|------------------------------------|-----------------------------------|-------------------------------|-------|
| Hintzsche et al. (2009)   | c                                  | a                              | b                                | a                                | b                                  | a                                 | a                             | 6     |
| Souza et al. (2014)       | c                                  | b                              | a                                | a                                | b                                  | a                                 | a                             | 5     |
| Gandhi et al. (2015)      | c                                  | b                              | b                                | a                                | b                                  | a                                 | a                             | 5     |
| Banerjee et al. (2016)    | c                                  | b                              | a                                | a                                | b                                  | a                                 | a                             | 5     |
| de Oliveira et al. (2017) | c                                  | b                              | b                                | a                                | b                                  | a                                 | a                             | 5     |
| Vanishree et al. (2018)   | c                                  | b                              | a                                | a                                | b                                  | b                                 | a                             | 5     |
| Ros-Llor et al. (2012)    | c                                  | a                              | b                                | a                                | a                                  | b                                 | a                             | 6     |

Quality Assessment of Cohort Study Included:

|                        | Selection 1)<br>a/b = 1<br>c/d = 0 | Selection 2)<br>a = 1<br>b/c = 0 | Selection 3)<br>a/b = 1<br>c/d = 0 | Selection 4)<br>a = 1 | Comparability 1)<br>a = 1<br>b = 1 | Outcome 1)<br>A/b = 1 | Outcome 2)<br>A = 1 | Outcome 3)<br>A/b = 1 | Score |
|------------------------|------------------------------------|----------------------------------|------------------------------------|-----------------------|------------------------------------|-----------------------|---------------------|-----------------------|-------|
| Ros-Llor et al. (2012) | c                                  | a                                | b                                  | a                     | a                                  | b                     | a                   | a                     | 7     |

This scale has been adapted from the Newcastle-Ottawa Quality Assessment Scale for cohort studies to perform a quality assessment of cross-sectional studies for the systematic review.

In our scale, we have specifically assigned one star for each of the domain. Higher the star Lower the risk of bias. Stars has been converted into scores for our convenience. Further, these scores have been categorized into high, unclear and low risk of bias using Review Manager Software version 5.3.



|                          | SELECTION | COMPARABILITY | OUTCOME |
|--------------------------|-----------|---------------|---------|
| Banerjee S et al (2016)  | +         | +             | +       |
| Cunha et al(2013)        | +         | +             | +       |
| Gandhi et al(2015)       | +         | +             | +       |
| Hintzsche H et al (2009) | +         | +             | +       |
| Olivera et al(2017)      | +         | +             | +       |
| Ros-Llor et al (2012)    | +         | +             | +       |
| Vanishree M et al (2018) | +         | +             | +       |

**Figure 1.** BIAS CHART

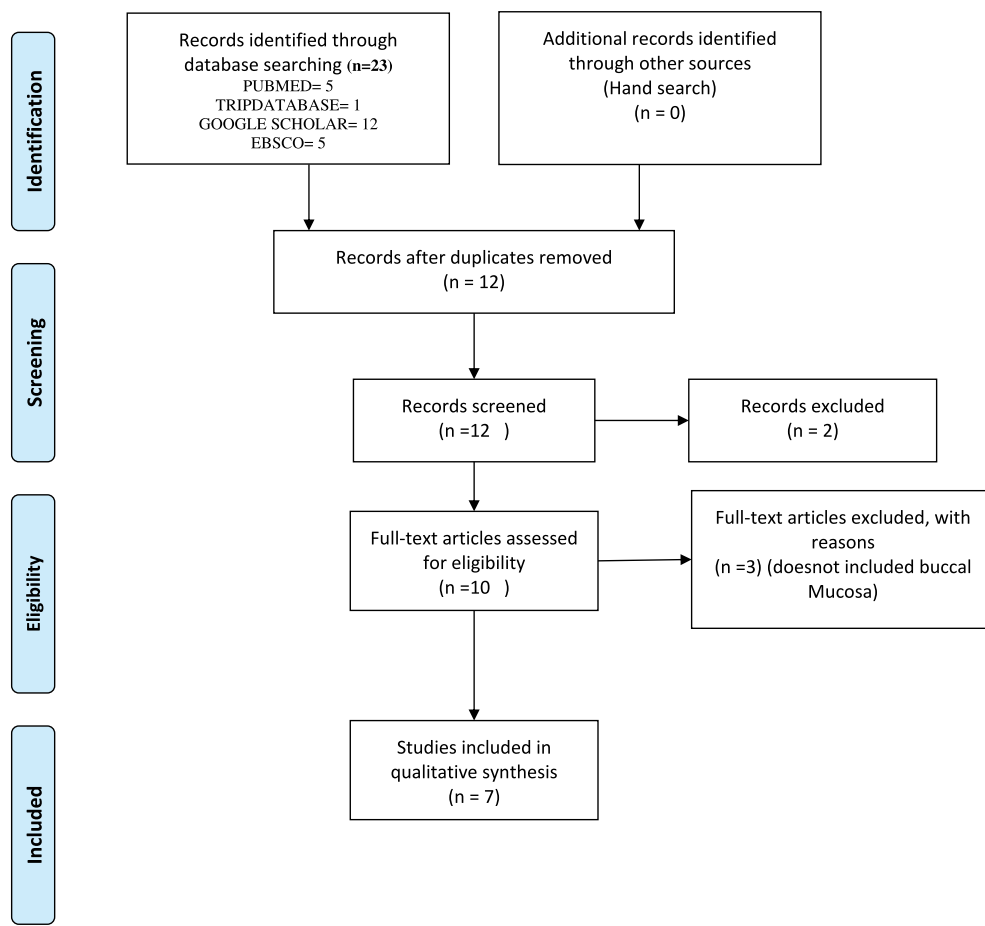


**Figure 2.** PRISMA (2009) flowchart for search strategy

users by using Buccal Cytome Assay. In the study, 60 male volunteers ageing 20–25 years using cell phones for 3 to 9 h per day were recruited and the Individuals were divided into groups according to their addiction habits (smoking, alcohol) and call duration. The same number (n = 60) of age-matched individuals using cell phones for less than 1 h and without any addiction were considered as least exposed individuals. The results of the study showed highly significant frequencies of various cell anomalies such as micronucleus, nuclear buds, pyknotic cells, karyorrhectic, condensed chromatin and karyolytic cells, in exposed Individuals as compared to the least exposed individual group (Shaikh et al. 2016).

Gandhi G in 2015 conducted a study on 25 healthy mobile phone users using mobile phones for 3–5 years and 25 non-mobile phone users in which the buccal cell preparations previously scored for MN were re-investigated for genomic instability and other biomarkers to assess DNA damage, cell-proliferation and cell-death. Buccal micronucleus cytome (BMCyt) assay was performed and the result showed a highly significant increase in chromosomal damage reflected by an

increase in micronucleated cells and cells with nuclear buds (Gandhi et al. 2015). In the year 2005, another study was conducted by the same author, where the investigation was carried out on the peripheral blood lymphocytes of individuals using mobile phones, being exposed to microwave frequency ranging from 800 to 2000 MHz in which in-vivo capillary blood micronucleus test among 24 mobile phone users revealed highly significant frequency of micronucleated cells in the blood smear showing the positive correlation between mobile phone use and genetic damage (Gandhi and Singh 2005).

A study was conducted by Vanishree et al. in 2018., on 60 participants who were divided into two groups – Group A as Low mobile phone users, using their mobiles for <4–5 h a week and Group B as high mobile phone users, using mobile for more than 10 h a week. The results showed that there was a significant increase in the mean MN count in Group B in comparison to the Group A. The findings were similar to the study conducted by Banerjee et al. (2016) in which the type of mobile phone users was assessed by the type of mobile

phone used, i.e., Code Division Multiple Access (CDMA) or Global System for Mobiles (GSM), which showed a significant increase in MN count of CDMA phone users when compared to GSM users.

Contradictory results were obtained by Ros-Llor et al. (2012), Hintzsche and Stopper (2010), and de Oliveira et al. (2017) who investigated the effect of mobile phone use on genomic instability of the human oral cavity's mucosa cell. There was no significant increase in the frequency of MN due to mobile phone use.

Among the seven studies taken for review, MN prevalence was found to be highest and a positive relation was seen between the mobile phone radiation and buccal cell anomalies. All these buccal cell changes were found to be genotoxic. Despite such findings, due to low evidence of studies, it was difficult to establish a causal association. Moreover, the mean MR count in exfoliated buccal mucosal cells is also associated with the type of staining procedures whether DNA-specific or DNA-nonspecific stains, so the count should be interpreted with caution to avoid the false-positive results (Metgud and Neelesh 2018).

Mobile phone radiation even in the permissible range, if used for the longer duration, can cause significant genotoxicity. The genotoxicity accentuates when the mobile phones are frequently used on the same side which may be due to more amount of radiation and an increase in the temperature.

Hence, in future, further studies with a higher quality of evidence and statistical evaluation of MN count for the different staining procedures are required to have concrete evidence.

## Conclusion

In conclusion, the results of the majority of the studies found that the effects of mobile phone radiation will have a detrimental effect on buccal mucosa with such exposures having the potential to cause some buccal cell anomalies. However, uncertainties do remain and a continued precautionary approach is recommended until the situation is clarified. Further human and epidemiological studies are required to evaluate the long-term effect of mobile phone on the health of the individual.

## Recommendations

It is important to spread awareness among people. Every nation should set safety guidelines for protection against RF-EMR as displaying of radiation level in the pamphlet of mobile phone by the manufacturer, discouraging young people from prolonged use of their mobile phones (Zaghloul and Banna 2019).

Precautions to minimize hazards, which may help alleviate health problems:

- Avoid extended calls by wireless phone and if necessary, placing more distance between the body and the mobile phone.
- Avoid late-night smartphone use for better sleep quality and to avoid blue light.
- Use the speaker or headset and put the wireless phone away from the user's body.
- During sleep, keep smartphones in "airplane mode" or deactivate mobile data, Wi-Fi and Bluetooth and disconnect the power supply to Wi-Fi routers.
- While sleeping, avoid magnetic sources in the bedroom or in the adjacent room as magnetic fields can pass through walls.
- Select the mobile phone with lower specific absorption rate (SAR) values printed on their batteries or searching for it on their websites.
- Avoid using the mobile if has a weak signal or when moving at high speed (for each bar lost in the signal strength the smartphone will raise its power by 1000% to endure the connection).
- Regular assessment for early detection of biological hazards and their progression.
- Using anti-radiation shielding technology that can block over 99% of RF radiation.

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