AN IN-VITRO COMPARATIVE STUDY ON THE EFFECT OF MOBILE PHONE RADIATION EXPOSURE ON METAL IONS RELEASE FROM FOUR DIFFERENT BRACKET SYSTEMS

By

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ABSTRACT

Background & Objectives:

Most of the orthodontic appliances are made of stainless steel containing 8% to 12% Nickel (Ni). In patients undergoing orthodontic treatment, Nickel is the most common metal to cause contact dermatitis. Similarly, Chromium induces hypersensitivity reactions. A significant carcinogenic and mutagenic potential has been demonstrated for these metals containing compounds. Nowadays mobile phone usage is reported to be higher among the teenagers. As the mobile phones are held closer to the oral cavity, the orthodontic appliances are prone to be exposed to electromagnetic radiation emitted from mobile phones. The aim of this in-vitro study is to evaluate the effect of radiation emitted from mobile phone on the Nickel and chromium ion release from 4 commercially available orthodontic bracket systems.

Methodology:

The effect of mobile phone radiation on Nickel and Chromium release from straight wire brackets were assessed by using Ormco -Mini 2000 (Group A), American Orthodontics - Mini Master Series (Group B) and Dorthom (Group C) Moriz gold bracket (Group D). Total samples will be divided into control and test groups with 10 samples. In control group, Maxillary premolar brackets from each system were placed in poly-ethylene capped vials containing 5 mL of artificial saliva at a pH of 7.2. The remaining 10 samples from each system were placed in 35mm petridish containing 5ml artificial saliva. To improve the specific absorption rate (SAR) homogeneity inside each sample, each dish is placed into another 50 mm dish. These sample holders were placed in wire patch cell antenna, which is designed for exposing the samples to mobile phone radiation. The test samples were exposed to mobile phone radiation for 2 hours per day for six weeks. Both control and test groups were incubated at 37°C for 6 weeks. After the incubation period the samples were assessed for Nickel and Chromium ion concentration using Atomic Absorption Spectrometer.

Result:

T test analysis showed statistical significance in Nickel ion concentration in ($p<0.05$) between control and test in Group D. T test analysis of Chromium ion concentrations in control and test samples in all bracket groups shows statistical significance.

Conclusion:

This study shows that mobile phone radiation has a positive effect on Nickel ion release from generic brackets. But all the bracket systems showed a significant effect on Chromium release by mobile phone radiation.

Key words**:** Nickel; Chromium; Orthodontic Brackets; Electromagnetic Radiation;

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INTRODUCTION

INTRODUCTION

Stainless steel brackets have been used for decades with highly successful clinical results. An alloy of iron with 12%- 30% Chromium is commonly called stainless steel.[1] Elements other than iron, carbon and chromium may be present, resulting in a wide variation in composition and properties of the stainless steels.[1] The Chromium in the Stainless Steel forms a thin, adherent passivating oxide layer that provides corrosion resistance by blocking the diffusion of oxygen to the underlying bulk alloy.[2] Approximately 12-13 wt% chromium is required to impart the necessary corrosion resistance to these alloys.[2] Nickel contribute towards the corrosion resistance and helps to strengthen the alloy.[3] The chromium, carbon and nickel atoms (and atoms of other metals in the composition) are incorporated into the solid solution formed by the iron atoms.[2] Since the nickel atoms are not strongly bonded to form some intermetallic compound, the likelihood of in vivo slow nickel ion release from the alloy surface is increased, which may have implications for the biocompatibility of these alloys.[2]

There are three major types of stainless steels, classified on the basis of crystal structures formed by the iron atoms. They are Ferritic, Martensitic and austenitic stainless steel. Among these, the austenitic stainless steel is the most corrosion resistant and are used for the fabrication of orthodontic wires, brackets, endodontic instruments and crowns in pediatric dentistry.[1] The major components of stainless steel alloy are Nickel (Ni) 8-12%, chromium (Cr) 18-20%, carbon with traces of manganese (Mn), copper (Cu) and titanium (Ti) in various proportions.[1] Austenitic stainless steel exists as a face-centered cubic crystalline structure, formed by heating the alloy above 912° C.[4] To maintain this structure when cooled, nickel is added to stabilize the austenitic phase. Chromium adds to the overall resistance through a passivation process by forming a complex spinel-type passive film $[(Fe,Ni)O(Fe,Cr)_2 0_3]$.[4] The corrosion resistance and appearance of stainless steel brackets are relatively good.[4] However, this material is challenged by the hostile environment in the mouth, as it is susceptible to localized corrosion in a low pH environment containing chlorine ions.[4]

These appliances may undergo biodegradation when exposed to potentially damaging thermal, microbiologic, and enzymatic agents in the oral cavity. Some of these corrosion products released from the appliance components can have a toxic effect on the surrounding oral tissues and may have the potential to trigger an allergic reaction. Nickel and chromium have dermatological, toxicological and possibly mutagenic effects. Among these leaching products Nickel is known to be a common cause of contact allergies and hypersensitivity reactions. Reports in the literature indicate that the incidence of Nickel hypersensitivity in the general population is up to 28.5 %.[5] The prevalence is higher in female individuals.[5, 6,7] The most common causes of nickel contact dermatitis have been direct contact from jewelry, garments, glasses, and watches. A great number of commonly used objects contain nickel and can therefore cause contact dermatitis.[8] Factors that have been documented to influence the development of sensitization include mechanical irritation, skin maceration, increased environmental temperature, and duration of exposure[8,9]. Nickel allergy is usually manifested as blisters and ulcerations extending to the perioral area, with or without eczematic and urticarial reactions of the face.[5]

Chromium is known to be an essential element for human beings and animals. In general, the most significant human exposure to this metal occurs through the diet, atmosphere, drinking water, jewelry, and iatrogenic uses of articles containing this metals.[10] Resistance to corrosion can be increased by using an alloy that makes strong chemical bonds with oxygen, creating a protective film on the surface of the materials. The chromium present the in stainless steel alloys forms a superficial a stable film of chromium-oxide which renders stainless steel corrosion resistant.[10] Chromium allergy is estimated at 10% in male subjects and 3% in female subjects.[11] After Nickel, Cr is believed to cause allergic reactions and is considered carcinogenic.[12] It has been suggested that chromium content of 16–27% will provide the optimal corrosion resistance for nickel-based alloys.[12] The average dietary intake for chromium has been estimated to be 280 μg/day.[10, 12] For nickel it is 200- 300 μg/day.[12]

Factors such as temperature, quantity and quality of saliva, salivary pH, plaque, the amount of protein in saliva, physical and chemical properties of food and liquids, and general and oral health conditions may influence corrosion in the oral cavity.[6] In 2015, Mohammed Al Saghiri et al, found that Mobile phone usage has a time-dependent influence on the concentration of nickel in the saliva of patients with Orthodontic appliances.[13]

In this modern era, mobile phone is the most dominant portal of information and communication technology and most of the global populations (especially college and university students), use smartphones, due to its wide range of applications. The number of mobile cellular subscriptions is constantly increasing every year. In 2016, there were more than seven billion users worldwide.[14] According to WHO, in many countries, over half the population use mobile phones and the market is growing rapidly. In 2014, there is an estimated 6.9 billion subscriptions globally.[15] Between 2008 and 2009 the use of mobile phones in developing countries exceeded 50% of the global population, reaching an estimated 57 per 100 inhabitants, while in high-income countries use has largely exceeded 100% (i.e. there is more than one mobile phone subscription for every inhabitant).[15] A number of studies have investigated the effects of radiofrequency fields on brain electrical activity, cognitive function, sleep, heart rate and blood pressure in volunteers and mobile phones are considered as a source of distraction that causes Road Traffic Accidents (RTA).[15]

The rapid increase in the use of mobile phones has brought about an urgent need to determine whether their emitted microwave radiation could cause health hazards. Orthodontic appliances are at high risk of exposure to radiation emitted from mobile phones as they are held closer to the oral cavity. Because of the increased use and close proximity to the oral cavity, it is important to confirm the relation between mobile phone radiation and the metal ion release from the brackets in orthodontic patients. In case of Nickel allergic individual even a little amount is sufficient to cause sensitization. Although the prevalence of Nickel sensitivity is less (28.5%), it is not negligible. Thus care should be taken to avoid Nickel release due to any factors.

Different types of brackets are available in the market. Some of them meet the standard specifications in terms of material composition, quality and quantity and manufacturing process, but some of them does not satisfy these specifications. All these kind of brackets are readily available in market too. Even though the treatment outcomes of the generic brackets are almost close to that of the standard brackets, the adverse reactions of the former are considered higher. In critical cases like Nickel sensitivity patients, material selection is very important. An orthodontist should be concerned not only about the treatment result, but the Patient safety as well. This study is designed to find the effect of mobile phone radiation on Nickel and Chromium release of different bracket systems.

OBJECTIVES

Aim

To measure and compare the Nickel and Chromium ions release from 4 different orthodontic bracket systems on exposure to mobile phone radiation.

Objectives

i) To compare the Nickel and Chromium ions release from mobile phone-radiation exposed and non-exposed brackets.

ii) To evaluate the Nickel and Chromium ion release from standardized and generic brackets after exposure to mobile phone radiation.

BACKGROUND &

REVIEW OF LITERATURE

BACKGROUND OF THE STUDY

The increasing use of mobile phones in the past few decades have raised many health concerns regarding the adverse effects of radiofrequency electromagnetic radiations on the anatomical structures and tissues, since it is held close to the head and neck structures. Many studies have been carried out in collaboration with different biophysics and organic laboratories to evaluate possible effects of electromagnetic fields on biological tissues. The evidence in the literature suggests that there are changes in parotid gland, physical, chemical properties saliva and temperature variations in adjacent tissue associated with mobile phone use.

The orthodontic appliances in the oral cavity are also in the vicinity of radiofrequency electromagnetic radiation in mobile phone users. Some studies have proved the association of these radiations with corrosion characteristics of metallic components in the oral cavity. This study becomes valid and relevant in modern era, since the prevalence of mobile phone usage is significantly higher in patients undergoing orthodontic treatment with an increased risk of exposure to radiofrequency electromagnetic radiation and subsequent metal ions release.

REVIEW OF LITERATURE

Peltonen (1979)[16] reported that women are 10 times more sensitive to Nickel than men. The incidence of Nickel sensitivity in a population above the age of 10 was examined through epicutaneous tests with 5% Nickel sulphate performed and found that Nickel sensitivity was observed in 4.5%, in 8% of the females and in 0.8% of the males.

Prystowsky, S.D (1979),[17] and colleagues found that, there was a strong correlation of nickel sensitivity with a history of pierced ears, earlobe rash, and jewelry rash. There was a consistently positive correlation between history of exposure and patch test reactivity. This suggests that the histories were valid and useful in that they were, in the aggregate, predictive of contact sensitivity. In this study Women with Pierced ears were four to five times more likely than other women to have a positive patch test reaction to nickel.

Council on Dental Materials, Instruments and Equipment (1982)[18] published that there is no experimental evidence that nickel compounds are carcinogenic when administered by oral or cutaneous routes. However, there is strong epidemiologic evidence to indicate that the occupational exposure of industrial workers to certain nickel compounds is associated with increased incidence of specific types of cancer. Cancer of the respiratory organs has been noted in workers exposed to nickel in Wales, Canada, Norway, the Soviet Union, Japan, France, Germany, and the United States. Workmen associated with the refining of nickel ore, smelting, and nickel electroplating operations have had the highest incidence of cancer of the respiratory organs. Increased risk of death from lung and nasal cancer was first found in workers at a nickel refinery in Clydach, Wales.

Originally, nickel dermatitis was seen exclusively in workers in the nickel industry-miners, smelters, refiners, and electroplaters. It was referred to as “nickel itch” - a skin disease characterized by an itching or burning papular erythema in the web of the fingers which would spread to the fingers, the wrists, and the forearms. A second type of nickel dermatitis was described as papular or papulo-vesicular dermatitis with a tendency for lichenification. Because of the ubiquity of nickel in our modern environment, nickel reactions appear with much greater frequency in the general population and are no longer exclusive to nickel workers.

H. Y. Park, (1983)[19] proved that the average release of metals was 40 ɥg nickel and 36 ɥg chromium per day for a full-mouth appliance. This was well below the average dietary intake of nickel and chromium consumed by Americans. Characteristic lesions of contact stomatitis vary from barely visible, mild erythema to a fiery red color with or without edema. Symptoms may include loss of taste, numbness, burning sensation, and soreness of the involved area, often accompanied by angular cheilitis. Itching is not a frequent symptom. Although it is more difficult to provoke contact stomatitis than contact dermatitis, severe gingivitis associated with orthodontic therapy may be a manifestation not only of poor oral hygiene but also of a contact hypersensitivity reaction to nickel and/or chromium ions released during the corrosion of stainless steel. In the oral cavity such factors as temperature, quantity and quality of saliva, plaque, pH, protein, physical and chemical properties of food and liquids, and general and oral health conditions may influence corrosion.

Shayne C. Gad (1989)[20] stated that the primary routes of exposure to chromium at hazardous levels are dermal and inhalation, though there are cases of accidents or attempted suicide where significant exposure by the oral route will occur. While chromium compounds are not likely to be sufficiently absorbed through the intact skin to produce systemic toxicity (kidney damage), if the integument of the skin is significantly disrupted (as in the well-known "chrome burn" process), absorption can occur and acute kidney damage may result as a secondary effect. Dermal contact with Cr (VI) compounds can also cause allergic dermatitis or sensitization. Compounds which are soluble in water or serum may be absorbed in the blood and transported to the kidney where, if sufficient Cr (VI) reaches the target organ without having been reduced to Cr (III) by natural body functions, acute damage may result. Oral exposure to chromium compounds generally represents an acute hazard and medical emergency. This emergency requires dealing with (i) burns and corrosion along the oral cavity and upper end of the trachea, and (ii) the acute renal toxicity of absorbed hexavalent chrome compounds. The primary cause of death to acute chrome exposures (either oral or dermal) is nephrotoxicity, ranging to complete renal shut down.

Justin K. Bass, Howard Fine, George J. Cisneros (1993)[8] stated that factors that have been documented to influence the development of sensitization include mechanical irritation, skin maceration, increased environmental temperatures, increased intensity, and duration of exposure. There may be a risk of sensitizing patients to nickel with long-term exposure to nickel-containing appliances as occurs in routine orthodontic therapy. Orthodontic therapy may enhance the liberation of nickel directly into the oral cavity and into the human system. This could lead to induced nickel sensitivity from routine orthodontic or dental appliances. Among the patients selected for their study, two patients converted from an initial negative patch test to a positive test. They concluded that Orthodontic treatment may induce nickel sensitivity.

Robert D. Barrett, Samir E. Bishara and Janice K. Quinn (1993)[21] reported that orthodontic appliances release measurable amounts of nickel and chromium when placed in an artificial saliva medium. The nickel release reaches a maximum after approximately 1 week, then the rate of release diminishes with time. On the other hand, chromium release increases during the first 2 weeks and levels off during the subsequent 2 weeks. The release rates of nickel or chromium from stainless steel and nickel-titanium arch wires are not significantly different. For both arch wire types, the release for nickel averaged 37 times greater than that for chromium.

Joseph A. yon Fraunhofer (1997)[22] reported that the incidence of adverse reactions in orthodontic patients has been estimated at 1:100, with 85% of these being contact dermatitis, many of which involve extraoral headgear. This high incidence of adverse reactions to orthodontic wires is surprising when compared with the very low incidence of adverse reactions to cast restorations, and it indicates a significant difference in the two clinical situations. The orthodontic patient has appliances of wires ligated into brackets, creating a system of galvanic cells throughout the mouth. In contrast, the prosthodontic patient has individual crowns or bridgework of the same metal and, therefore, there should be a lower incidence of galvanic cells. Whenever dissimilar metals are used, galvanic couples may be created with the concomitant potential for adverse reactions.

Heidi Kerosuo, Grete Moe, and Arne Hensten-Pettersen (1997)[23] investigated nickel and chromium concentrations in saliva of patients with different types of fixed appliances. The appliances used were headgear, quad helix, and fixed appliance with a minimum of two bands and four brackets and the arch wire. They observed a considerable variation in the concentrations of both nickel and chromium. No significant differences were found between the no-appliance samples and the samples obtained after insertion of the appliances. The results suggest that nickel and chromium concentrations of saliva are not significantly affected by fixed orthodontic appliances during the first month of treatment. Although the orthodontic appliances did not have any effect on the general level of nickel concentration of saliva, it cannot be excluded that minor amounts of nickel dissolved from appliances could be of importance in cases of hypersensitivity to nickel. Local concentrations of nickel on the oral mucosa might be sufficient to elicit allergic reactions, though it cannot be detected as increased nickel concentration in saliva. Also, over a longer time period, there exists a possibility for induction of immunological tolerance to nickel through presence of orthodontic appliances in the mouth.

Platt JA, Guzman A, Zuccari A, et al. (1997)[4] compared the corrosion behavior of 2205 duplex stainless steel (low nickel content- 4 to 6 wt%) with that of AISI type 316L stainless steel (nickel content: 10 to 14 wt%). Both stainless steels were subjected to electrochemical and immersion (crevice) corrosion tests in 37°C, 0.9 wt% sodium chloride solution. It was found that 316L suffered from crevice corrosion. On the other hand, 2205 stainless steel did not show any localized crevice corrosion, although the surface of 2205 was covered with corrosion products, formed when coupled to NiTi and stainless steel wires. This study indicates that considering corrosion resistance, 2205 duplex stainless steel is an improved alternative to 316L for orthodontic bracket fabrication when used in conjunction with titanium, its alloys, or stainless steel arch wires. From the standpoint of corrosion resistance, the use of 2205 as an orthodontic bracket material seems to be justified when the arch wire material is stainless steel or titanium. Use of this alloy could decrease the amount of corrosion products to which a patient would be exposed that could minimize nickel allergy problems potentially associated with orthodontic treatment.

G J Hyland (2000)[24] suggested that heating of biological tissue is a consequence of microwave energy absorption by the tissue's water content. The amount of heating produced in a living organism depends primarily on the intensity (or power density) of the radiation once it has penetrated the system, on certain electrical properties of the biomatter and on the efficiency of the body's thermoregulation mechanism. Amongst the most thermally vulnerable areas of the body, because of their low blood supply, are the eyes and the testes, and cataract formation and reduced sperm counts are well-documented acute exposure hazards. Animal studies indicate that a variety of behavioral and physiological disorders can be provoked by temperature rises below 1°C—ie, under much less acute exposure condition.

Tsui-Hsien Huang, Chen-Chieh Yen,b and Chia-Tze Kao (2001)[25] compared Nickel release from the brackets in the different solutions and showed that an increased release was observed in artificial saliva. This could be due to the chloride content of saliva. In the microenvironment of the mouth, the presence of a chloride gradient could contribute to the increased metal degradation observed as one progresses deeper into the crevice between the teeth. Also, incubation in pH 4 buffer resulted not only in a greater release of nickel, but also of chromium, iron, and manganese, than that observed in pH 7 or pH 10. This agrees with Weisman's findings that acidic conditions provide a reducing environment in which the stainless steel oxide film required for corrosion resistance is less stable. This study showed that the level of nickel ions released was several times that of the chromium, with increased release observed after recycling. However, after 12 weeks of immersion, the total ion release was still less than the dietary intake for that period. Overall, the recycled brackets released greater amounts of metal ions than did the new brackets, especially in the artificial saliva and pH 4 solution. This indicates the ease with which heat treatment increases the release of metal ions from the brackets in solution. To avoid the release of nickel, manufacturers have designed the cobalt-chromium bracket. Because this is essentially nickel-free, it would substantially reduce the release of nickel in vivo as compared with stainless steel brackets and thus would be more suitable for the nickel-hypersensitive patient.

Gunseli Agaoglu, Tulin Arun, Belgin Izgu, Aysen Yarat (2001)[11] evaluated the concentrations of nickel and chromium ions in salivary and serum samples from patients treated with fixed orthodontic appliances. In the first group, saliva and blood samples were collected before insertion of the fixed appliances. In the second, third, fourth, and fifth groups, samples were collected at 1 week, 1 month, 1 year, and 2 years after appliance insertion. The results indicated certain differences in the amounts of nickel and chromium released from fixed orthodontic appliances during different periods of treatment. In the serum, there were statistically significant increases in ion concentration in the second-year groups. In saliva samples, nickel and chromium reached their highest levels in the first month and decreased to their initial level in the rest of the groups. It can be concluded that fixed orthodontic appliances release measurable amount of nickel and chromium when placed in the mouth, but this increase doesn't reach toxic levels for nickel and chromium in the saliva and serum.

Michael H. Repacholi ((2001)[26] reported that exposure to EMF at frequencies above 100 kHz can lead to significant absorption of energy and temperature increases. Reports from in vitro research indicate that low-level RF fields may alter membrane structural and functional properties that trigger cellular responses. Most cancer studies of animals have sought evidence of changes in spontaneous or natural cancer rates, enhancement by known carcinogens, or alterations in growth of implanted tumors (IEGMP, 2000). Other health outcomes investigated following RF exposure include headaches, general malaise, short-term memory loss, nausea, changes in electroencephalography and other central nervous system functions, and sleep disturbances. Adverse maternal health outcomes, particularly spontaneous abortions and haematological or chromosome changes, have been reported to occur in certain populations exposed to RF fields.

Theodore Eliades, Athanasios E. Athanasiou (2002)[27] have indicated in their in vivo investigations an increased salivary concentration of Ni and Fe three weeks after the insertion of fixed orthodontic appliances. In general, the clinical manifestations of Ni hypersensitivity are easy to diagnose, and extraoral or intraoral appliances containing Ni must be removed after the development of dermal or mucosal signs in the form of rashes or swelling.

G. Rahilly (2003)[9] reported that Nickel is the most common metal to cause contact dermatitis in orthodontics, with more cases of allergic reactions than all the other metals combined. Nickel-titanium alloys may have nickel content in excess of 50% and can thus potentially release enough nickel in the oral environment to elicit manifestations of an allergic reaction. It has been suggested that a threshold concentration of approximately 30 ppm of nickel may be sufficient to elicit a cytotoxic response. It has been stated that oral antigenic contacts in non-sensitized individuals may induce tolerance to nickel, rather than sensitization. Nickel sensitization is believed to be increased by mechanical irritation, skin maceration, or oral mucosal injury, all of which may occur in orthodontic treatment. Environmental temperatures and duration of exposure may also be factors. It has also been reported that the in vitro release rate for full mouth orthodontic appliances to be 40 ɥg/day for nickel and 36 ɥg/day for chromium.

Her-Hsiung Huang et al (2003) [28] described that the potential risk associated with corrosion, in the use of NiTi orthodontic wires, comes from the biological side effects of Ni. On the other hand, it has been reported that Ti, a main component of NiTi wire, is not cytotoxic. However, an increase in the release of Ti ions indicates the deterioration of the protective surface film on NiTi alloys. This will lead to a concurrent increase in Ni ion release. Therefore, NiTi orthodontic wires with good corrosion resistance are very crucial when biocompatibility is of great concern. They assayed the corrosion resistance, in terms of ion release, of different NiTi orthodontic wires in artificial saliva with various acidities. The manufacturer, pH, and immersion period, had a statistically significant influence on the release amount of Ni and Ti ions from the as received commercial NiTi wires in acidic (pH 2.5–6.25) artificial saliva. The release amount of metal ions increased with immersion period in all test solutions, while the average ion released per day decreased with immersion period.

Fiorenzo Faccioni, Paola Franceschetti, Marzia Cerpelloni, and Maria E. Fracasso (2003)[29] suggested that corrosion events are very frequent in the oral cavity. The alloys used in dentistry are exposed to several aggressive physical-chemical events, such as high concentrations of oxygen and chloride mixtures in saliva, tartar, and plaque, and acid product deposit from microbiologic metabolism. The results indicate that nickel and cobalt concentrations were 3.4-fold and 2.8-fold higher, respectively, in the orthodontic patients than in the controls; cellular viability was significantly lower in the patients than in the controls, and there was a significant negative correlation with metal levels. The biologic effects, evaluated by alkaline comet assay, indicated that both metals induced DNA damage (more cells with comets and apoptotic cells). There were significant positive correlations between (1) cobalt levels and the number of comets and apoptotic cells, (2) nickel levels and number of comet cells, and (3) cobalt levels and comet tails. This study corroborates that nickel and cobalt released from fixed orthodontic appliances can induce DNA damage in oral mucosa cells. These data indicate that nickel and cobalt alloys of orthodontic appliances, which are in the mouth for 2 or 4 years, emit metal ions in sufficient quantities to induce evident cytotoxic effects.

G. Monfrecola G. Moffa E.M. Procaccini (2003)[30] did study to assess the effects of non-ionizing EMRs (frequency 3×10^8 to 3×10^{11} Hz), emitted by cellular phones, on cutaneous blood flow in healthy volunteers. Microflow values were recorded without cellular phone contact with the skin (T0), with the cellular phone turned off but in contact with the ear skin (T1), with cellular phone contact and turned on (T2), with cellular phone contact, turned on and receiving (T3). Results obtained with their study shows an increase in cutaneous microcirculation when a cellular phone is in contact with ear skin, turned on and in a receiving mode (T2 and T3 phases). This increase is statistically significant in comparison with values obtained with the cellular phone turned off (T1). This means first off all that the increase in cutaneous flow cannot be due to a simple contact between the cellular phone and the skin. The cutaneous microflow modification registered during the T1 phase (cellular phone in contact with the ear skin but turned off) could be due to an increase in skin temperature, but the additional microflow increase obtained during the phases T2 and T3 can be due only to the non-ionizing EMRs that are emitted by the cellular phone during the T2 phase and in particular during the T3 phase. The effect on microcirculation is probably due to the energy transfer from the electromagnetic field to the ear skin and subsequent thermal effect. Then, when the cellular phone was turned off, the cutaneous microflow decreased. In conclusion The non-ionizing EMRs emitted by cellular phones induce transient but significant modifications of cutaneous blood flow.

Tsui-Hsien Huang, Shinn-Jyh Ding, Yan Min, Chia-Tze Kao (2004) [31] stated that both new and recycled brackets will corrode in the oral environment. To avoid clinical side effects, metal brackets should be made more resistant to corrosion, and recycled brackets should not be used. The use of recycled brackets can accelerate the corrosion process, which in turn can be responsible for the failure of orthodontic appliances, either fixed or removable. The results of this study indicate that metal brackets used in orthodontic appliances will corrode in an acid or neutral environment after long-term use.

Theodore Eliades, Harris Pratsinis, Dimitris Kletsas, George Eliades, and Margarita Makou (2004)[32] concluded that the ions released from stainless steel and Ni-Ti orthodontic alloys were found to have no measurable effect on the viability and physiology of PDL and gingival fibroblasts. This can be assigned to either the decreased level of ionic release or the formulation and binding state of the ions. Nickel-intake sources include many every day and occupational activities ranging from airborne particulates and dust, drinking water, food, and soil to cooking utensils and cosmetics such as eye shadows. However, the relevance of the results reported in the foregoing studies to orthodontics is questionable because the binding state and formulation of nickel derivatives play a pivotal role in modulating the biologic reactions induced by nickel-containing materials. Besides, nickel is an important nutrient as evidenced by its incorporation in dietary supplements in the form of ions on the order of 5ɥg per tablet per day. Given the suggested daily intake of these vitamin and mineral formulas, it can be postulated that the reaction of nickel with certain species affects the hazardous nature of the nickel moieties.

Seda Gursoy, Ahu Gu ngor Acar, Cagla Sesen (2004)[6] reported that the literature indicate approximately 10% of the general population is sensitized to Ni and that the prevalence is higher in female individuals. According to this results, the use of recycled brackets results in significantly higher amounts of metal released into artificial saliva. In contrast, reuse of arch wires is associated with very low levels of metal release. Although experimental conditions and oral conditions in vivo differ, the amounts of metals that were released from the new or recycled orthodontic appliances in this study was insignificant in comparison with the amounts ingested during daily food intake. Thus, the release of metal ions from these materials may have no biological effects.

Menezes LM, Campos LC, Quintao CC, Bolognese AM (2004)[7] found that statistically significant positive reactions for patch test were observed for nickel sulfate

(21.1%), potassium dichromate (21.1%), and manganese chloride (7.9%); reactions to nickel sulfate had the greatest intensity. No differences were observed between the reactions before and after placement of the orthodontic appliances; this indicates that they did not sensitize the patients or affect their tolerance to these metals during the study period. No statistical difference was observed regarding sex for any evaluated substance, although a greater tendency to positivity to nickel sulfate was observed among female patients and to potassium dichromate in male patients.

Marisa Cristina Leite Santos Genelhu et al (2005)[33] described that some oral clinical manifestations in orthodontic patients, such as gingival hyperplasia, labial desquamation, angular cheilitis, multiform erythema, and periodontitis might be associated with an inflammatory response induced by the corrosion of orthodontic appliances and the subsequent release of nickel. Most patients with nickel-induced allergic contact stomatitis (NiACS) clinical manifestations were young and female, and had a history of allergies; NiACS was not associated with how long the patients were exposed to fixed orthodontic appliances. Previous allergic history was the most important variable characterizing NiACS. Ear piercing has been the most frequent allergy mentioned by patients. Most patients (69.2%) with NiACS clinical manifestation had a previous allergic history; only 30.8% of them reported no allergic history. In addition, no patients in the group with any clinical manifestations reported previous allergic episodes. Patients seeking orthodontic therapy who might be hypersensitive to nickel can be treated with alternative materials or techniques, such as appliances coated with epoxy resin. Ceramics and new metals, such as titanium, vanadium, and aluminum, might also help these patients avoid NiACS.

Theodore Eliades and Christoph Bourauel (2005)[34] reported that exposure of orthodontic materials to the oral cavity is associated with a nonspecific aging pattern characterized by calcification of the adsorbed complexes of ions and proteinaceous matter. This effect, coupled with the variety and potency of several other factors making up the environmental conditions of the oral cavity, might alter the morphologic, structural, and compositional characteristics and the mechanical properties of orthodontic alloys and polymers. Orthodontic materials in the oral cavity might not perform identically to their as-received or in-vitro-aged counterparts, and their properties might deviate from those specified by the manufacturer. Clinicians should understand the limitations of materials arising from aging, modifying their expectations and monitoring treatment progress accordingly.

Aksel Straume, Gunnhild Oftedal, and Anders Johnsson (2005)[35] reported that mobile phone users often complain about burning sensations or a heating of the ear region. The increase in temperature may be due to thermal insulation by the phone, heating of the mobile phone resulting from its electrical power dissipation, and radio frequency (RF) exposure. In the present study they have tried to explore to a certain extent an IR-camera method to record the skin temperature changes due to use of a mobile phone. The results of this study showed that the heat insulation was the main reason for the increase in skin temperature, both for the ear and the cheek and both at 15 and 30 min of exposure. The insulation of the mobile phone led to a statistically significant rise in skin temperature. The electrical heating of the phone caused by power dissipation gave a statistically significant increase in the temperature of the ear region only, compared to just the effect of insulation of the phone. The effect of the RF exposure beyond that caused by the insulation and electrical heating was not sufficiently large to be detected. Therefore, the heat sensations reported by some mobile phone users are most likely caused by the insulation and to some extent by the electrical power dissipated in the phone, while the RF exposure may hardly be detected, unless the SAR is higher than for the phone used in this study.

Max Costa and Catherine B. Klein (2006)[36] stated that Chromium is a human carcinogen primarily by inhalation exposure in occupational settings. This review highlights the most recent data on the induction of skin tumors in mice by chronic drinking-water exposure to hexavalent chromium in combination with solar ultraviolet light. This experimental system represents an important new animal model for chromate-induced cancers by ingestion of drinking water and it suggests by extrapolation that chromate can likely be considered a human carcinogen by ingestion as well. Mounting experimental evidence points to the fact that hexavalent Cr exposure, by either inhalation or ingestion, can have systemic effects that are distant from the site of exposure.

Maria Francesca Sfondrini (2008)[10] stated that, in the oral environment, orthodontic appliances are exposed to potentially damaging physical and chemical agents. Factors such as quantity and quality of saliva, salivary pH, plaque and amount of protein in the saliva, physical and chemical properties of food and liquids, and general and oral health conditions may influence corrosion in the oral cavity. A more important factor in metal corrosion is the flow rate of saliva. In the clinical setting, the brackets are mechanically activated to enable movement of the teeth. Movements of wires and friction in the brackets might result in various types of corrosion, which might further enhance the release of ions from the appliance.

Siegal Sadetzki, et al. (2008)[37] suggested a relation between long-term and heavy cellular phone use and parotid gland tumors (PGTs). Because radiofrequency energy absorption is very localized, if radiofrequency exposure increases the risk of PGTs, any increase will be seen on the side of the head where the phone is usually held, and no effect will be observed on the opposite side.

In conclusion, based on the largest group of benign PGT patients reported to date, a number of complementary analyses suggest a positive association between cellular phone use and PGTs. Their results suggest a relation between long-term and heavy cellular phone use and PGTs. This association was seen in analyses restricted to regular users, analyses of laterality of phone use, and analyses of area of main use. Increased risk estimates were found for ipsilateral regular use 5 and 10 years in the past, although the latter was based on small numbers. Significantly elevated odds ratios were observed consistently in the highest category of each of the measures of cellular phone use on the ipsilateral side, supporting a dose-response association. This association between side of use and PGTs was also seen by a case-only analysis. In addition, a positive association was seen for cellular phone use in rural areas, which was not shown for use mainly in urban areas.

Agency for Toxic Substances and Disease Registry (2008)[38] reported human occupational experience clearly indicates that, when inhaled, chromium compounds are respiratory tract irritants, resulting in airway irritation, airway obstruction, and lung, nasal, or sinus cancer. A delayed anaphylactoid reaction was reported in a male worker occupationally exposed to chromium vapors from Cr (VI) trioxide baths and chromium fumes from stainless steel welding. A subsequent inhalation challenge with sodium chromate resulted in a reaction including late-onset urticaria, angioedema, and bronchospasm accompanied by tripling of plasma histamine levels. Primary irritant dermatitis is related to the direct cytotoxic properties of chromium, while allergic contact dermatitis is an inflammatory response mediated by the immune system. Sensitized individuals will exhibit an allergic dermatitis response when exposed to chromium above a threshold level. Localized erythematous or vesicular lesions at points of contact or generalized eczematous dermatitis should suggest sensitization.

Maja Kuhta et al (2009)[39] emphasized the importance of several factors that can influence the release of metal ions from fixed orthodontic appliances, namely, the type of alloy, the pH of the solution, and the length of immersion. The results showed the greatest release of ions during the first 7 days and a gradual decline thereafter. Release of metal ions was influenced by composition of the orthodontic archwire, but this was not proportional to the content of metal in the wire. Quantities of all released ions were below toxic levels and did not exceed the daily dietary intake. However, these levels are sufficient to cause an allergic reaction because of the high haptenic potential of released elements. Even such small quantities of metal ions can cause allergic reactions, especially because fixed orthodontic appliances remain in the oral cavity for a long time (2 to 3 years). Although NiTi wires have a high percentage of nickel, the quantity of released nickel ions is smaller than that released from SS wire.

Olga Elpis Kolokitha, Evangelia Chatzistavrou (2009)[5] reported that exposure to nickel-containing orthodontic appliances may cause intra- or extraoral allergic reactions. Nickel is the most typical antigen implicated in causing allergic contact dermatitis, which is a Type IV delayed hypersensitivity immune response. Orthodontic therapy may enhance the liberation of nickel directly into the oral cavity and allergen may diffuse through the oral mucosa and distributes in the blood and lymph circulation provoking the hypersensitivity reactions. This could lead to induced nickel sensitivity from routine orthodontic or dental appliances. Females have been reported to have a much higher prevalence than males at 10 to 1.

Luciane Macedo de Menezes, Rodrigo Matos de Souza, Gabriel Schmidt Dolci, Berenice Anina Dedavid (2010) [40] suggested that the use of alloys with a lower biodegradation rate would reduce the risk of harm to patient health. Their results showed that recycled brackets release more ions than new brackets. This study demonstrates that although both new and recycled brackets will suffer corrosion in the oral environment, the cleaning and sterilization procedures involved in the recycling process result in microstructural changes that increase corrosion.

Goldwein, DJ Aframian (2010) [41] concluded that Parotid glands adjacent to handheld mobile phones in use respond by elevated salivary rates and decreased protein secretion reflecting the continuous insult to the glands. The repetitive use of the hand herld mobile phones causes an elevation in skin temperature and induces an increase in the perfusion of the tissue to cool it down. They hypothesized that the enriched capillary bed adjacent to the parotid glands may result in an increase of perfusion because of blood vessel propagation over an extensive time of exposure to heat, leading to an increase in the salivary rate flow.

Marcin Mikulewicz, Katarzyna Chojnacka (2011)[42] suggested that brackets, bands, and arch wires in oral environment are permanently exposed to conditions, such as variable (acidic) pH, which can be related with dietary intake, temperature, mechanical fatigue, and susceptibility of alloys to corrosion. Metal ions which can be potentially released from SS elements include Cu, Cr, Fe, and Ni, and from NiTi wires- Ni and Ti. The less biocompatible material was SS, which released the highest quantity of nickel and chromium. Acidic environment significantly increased the degree of metal ions release.

Shahabi M, Jahanbin A, Esmaily H, Sharifi H, Salari S (2011)[43] found that the resistance to corrosion is an advantageous property of orthodontic brackets; however, due to low levels of pH found in the mouth of a patient, localized corrosion may occur. This can affect tooth movement by increasing friction between the arch wire and bracket slot and initiate enamel discoloration. Corrosion can also significantly deteriorate mechanical properties of the brackets and cause the release of external elements that are capable of producing cytotoxic and biologic side effects. Through constant contiguity and in the presence of an electrolyte such as saliva, fixed orthodontic appliances act as an electric cell and are capable of releasing heavy metals. They studied the corrosion of stainless steel brackets in the orthodontic practice in patients with different acidic diets. According to this study, the highest amount of corrosion after six weeks was recorded for the cola solution and artificial saliva, followed by vinegar and the lowest was recorded for lemon juice and artificial saliva. The experiments that were conducted in this study solely evaluated the amount of bracket corrosion in different pH, whereas in the oral cavity other conditions including galvanic corrosion because of the contact of non-homogenous arch wires and brackets, or crevice corrosion because of the alteration in oxygen concentration in different areas (because of debris accumulation) and other uncontrollable conditions were the dominant factors involved in corrosion resistance. The results of this study showed that the amount of corrosion in orthodontic brackets was highest in cola followed by vinegar and lemon juice, respectively. It seems that effervescent drinks such as cola have to be eliminated or minimized in the nutritional diet of orthodontic patients because of their harmful effects on the brackets.

Shahla Momeni Danaei et al (2011)[44] measured the amount of metal ion release from orthodontic brackets when kept in different mouthwashes. Fluoridated mouthwashes are often recommended to orthodontic patients to reduce the risk of white-spot lesions around their brackets. A comparison of nickel release from the brackets in the various solutions showed that the maximum release was in deionized water and the next highest was in chlorhexidine mouthwash. Chlorhexidine mouthwash released greater amounts of metal ions (except manganese) than did the Oral B and Persica mouthwashes. Chlorhexidine not only caused the release of significantly higher amounts of nickel and chromium ions among the 3 mouthwashes studied, but it also caused not significantly higher release of copper than did Persica. The level of manganese release was significantly different in all 4 groups and, interestingly, it was lowest in chlorhexidine. The orthodontic brackets released the most ions in the presence of chlorhexidine mouthwash. It might be recommended to avoid prolonged application of chlorhexidine in patients who have allergies. If ion release is a concern, Oral B and Persica mouthwashes might be better options than chlorhexidine for orthodontic patients with stainless steel brackets.

Madhumitha Natarajan, Sridevi Padmanabhan, Arun Chitharanjan, and Malathi Narasimhan (2011)[45] evaluated genotoxic damage in the oral mucosal cells of patients wearing fixed appliance, and the nickel and chromium ion contents in these cells. The oral mucosal cells showed genotoxic damage in healthy patients undergoing orthodontic treatment as evidenced by the higher micronucleus (MN) frequency. Their findings indicated that nickel and chromium alloys of orthodontic appliances, which are in the mouth for a minimum of 18 months, emit metal ions in sufficient quantities to induce localized genotoxic effects, but these changes revert on removal of the source of genotoxicity. Therefore, it does not appear to be a process that should cause concern in healthy people. Future areas of research might focus on identifying high-risk patients and treating them with appliances with less genotoxic potential.

Fariborz Amini, Alireza Jafari, Parviz Amini and Sepehr Sepasi (2012)[46] estimated the mean salivary nickel (Ni) content in subjects with and without a fixed orthodontic appliance was 18.5 ±13.1 and 11.9 ±11.4 ng/ml, respectively. A statistically significant difference ($P< 0.035$) was found between the two groups. The mean salivary chromium (Cr) ion level recorded was 2.6 ±1.6 ng/ml in the study group and 2.2 ±1.6 ng/ml in the control group. The difference, however, was statistically insignificant. Within the limits of this in vivo study, it can be concluded that the presence of fixed orthodontic appliances leads to an increased concentration of metal ions in salivary secretions. Fixed orthodontic appliance therapy for an average period of 16 months can lead to increased levels of Ni and Cr ions in the saliva of patients.

Marcin Mikulewicz (2012) [47] reported that elevated levels of metals in saliva are thought to occur by corrosion of the chemical elements in the alloys or welding materials. The use of fixed rthodontic appliances made of stainless steel can be a source of risk exposure to nickel. European Council Directive for the quality of water intended for human consumption (80/778/EEC), Ni and Cr ions are classified into the group of toxic substances and Fe and Mn as substances potentially toxic. For the first two elements, the maximum admissible concentration (MAC) was 50µg/l for Ni and Cr. For Fe and Mn, their MACs were 200 and 50μg/l, respectively, while the recommended (or guide) levels were 50μg/l for Fe and 20μg/l for Mn.

Ionut-Cornel Ionescu And Ecaterina Ionescu (2012)[48] recorded a temporary decrease in pH values of saliva in patients exposed to GSM 900-MHz. The average pH value under normal conditions was 7.02 (SD=0.48). When the mobile phone was used, the average pH value decreased to 6.88 (SD=0.48). When the mobile phone was used in combination with NiTi round orthodontic wires of 0.014mm and ceramic brackets the average pH value decreased to 6.81 (SD=0.53). In the presence of NiTi rectangular orthodontic wires of 0.021mm ×0.025 mm and NiTi brackets, the average pH value decreased even further to 6.73 (SD=0.5). The results suggest that the pH average values in the presence of mobile phones and orthodontic appliances behave almost linearly. It appears to be a direct correlation between the amount of metal in the oral cavity and the temporary decrease of pH in the presence of mobile phones and can observe a lower impact on pH of NiTi wires and ceramic brackets in the presence of mobile phones. In the presence of an electromagnetic field, the biological tissue is considered as a medium with losses (absorbance). People using cell phones absorb some of the transmitted energy in their bodies.

Stuti Bhargava, Mukta Bhagwandas Motwani, and Vinod Madan (2012)[49] reported that mobile phones are known to generate heat and emit radio frequency radiation in the form of nonionizing electromagnetic radiations in the range of 800-2,200 MHz, similar to many home appliances. But the long duration and proximity of mobile phones to human body during use has given rise to concerns of possible adverse effects resulting from absorption of these emissions by the tissues adjacent to the area of mobile phone handset use. The radiofrequency radiation of the mobile phones are a type of microwave energy which may be absorbed by the water contained in the adjacent tissues raising their temperature. A significant increase in salivary flow rate along with increased blood flow rate and volume of the parotid glands of the side where mobile phones are frequently placed was observed in the heavy user group.

Teerapot Wessapan, Siramate Srisawatdhisukul, Phadungsak Rattanadecho (2012)[50] presented a numerical analysis of specific absorption rate (SAR) and temperature distributions in the realistic human head model exposed to mobile phone radiation at 900 MHz and 1800 MHz with various gap distances between the mobile phone and the human head. For both frequencies, the highest SAR values are obtained in the region of the skin near the antenna. In all cases of exposure, the highest SAR in the human head occurred near the surface, directly beneath the feed point of the mobile phone antenna. A smaller gap distance between the mobile phone and the human head leads to higher electric field intensities, SAR, and heat generation inside the human head, thereby increasing the temperature within the human head.

Soghra Yassaei, Shayesta Dadfarnia, Hakima Ahadian, Farshad Moradi (2013) [51] found that the average amount of nickel in the saliva 20 days after appliance placement was 0.8 µg/L more than before placement. Also, the amount of salivary nickel 20 days after the appliance placement was more than at the other stages, but the differences were not significant. The average amount of chromium in the saliva was found to be between 2.6 and 3.6 µg/L. The amount of chromium at all stages after appliance placement was more than before, but the differences between the chromium levels of saliva at all stages were not significant.

Yaniv Hamzanyet al (2013)[52] reported that increasing use of mobile phones creates growing concerns regarding harmful effects of radiofrequency nonionizing electromagnetic radiation on human tissues located close to the ear, where phones are commonly held for long periods of time. They compared salivary outcomes (secretion, oxidative damage indices, flow rate, and composition) between mobile phone users and nonusers. They report a significant increase in all salivary oxidative stress indices studied in mobile phone users. Salivary flow, total protein, albumin, and amylase activity were decreased in mobile phone users. These observations lead to the hypothesis that the use of mobile phones may cause oxidative stress and modify salivary function. The significant, profound increase in salivary malondialdehyde (MDA) and carbonyl levels found in the mobile phone users as compared to the nonusers. The MDA levels increased by 4.18-fold, indicating the induced oxidative alterations to cell membranes and other fatty macromolecules. The significant increase of the salivary flow rate in mobile-phone users as opposed to those who do not use mobile phones is not surprising (90% of the nonmobile individuals are deaf), since mastication is much more developed in hearing people who speak, thus activating their mastication muscles. Noteworthy is the fact that this increase in the flow rate is composed mainly by parotid secretion, which is diluted and watery in nature (serous fluid). It could be postulated that the mastication muscles in the nonmobile individuals are less developed due to their relatively limited use of mastication muscles for speech, as compared to the general population. In summary, this study indicates that mobile phone users experience considerable oxidative stress on proximal tissue as shown in the saliva, which mostly originates from the parotid glands. Oxidative stress is a potential contributor for the risk for developing cancer, and the currently demonstrated rise in salivary oxidative damage indices may result from an atempt to counteract this risk.

Fariborz Amini, Saghar Harandi, Mobina Mollaei, and Vahid Rakhshan (2014)[53] described that metals are not biodegradable, and their sustained release and accumulation in the tissues might leave irreversible toxic influences. Even the current trivial dose of corroded nickel and chromium ions is sufficient to damage the DNA, activate endothelial cells or monocytes or to modify cellular metabolism and morphology, especially in long-term exposures. Nickel might increase in patients undergoing treatment with both bracket types, although the rate of increase might be greater in patients under treatment with conventional brackets. Using MIM brackets might reduce salivary chromium for a trivial but generalizable amount. Still, ion levels leached from conventional versus MIM brackets might not show a difference after 2 months. Age and gender might not affect the ion levels in normal people or orthodontic patients.

M S Hashemipour, M Yarbakht, A Gholamhosseinian, H Famori (2014)[54] conclude that in subjects who predominantly used their mobile phone on the right side, the mean stimulated parotid gland salivary flow rate was 1.3 times higher in the right parotid gland than in the left gland. For those whom the left side was dominant, the mean stimulated parotid gland salivary flow rate in the left gland was almost equal to that in the right gland. In addition, there was a decrease in concentrations of amylase, lipase, lysozyme, lactoferrin and peroxidase. In cases in which the right side was dominant, a significantly higher concentration of protein was observed in the parotid saliva on the right side (compared with the left side). Despite a higher salivary flow rate on the dominant side, an increased protein concentration was measured on the right-dominant side in comparison with the non-dominant left side. This might reflect the different effects of mobile phone use on the sympathetic and parasympathetic pathways.

M. R. Iqbal-Faruque, N. Aisyah-Husni, Md. Ikbal-Hossain, M. Tariqul-Islam and N. Misran (2014)[55] analyzed the effects of electromagnetic (EM) radiation mobile phone on human head with different holding positions. The specific absorption rate (SAR) was measured for two common holding positions of mobile phone: Cheek and Tilt. In this tilt position, the mobile phone tilted for 15° and 30° from a person's head. SARs exhibited in much lower values as the mobile phone held in cheek position than that of tilt position. The electromagnetic radiation was absorbed mostly toward the skin at the closest area of the head from the mobile phone was held to. The highest absorption of radiation is at the head part; mainly over the area of the frontal lobe and side of the brain which is the usual placement of the mobile phone among the users. Since the brain is one of the conductive parts of the body, the radiation was more susceptible to be absorbed in this region. A mobile phone with mounted antenna on top and hold in tilt position results in more absorption of EM radiation by the head.

Kalati FA, Salimi S, Rabiee AV, Noraeei M (2014)[56] investigated the effects of duration of mobile phone use on the total antioxidant capacity of saliva. They noticed that salivary flow was reduced in the people speaking on the mobile phone between 20 minutes and 1 hour. As the time of mobile phone use exceeds 1 hour, the salivary flow will increase too. In spite of the increased salivary flow, total antioxidant capacity of saliva has not raised. it may be attributed to different effects of using mobile phone on the sympathetic and parasympathetic pathways. Salivation is controlled by the sympathetic and parasympathetic nervous systems; parasympathetic pathway controls the fluid and the sympathetic pathway controls the secretion of protein components. Using mobile phone increases parasympathetic activity, but it decreases sympathetic activity at the same time. The salivary IgA levels was increased significantly, as the time of using mobile phone exceeds an hour, it may suggest to the effect of prolonged use of mobile phone on the reduction of immune capacity of saliva. This may increase the risk of inflammatory diseases or mouth cancer in the people. The cell phone use decreases total antioxidant capacity of saliva also.

Mohammad Ali Saghiri, Jafar Orangi, Armen Asatourian, Peiman Mehriar, and Nader Sheiban (2015)[13] reported a significantly higher concentration of nickel ions in patients' saliva after using their mobile phones compared with the control group. This might be attributed to the greater flow rate and the lower concentration of the components in saliva, which in turn result in more nickel released From fixed orthodontic appliances into the saliva. An increase in temperature affects the resistance to localized corrosion by reducing the ability of the material to repassivate. Temperature can also affect the nature of the environment by changing the solubility of a constituent that can affect the corrosion behavior of a material. It was also claimed that when a mobile phone was used, the average pH value decreased, and this decrease was more evident when the patient had orthodontic appliances. Thus, heat generated by the mobile phone will change the properties, flow rate, and pH of saliva; these changes might increase the corrosion rate of orthodontic appliances and influence the passive layer on the metal surface. According to results of this study, mobile phone radiation might cause DNA damage indirectly by influencing the release of nickel from fixed orthodontic appliances. it can be concluded that mobile phone radiation, regardless of the type of phone, can influence the concentration of nickel in saliva in a time-dependent manner. In addition, this adverse effect of radiation on the release of nickel was more prominent in women because of longer usage times.

Sandeep Parashar, Rajkumar Maurya, Ankur Gupta, Chatura Hegde, Neelima Anand (2015)[12] did a study to assess the amount of nickel and chromium release from Indian made orthodontic brackets, bands and arch wires. This study was conducted on simulated appliances consisting of brackets from second premolar to central incisor, buccal tube and 0.019×0.025- inch SS arch wires secured with SS ligatures. They found that Peak nickel release was on 7th day and subsequently declined over the 14th and 28th day. The peak level of chromium concentration was on 14th day, which declined thereafter. When the finding pertaining to chromium level was taken into consideration the average daily release of chromium was 47.664 µg/day (Normal daily intake 280µg/day). At every time interval (1, 7, 14 and 28 Days) the chromium concentration was significantly less than the nickel concentration. In this study the release of nickel is 2.04 times more than chromium.

The 9th international symposium on advanced topics in electrical engineering (2015)[57]presented Specific Absorption Rate (SAR) which is obtained inside a human head and thermal effect due to exposure to electric field from mobile phone. If biological tissue is in the path of EM wave propagation, the wave penetrates the tissue and a portion of the wave energy is absorbed in the tissue. A force affects the charged particles due to electric and magnetic components of the EM field. The internal energy increases and, consequently, the temperature increases and thermal energy dissipates. The difference of input and output wave energy at the boundaries of an object represents absorbed energy. The SAR quantity has been introduced to precisely define absorbed energy. Naturally, the highest radiation level is in the area next to the phone antenna, and it gradually decreases with every subsequent area. It can be noted that the specific absorption rate is the highest in surface layers and decreases with distance from the radiation source, i.e. mobile phone.

Ghazal Mortazavi, S.M.J. Mortazavi (2015)[58] reviewed the risks associated with increased mercury release from dental amalgam after exposure to electromagnetic fields. Increased release of mercury from dental amalgam restorations after exposure to electromagnetic fields such as those generated by MRI and mobile phones has been reported. Their findings regarding the effect of exposure to electromagnetic fields on the release of mercury from dental amalgam fillings lead them to this conclusion that pregnant women with dental amalgam fillings should limit their exposure to electromagnetic fields to prevent toxic effects of mercury in their fetuses. Furthermore, substantial evidence can lead to the conclusion that maternal exposure to electromagnetic fields in mothers with dental amalgam fillings during pregnancy may increase the mercury level and trigger the increase risk of autism.

Camila Alessandra Pazzini (2016)[59] concluded that Nickel-free devices release low amounts of nickel ions, which could diminish hypersensitivity among allergic patients. It has been suggested that nickel exerts an influence on local and systemic inflammatory reactions throughout orthodontic treatment. They suggest less gingival inflammation with the use of nickel-free braces. Nickel-free stainless steel braces do not to have a significant amount of nickel in their composition. This suggests that they may be a viable alternative for allergic patients, despite their poorer mechanical properties, which are a limitation during orthodontic mechanics, since nickel considerably enhances resistance to oxidation and corrosion.

Lalita Girish Nanjannawar et al (2017)[60] assessed the level of nickel ions in saliva and pH of saliva in mobile phone users undergoing fixed orthodontic treatment. They suggested that mobile phone usage may affect the pH of saliva and result in increased release of nickel ions in saliva of patients with fixed orthodontic appliances in the oral cavity. Statistical analysis revealed that though the pH levels were reduced and the nickel ion levels were higher in the experimental group compared to the control group, the results were non-significant. This issue clearly shows that mobile phone usage can harm the oral cavity in several ways especially in patients with fixed orthodontic appliances.

A. Keykhosravi, M. Neamatshahi, R. Mahmoodi, and E. Navipour (2018)[61] reviewed that the use of mobile phones was associated with a mildly increased risk of skin problems. Overall evaluations showed that the effects of mobile phone radiation on skin diseases are weak and have no statistical significance. Some studies have shown weak impacts, and some studies have found that over ten years of mobile use have been effective, but mobile phones are still a new technology and little evidence about long-term side effects is available, as a result, prevention is the best approach. Overall evaluations showed that the level of evidence associated with the effects of radiation from the mobile phone and tablet on the skin is poor.

Seyed Mohammad Javad Mortazavi, Maryam Paknahad, Iman Khaleghi, Mahsa Eghlidospour (2018)[62] evaluated the effects of radiofrequency electromagnetic fields (RF-EMFs) emitted from mobile phones on the level of nickel release from orthodontic brackets. Findings of this study showed a statistically significant difference between the mean nickel levels in the exposed and non-exposed groups. It was shown that exposure to RF-EMF had led to statistically significant increased release of nickel from orthodontic brackets (11.95mg/l vs. 2.89mg/l, in exposed and non-exposed groups, respectively). Exposure to RF-EMFs emitted from mobile phones can lead to human exposure to higher levels of nickel in saliva in patients with orthodontic appliances.

RELEVANCE

RELEVANCE

Stainless steel alloys represent a group of corrosion-resistant alloys that are widely used in Orthodontics. Metallic products in oral cavity may undergo corrosion due to the presence of saliva. The most common elements leaching from SS are iron, Nickel and Chromium. As the Ni atoms are not strongly bonded to form any intermetallic compound, the likelihood of slow Ni ion release from the alloy surface is increases, which may have implications in the biocompatibility of these alloys. According to the International Agency for Research on Cancer (IARC), Nickel compounds, even at nontoxic concentrations, act as mutagens and carcinogenic substances.

Currently, several brands of orthodontic brackets are made of stainless steel and potentially have the required nickel content to provoke allergic reactions in the oral cavity. Recently there has been an increasing trend towards using generic products because of their low cost and easy availability directly from the manufacturers . In the present orthodontic scenario, it is essential to know the biocompatibility these materials as well.

The worldwide dramatic increase in the use of cell phones have generated great concerns about its potential adverse health effects. Several studies have been conducted on the effect of mobile phone radiation on salivary secretion, composition and its pH changes in the oral cavity. The effect of mobile phone radiation on corrosion of orthodontic appliances on patients has been reviewed previously by Alsaghiri et al.[13]

This study was conducted to compare and quantify Nickel and Chromium ions release from four different bracket systems when exposed to Radiofrequency electromagnetic radiations emitted from mobile phones.

METHODOLOGY

Sample size

The sample size (n) =10 for each group which was calculated using the statistical package G*Power (3.1.5). The total sample size is 80. The samples were divided into control and test groups with 4 subgroups. Each subgroup consists of 10 samples.

- Control group

Groups	Description	Sample size
A	Mini 2000 brackets -Ormco	10
B	Mini Master Series brackets- American orthodontics	10
C	Dorthom brackets	10
D	Moriz Gold bracket	10

- Test group

Groups	Description	Sample size
A	Mini 2000 brackets -Ormco	10
B	Mini Master Series brackets- American orthodontics	10
C	Dorthom brackets	10
D	Moriz Gold bracket	10

Materials required

- Maxillary 1st premolar brackets (0.022" slot straight wire) (Fig 1)
    i) Mini 2000 – Ormco (Standardized)
    ii) Mini Master Series - American orthodontics (Standardized)
    iii) Dorthom (Non-Standardized)
    iv) Moriz Gold bracket (Non-Standardized)
- Artificial saliva
- Poly-ethylene capped Vials

- Petridishes- 35mm, 50mm

Instruments

- GSM Module
- Wire patch cell antenna

Methodology

The study was conducted in St Gregorios Dental College, Chelad, Kothamangalam and was approved by ethics committee, St Gregorios dental college.

Control group

Each bracket system has a control and a test group. Maxillary 1st premolar brackets from each system were placed in poly-ethylene capped vials containing 5 ml of artificial saliva at a pH of 7.2. Artificial saliva was prepared based on the modified Fusayama solution components [63] (Table 1). The samples from each group without EMW exposure will be considered as control group (Fig 2).

Test group

The remaining samples from each group, exposed to EMW from mobile phone were considered as test group. A wire patch cell [64] was designed for exposing the specimens (Fig 3).

Maxillary 1st premolar brackets from each system were placed in 35mm petridish with 3ml of artificial saliva. This was placed into another Petridis of 50mm dimension (Fig 4) to improve and for uniform SAR for all samples. The entire system kept in the wire patch cell at its four corners, one sample holder over the other. Therefore total 8 sample holders were placed for radiation exposure simultaneously (Fig 5). In test group, 10 samples from each bracket system were exposed to radiofrequency electromagnetic radiation emitted from a Global System for Mobile phone communication (GSM) (Fig 6) module for 2 hours per day for 6 weeks. The GSM mobile phone simulator was activated by making phone calls.

Both the control and the test groups were incubated at 37°C for 6 weeks (Fig 7, 8). Then the solutions from the sample holders were analyzed to determine the amount of metal ions using an Atomic Absorption spectrometer (AAS) at Kerala Forest Research Institute (KFRI), Peechi, Thrissur (Fig 9).

Table 1. Fusayama Meyer's artificial saliva solution components

Component	**Concentration: g/l**
Potassium chloride (KCl)	0·4
Sodium chloride (NaCl)	0·4
Calcium chloride dihydrate ($CaC_{l2}·2H_2O$)	0·795
Monosodium phosphate dihydrate ($NaH_2PO_4·2H_2O$)	0·69
Sodium sulfide nonahydrate ($Na_2S·9H_2O$)	0·005
Urea	1·0

Wire patch cell antenna[59]

A wire patch cell designed and developed for biological applications during in vitro experiments studying possible effects of mobile radio telephone. It consists of two metallic planes (the ground plane and the roof), four props, and one coaxial probe located at the center of the cell, going through the ground plane and connected to the roof (Fig 10). Both metallic planes are of the same size in order to increase the electric field amplitude under the roof. The four metallic grounding contacts were located at each corner of the cell roof in order to maintain a large free area at the center of the device, where the electric fields remain homogeneous.

This 15x15x2.9 cm cell works with a maximum of eight 35 mm petridishes containing specimens. Every dish was placed into a 50 mm dish in order to improve SAR distribution and to obtain identical SAR values at both levels (Fig 11). This device induces a similar SAR at the same time within eight samples, which improves the statistical data for biological studies. This open device was placed into an incubator, leading to better ventilation for biological media and avoiding a possible temperature increase inherent to closed systems.

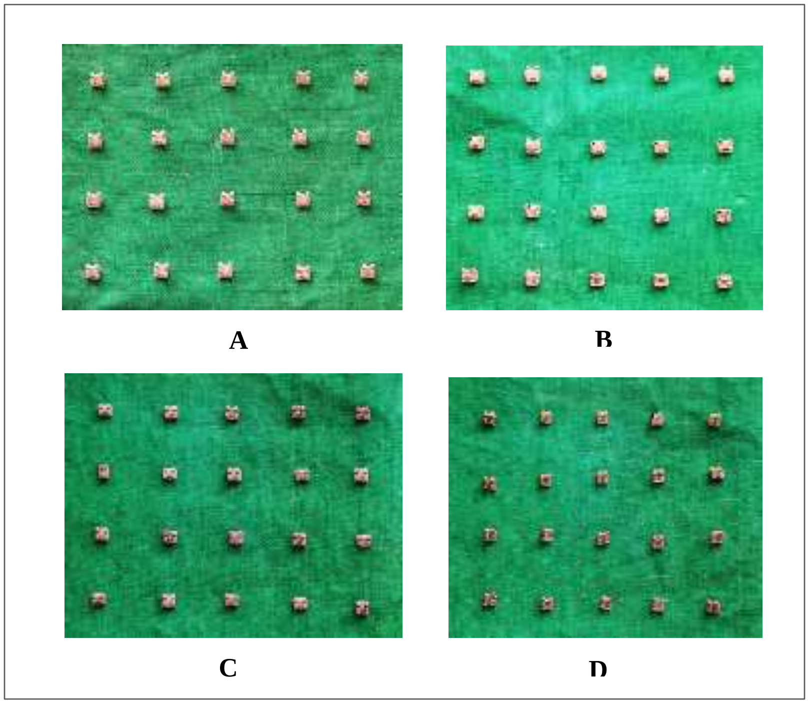


Fig 1. Orthodontic brackets used. A) Mini 2000 -Ormco. B) Mini master series - American Orthodontics C) Dorthom brackets. D) Moriz gold brackets.

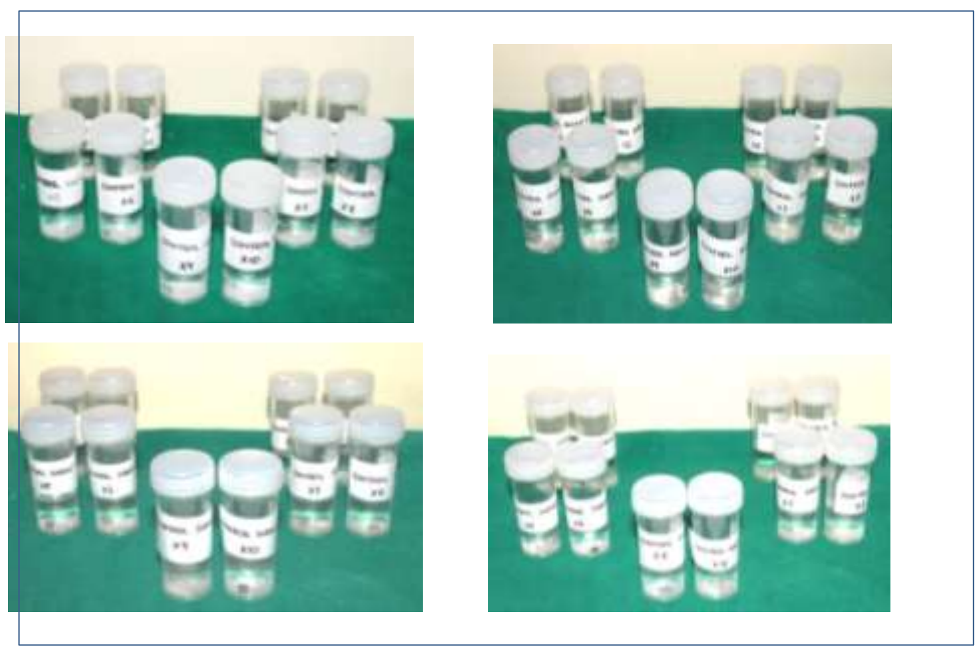


Fig 2. Control group samples of Group A, B, C, D kept in 5 ml artificial saliva without exposing to mobile phone radiation.

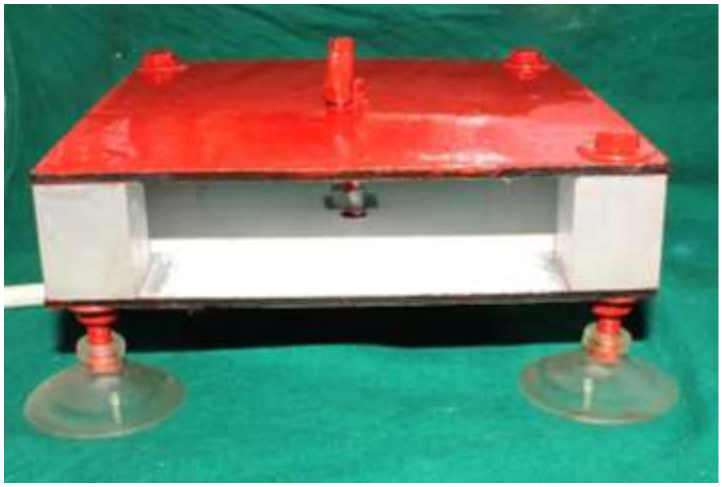


Fig 3. Wire patch cell antenna

Fig 4. Bracket placed in 35mm petridish containing 5 ml artificial saliva. Then the sample carrier placed in 50mm petridish.

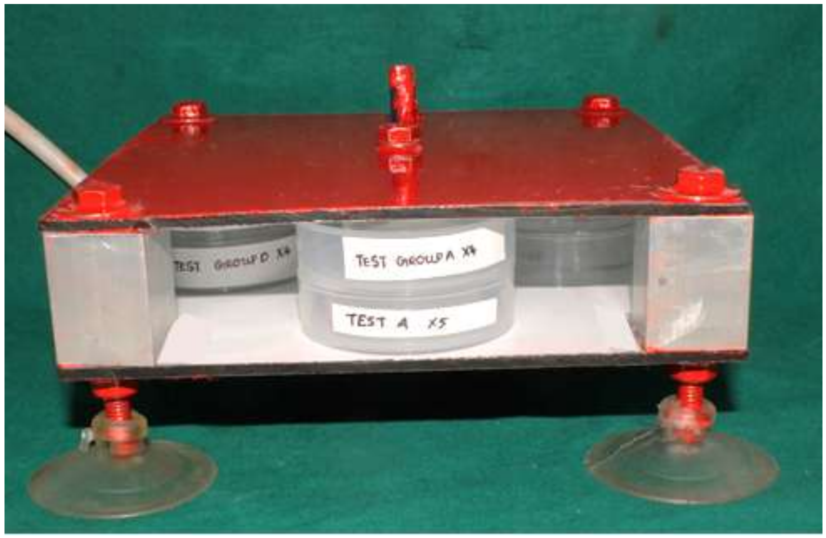


Fig 5. Sample holders kept in wire patch cell antenna.

Fig 6. GSM Module

Fig 7. Control group samples kept in incubator for 6 weeks.

Fig 8. Test group sample kept in wire patch cell antenna and incubated for 6 weeks.

Fig 9. Atomic Absorption Spectrometer

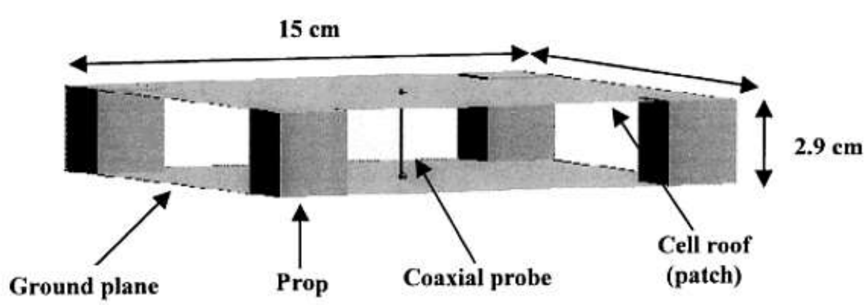


Fig 10. 15x15x2.9 cm empty exposure cell. The cell consists of two planes, four props, one coaxial probe located at cell center soldered at the cell roof. The ground plane is connected to external conductor of connector.

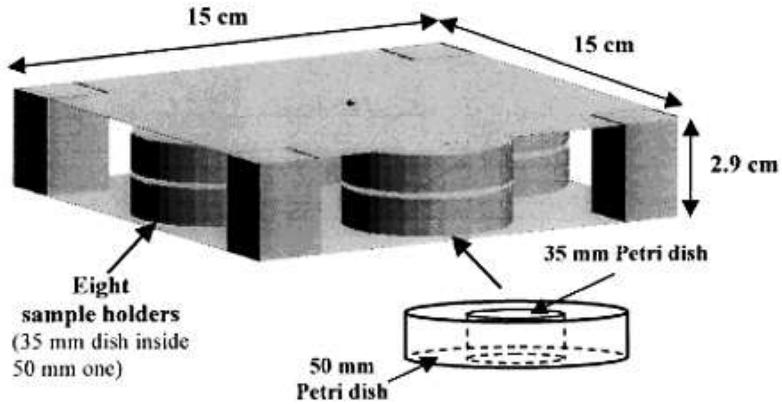


Fig 11. The 15x15x2.9 cm wire patch cell with eight sample holders. Four 35 mm dishes situated into 50 mm dishes are put on another series of four dishes. The prop size is 23x23 mm.

RESULTS

STATISTICAL ANALYSIS

Data was analyzed using the statistical package SPSS 22.0 (SPSS Inc., Chicago, IL) and level of significance was set at $p<0.05$. Descriptive statistics was performed to assess the mean and standard deviation of the respective groups. Normality of the data was assessed using Shapiro Wilkinson test. Inferential statistics to find out the difference between the groups was done using One way ANOVA test followed by Tukey’s Post hoc analysis to find out the difference between any two groups. Independent t test was done to find out the significant difference between the groups.

RESULT

The concentration of Nickel and Chromium ions in control and test groups were measured using Atomic Absorption Spectrometry.

Release of Nickel

In group A, the concentration of Nickel in control and test groups was not significant. It suggests that mobile phone radiation does not cause the Nickel ion release in these brackets. The Comparison of Nickel concentration between control and test group of Group A is given in Table 1. In group B, there is no statistical difference in the Nickel concentration between control and test groups (Table 2). In group C, p value is >0.05, indicates Nickel concentration is not significant among control and test groups (Table 3). But in Group D, the values are significant since the p value is 0.026 (Table 4). Thus this results shows that mobile phone radiation has a significant effect on Nickel ion release from group D brackets. Graphical representation of concentration of Nickel in control and test group is given in Fig. 1, 2 respectively. Fig 3 shows the comparison of mean Nickel concentration in control and test groups.

One way ANOVA test followed by Tukey's Post Hoc analysis was done to find out the difference between any two groups. Within the group analysis by ANOVA and posthoc test of control and test groups for Nickel showed no statistical significance between the A, B, C&D groups (p>0.05) (Table 5, 6).

Release of Chromium

All the groups showed significant increase in Chromium ion concentration in test group. This is an indication of effect of mobile phone radiation exposure on Chromium release from brackets. Table 7, 8, 9, 10 depicts the comparison of Chromium concentrations in Groups A, B, C and D. the graphical illustration of Chromium concentration control and test groups are given in Fig 4, 5 respectively. Fig 6 shows comparison of Chromium concentration in control and test groups.

Within group analysis by ANOVA and Post Hoc test of control group for Chromium showed no statistical significance between the A, B, C&D groups ($p>0.05$) (Table 11). But group analysis by ANOVA and Post Hoc test of Test group for Chromium showed statistical significance between the Group A vs B, Group B vs C& Group B vs D ($P<0.05$) (Table 12).

T test analysis showed no statistical significance in Nickel concentration ($p>0.05$) between test and control in Group A, B, and C. But the Nickel concentration is significant between control and test in Group D (p - 0.026). The same analysis showed statistical significance in Chromium concentration ($p<0.05$) between test and control in all groups. The results shows that the Nickel ion concentration is higher in radiation exposed samples of non-standardized brackets. Its concentration in all the unexposed samples is not statistically significant. There is a significant increase in chromium concentrations on exposure to mobile phone radiation in standardized as well as non-standardized brackets. Within group analysis by ANOVA and Post Hoc test of control and test groups of Nickel and control group of Chromium showed no statistical significance between the A, B, C & D groups ($p>0.05$). But the test group of Chromium shows statistical significance between the Group A vs B, Group B vs C& Group B vs D ($P<0.05$).

It can be concluded that the mobile phone radiation exposure will increase the Nickel ion release from non-standardized brackets. Hence the null hypothesis is rejected. Mobile phone radiation significantly increases the Chromium release from both standardized as well as non-standardized brackets. Therefore the research hypothesis is proved.

Table 2. Comparison of Nickel concentration between control and test- group A

NICKEL	GROUP A	
	CONTROL	**TEST**
MEAN	0.007	0.0073
SD	0.001	0.0023
P VALUE	0.709	
T VALUE	0.378	

*P<0.05 is statistically significant. T test analysis showed no statistical significance in Nickel group (p>0.05) between test and control in Group A.

Table 3. Comparison of Nickel concentration between control and test- group B

NICKEL	GROUP B	
	CONTROL	**TEST**
MEAN	0.0061	0.0063
SD	0.0023	0.0016
P VALUE	0.824	
T VALUE	0.225	

*P<0.05 is statistically significant. T test analysis showed no statistical significance in Nickel group (p>0.05) between test and control in Group B.

Table 4. Comparison of Nickel concentration between control and test- group C

NICKEL	GROUP C	
	CONTROL	**TEST**
MEAN	0.0064	0.007
SD	0.0026	0.001
P VALUE	0.407	
T VALUE	0.848	

*P<0.05 is statistically significant. T test analysis showed no statistical significance in Nickel group (p>0.05) between test and control in Group C.

Table 5. Comparison Nickel concentration between control and test – group D

NICKEL	GROUP D	
	CONTROL	**TEST**
MEAN	0.0069	0.008
SD	0.0017	0.002
P VALUE	0.026*	
T VALUE	2.409	

*P<0.05 is statistically significant. T test analysis showed statistical significance in Nickel concentration (p<0.05) between test and control in Group D.

Table 6.1. Comparison of concentration of Nickel within control groups

CONTROL	CONCENTRATION OF NICKEL			
	GROUP A	**GROUP B**	**GROUP C**	**GROUP D**
MEAN	0.007	0.0061	0.0064	0.0069
SD	0.001155	0.002331	0.002675	0.001729
P VALUE	0.404			

*P<0.05 is statistically significant.

Table 6.2. The results of the one-way ANOVA.

	Sum of squares	df	Mean Squares	F	sig
Between Groups	0.0000	3	0.0000	1.0000	0.404
Within Groups	0.0001	36	0.0000		
Total	0.0001	39			

Table 6.3. Post Hoc Tukey's HSD Test

Group(I)	Group(J)	Mean difference (I-J))	95% of confidence interval		P VALUE
			Lower	upper	
Group 1	Group 2	-0.0010	-0.0029	0.0009	0.4990
	Group 3	-0.0010	-0.0029	0.0009	0.4990
	Group 4	-0.0010	-0.0029	0.0009	0.4990
Group 2	Group 3	0.000	-0.0019	0.0019	-
	Group 4	0.000	-0.0019	0.0019	-
Group 3	Group 4	0.000	-0.0019	0.0019	-

*P<0.05 is statistically significant. Within group analysis by ANOVA and Post Hoc test of control group (Nickel) showed no statistical significance between the A, B, C & D groups (p>0.05)

Table 7.1. Comparison of concentration of Nickel within test groups

TEST	CONCENTRATION OF NICKEL			
	GROUP A	**GROUP B**	**GROUP C**	**GROUP D**
MEAN	0.0073	0.0063	0.007	0.008
SD	0.002312	0.001636	0.001414	0.002494
P VALUE	0.138			

*****P<0.05 is statistically significant

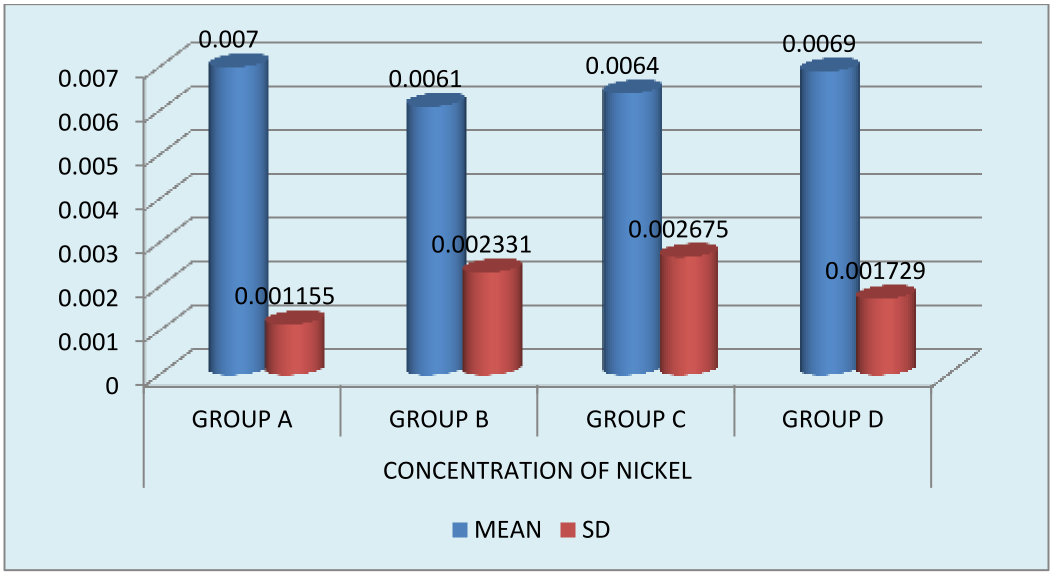
Table 7.2. The results of the one-way ANOVA.

	Sum of squares	df	Mean Squares	F	sig
Between Groups	0.0000	3	**0.0000**	1.956	0.138
Within Groups	0.0001	36	0.0000		
Total	0.0001	39			

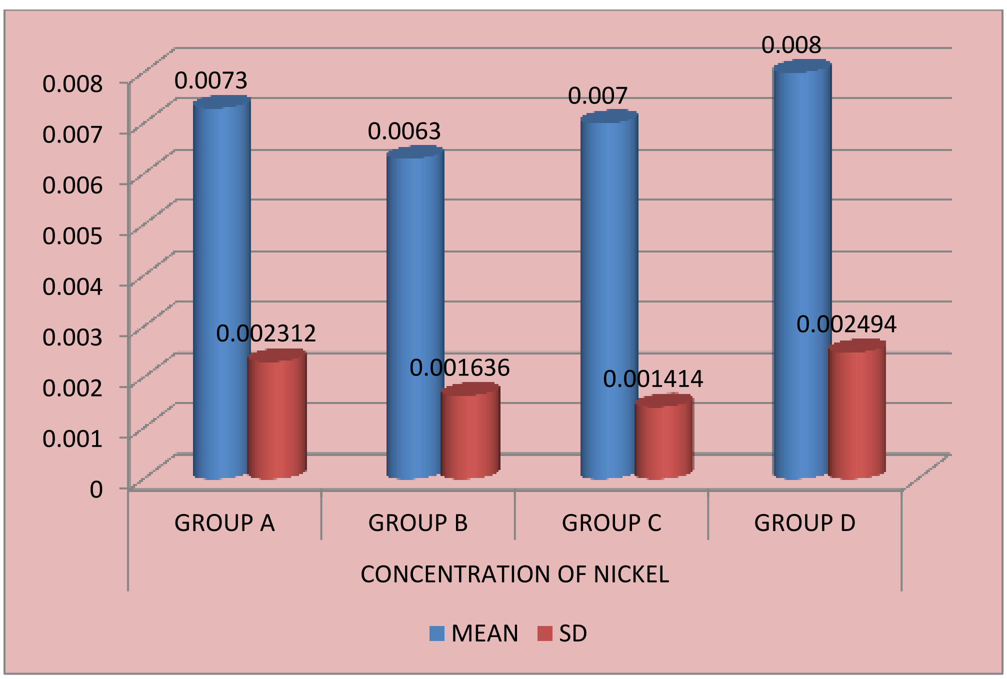
Table 7.3. Post Hoc Tukey's HSD Test

Group(I)	Group(J)	Mean difference (I-J))	95% of confidence interval		P VALUE
			Lower	upper	
Group 1	Group 2	-0.0007	-0.0026 to	0.0012	0.756
	Group 3	0.000	-0.0019 to	0.0019	--
	Group 4	0.0010	-0.0009 to	0.0029	0.499
Group 2	Group 3	0.0007	-0.0012 to	0.0026	0.756
	Group 4	0.0017	-0.0002 to	0.0036	0.094
Group 3	Group 4	0.0010	-0.0009 to	0.0029	0.499

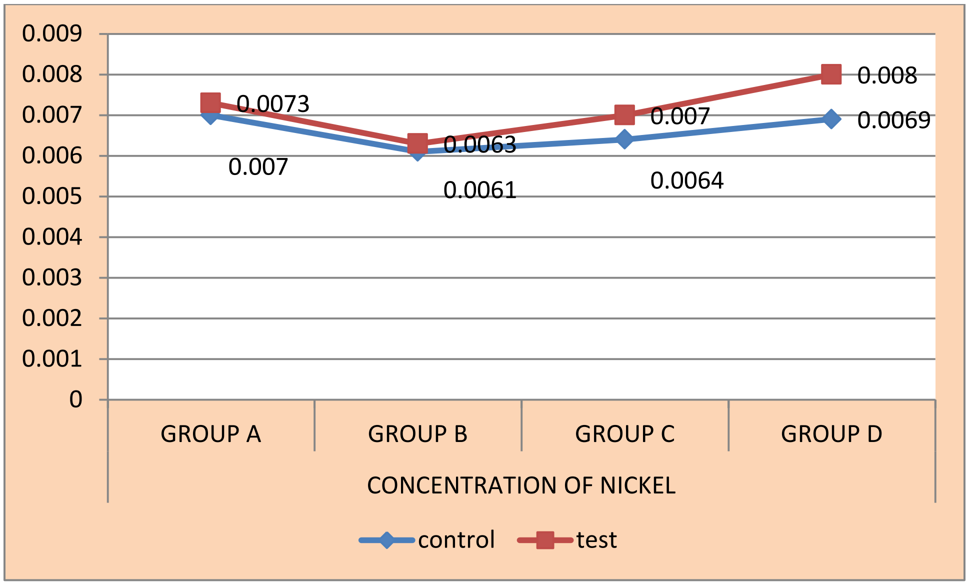
*P<0.05 is statistically significant. Within group analysis by ANOVA and Post Hoc test of test group (Nickel) showed no statistical significance between the A, B, C & D groups (p>0.05)



Graph 1. Concentration of Nickel-control groups



Graph 2. Concentration of Nickel- test group



Graph 3. Comparison of Nickel concentration in control and test groups.

Table 8. Comparison of Chromium concentration between control and test - Group A

CHROMIUM	GROUP A	
	CONTROL	**TEST**
MEAN	0.2283	0.4395
SD	0.0332	0.0429
P VALUE	**0.001***	
T VALUE	13.345	

*P<0.05 is statistically significant. T test analysis showed statistical significance in Chromium group (p<0.05) between test and control in Group A.

Table 9. Comparison of Chromium concentration between control and test – Group B

CHROMIUM	GROUP B	
	CONTROL	**TEST**
MEAN	0.2357	0.6059
SD	0.0151	0.1321
P VALUE	**0.001***	
T VALUE	8.807	

*P<0.05 is statistically significant. T test analysis showed statistical significance in Chromium group (p<0.05) between test and control in Group B.

Table 10. Comparison of Chromium concentration between control and test -Group C

CHROMIUM	GROUP C	
	CONTROL	**TEST**
MEAN	0.2402	0.4596
SD	0.0122	0.0562
P VALUE	**0.001***	
T VALUE	13.261	

*P<0.05 is statistically significant. T test analysis showed statistical significance in Chromium group (p<0.05) between test and control in Group C.

Table 11. Comparison of Chromium concentration between control and test – Group D

CHROMIUM	GROUP D	
	CONTROL	**TEST**
MEAN	0.2367	0.3873
SD	0.0182	0.0757
P VALUE	**0.001***	
T VALUE	6.752	

*P<0.05 is statistically significant. T test analysis showed statistical significance in Chromium group (p<0.05) between test and control in Group D

Table 12.1. Comparison of concentration of Chromium within control groups

CONTROL	CONCENTRATION OF CHROMIUM			
	GROUP A	**GROUP B**	**GROUP C**	**GROUP D**
MEAN	0.2283	0.2357	0.2402	0.2367
SD	0.0332	0.0151	0.0122	0.0182
P VALUE	0.1023			

*****P<0.05 is statistically significant

Table 12.2. The results of the one-way ANOVA.

	Sum of squares	df	Mean Squares	F	sig
Between Groups	0.0020	3	0.0007	2.2222	0.1023
Within Groups	0.0108	36	0.0003		
Total	0.0128	39			

Table 12.3. Post Hoc Tukey's HSD Test

Group(I)	Group(J)	Mean difference (I-J))	95% of confidence interval		P VALUE
			Lower	upper	
Group 1	Group 2	0.0100	-0.0109 to	0.0309	0.5745
	Group 3	0.0200	-0.0009 to	0.0409	0.0643
	Group 4	0.0100	-0.0109 to	0.0309	0.5745
Group 2	Group 3	0.0100	-0.0109 to	0.0309	0.5745
	Group 4	0.0000	-0.0209 to	0.0209	--
Group 3	Group 4	0.0100	-0.0309 to	0.0109	0.5745

*P<0.05 is statistically significant. Within group analysis by ANOVA and Post Hoc test of control group (chromium) showed no statistical significance between the A,B,C & D groups(p>0.05)

Table 13.1. Comparison of concentration of chromium within test groups

TEST	CONCENTRATION OF CHROMIUM			
	GROUP A	**GROUP B**	**GROUP C**	**GROUP D**
MEAN	0.4395	0.6059	0.4596	0.3873
SD	0.042922	0.132123	0.056281	0.075775
P VALUE	**0.000***			

*P<0.05 is statistically significant

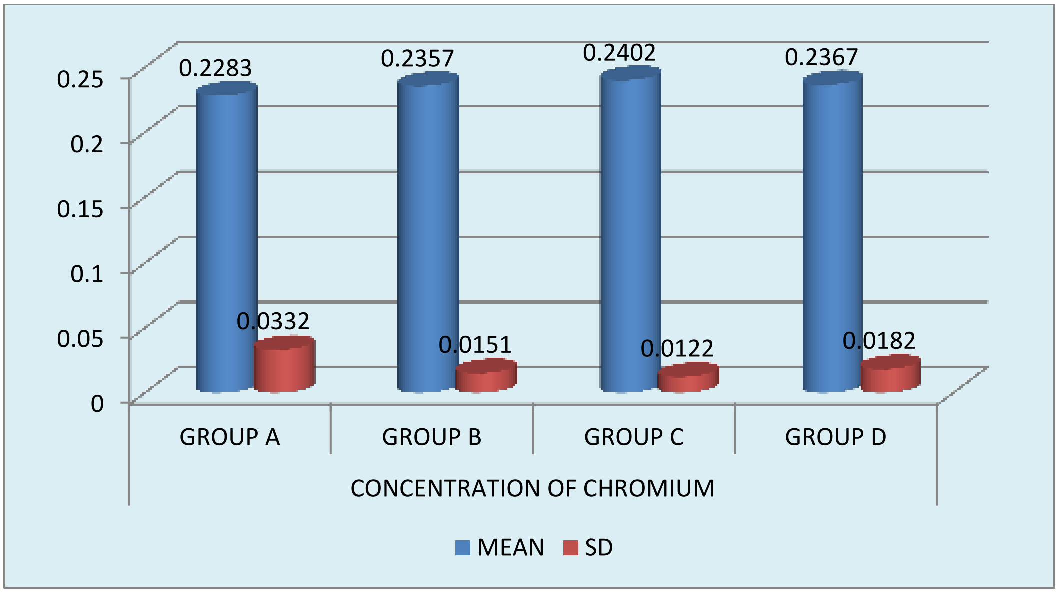
Table 13.2. The results of the one-way ANOVA.

	Sum of squares	df	Mean Squares	F	sig
Between Groups	0.2617	3	0.0872	13.4728	**0.000***
Within Groups	0.2331	36	0.0065		
Total	0.4948	39			

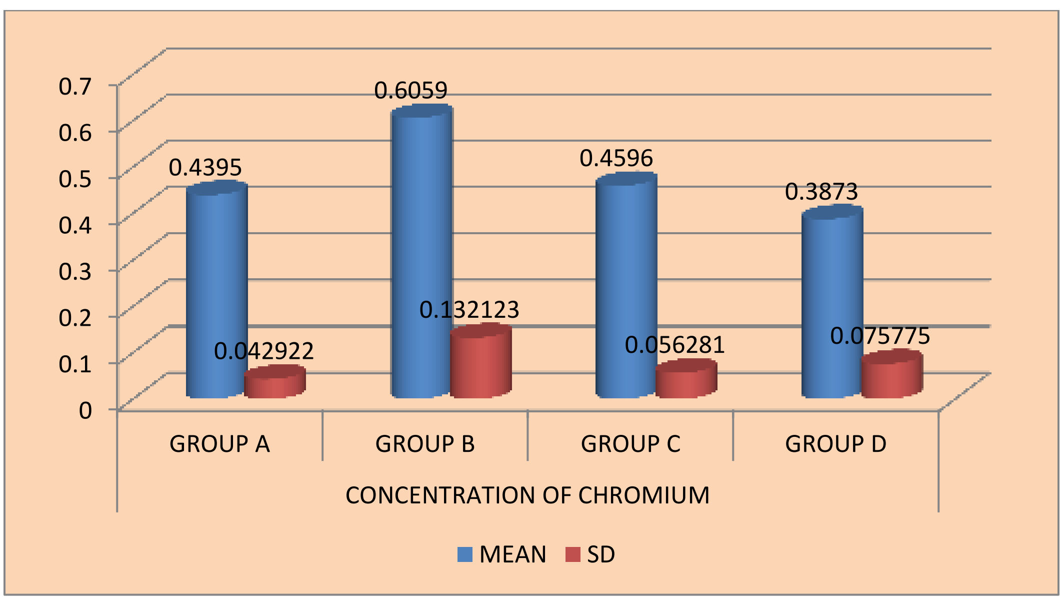
Table 13.3. Post Hoc Tukey's HSD Test

Group(I)	Group(J)	Mean difference (I-J))	95% of confidence interval		P VALUE
			Lower	upper	
Group 1	Group 2	0.1660	0.0691 to	0.2629	**0.0003***
	Group 3	0.0200	-0.0769 to	0.1169	0.9444
	Group 4	-0.0520	-0.1489 to	0.0449	0.4805
Group 2	Group 3	-0.1460	-0.2429 to -	0.0491	**0.0014***
	Group 4	-0.2180	-0.3149 to -	0.1211	**0.0000***
Group 3	Group 4	-0.0720	-0.1689 to	0.0249	0.2066

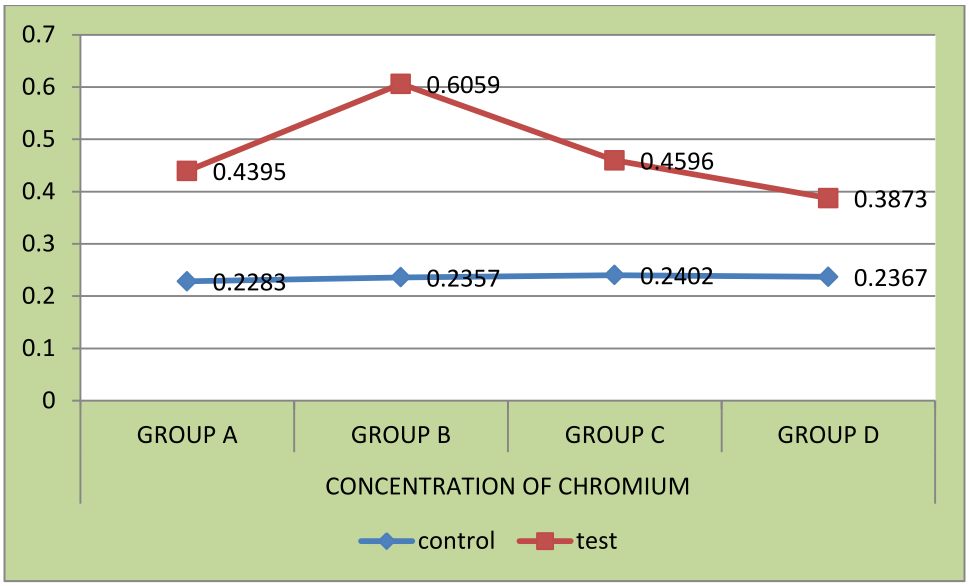
*P<0.05 is statistically significant. Within group analysis by ANOVA and Post Hoc test of test group (Chromium) showed statistical significance between the Group A vs B, Group B vs C& Group B vs D (P<0.05)



Graph 4. Concentration of Chromium in control groups.



Graph 5. Concentration of chromium in test groups.



Graph 6. Comparison of Chromium concentration in control and test groups.

DISCUSSION

DISCUSSION

There was a great revelation in the communication system by the invention of mobile phones by Motorola in 1973. This instant communication system gained rapid popularity because of its reduced size, portability and ease of use. But the long duration of calls and the proximity of mobile phones to the body during use have given rise to concerns of possible adverse effects resulting from absorption of these emissions by tissues that are adjacent to the instrument.

Mobile telephone system operates by two-way radio communication between a portable handset and the nearest base-station. The radio communication utilizes electromagnetic waves, specifically radiofrequency (RF) waves and microwaves.[41] Cellular telephones and their base stations transmit and receive radiofrequency signals in the range of frequencies between 800 and 2200 MHz.[24, 65] The radiation emitted is non-ionizing and the rate of exposure is defined as the rate of RF energy absorption in a weight or mass unit of a biologic body. It is measured by SAR (specific absorption rate).[41] The proximity of mobile phones to the body during use and long duration of calls has given rise to concerns of possible adverse effects resulting from absorption of these emissions by tissues that are adjacent to where the phone is held.

In the oral environment, biodegradation of metals occurs usually by electrochemical breakdown. This phenomenon requires an electrolyte and two electrodes made of dissimilar metals or a concentration cell solution.[66] In the oral environment the saliva with ions and non-electrolytes flow constantly against wires, brackets and bands. Galvanic differences between metal alloys and physiological fluids in the oral cavity can trigger electrochemical reactions which can further lead to corrosion. Generally, corrosion processes occur from the progressive dissolution of a surface film or loss of metal ions directly into solution.[48]

Among these leaching products, nickel is the most common metal to cause contact dermatitis in orthodontic patients. It has been suggested that a threshold concentration of approximately 30 ppm of nickel may be sufficient to elicit a cytotoxic response.[9] Nickel sensitization is believed to increase by mechanical irritation, skin maceration and oral mucosal injury, all of which may occur in orthodontic treatment.[9] Intraoral Signs and symptoms of nickel allergy are Stomatitis with mild to severe erythema, peri-oral rash, loss of taste or metallic taste, burning sensation, angular cheilitis and severe gingivitis in the absence of plaque. Extraoral Signs and symptoms include generalized urticarial changes, widespread eczema and flare-up of allergic dermatitis.[9]

Chromium also reported to have dermatological, toxicological and mutagenic effects.[11] Chromium allergy is estimated at 10% in male subjects and 3% in female subjects.[11] In adult human subjects, the lethal oral dose is considered to be 50 –70 ppm.[67]

The aim of this study was to determine the effect of mobile phone radiation on metal ion release in 4 different commercially available straight wire brackets. Among these 4 groups, two were standardized and 2 were generic brackets. Nowadays arrays of bracket systems are available in the market. An orthodontist has the freedom to select the brackets according to the treatment requirements. More than the bracket prescription and design, cost is also a major factor in choosing an appliance. In case of generic products, the quality of materials may be compromised and the substandard supplies can cause certain health hazards. Selection of the orthodontic bracket system on the basis of the alloy and manufacturing process is fundamental for biocompatibility. Several studies have reported that the two characteristics - the alloy and the manufacturing process are the main factors influencing the corrosion of brackets.[4, 68] This study is designed to analyze the difference in metal ion release from different commercially available orthodontic bracket systems with respect to mobile phone radiation.

The wire patch cell antenna is a specialized device that can be used in biological studies. It is designed for exposing cell cultures during in-vitro experiments to study the possible effects of mobile phone radiations. This small open device is easy to construct and fits into an incubator. The incubator shields the exposed specimens from external disturbances.[64] Instead of a Radiofrequency (RF) Generator, this antenna is directly connected to the GSM module. The samples are exposed to mobile phone radiation 2 hours per day for 6 weeks.

Titto Varghese et al conducted a study in 2013, to analyze the media (including the traditional media) habits of teenagers in terms of the time spent for it, place and medium of accessing internet and the motivations for the usage of these media.[69] According to this study, 51% of the teenagers in Trivandrum City own a mobile phone. About 12% of the students do not use mobile phone at all whereas 39.4% use mobile for 15 minutes or less; 22.7% use it up to 30 minutes; 20.3% use it from half an hour to 2 hours and 5.6% spend more than 2 hours on mobile every day.[69] There are students who use mobile phone for more than 5 or 6 hours daily. Among the 283 students with mobile phones 64% are boys. Those who use mobile phones for more than two hours, 71% are boys. Internet is used not much for education purpose both by boys and girls.[69] More time in internet is spent on Social Networking sites compared to the time they spend for educational needs. It is estimated that 38.3% spend less than 1 hour for internet daily; 20% spend 1 to 2 hours; 15.6% spend 2 to 3 hours; 10% each spend 3 to 4 hours and 4 to 5 hours daily. Almost 4.5% spend more than 5 hours for internet daily. [69] It must be noted that almost 42% of the teenagers spend more than 2 hours on internet daily and among them only a negligible percentage of students use it for education purpose.[69] In view of the results of this study, average phone usage among the teenagers is taken to be 2 hours per day. Thus an average time of daily exposure of the specimen in this study is chosen to be 2 hours.

Several studies have demonstrated that levels of metal release from fixed orthodontic appliances peak at day 7 and that all the release is completed within four weeks. [6] Considering this, orthodontic brackets were kept in artificial saliva of neutral pH at 37°C for six weeks.

When nickel-sensitive patients were exposed intraorally to a nickel-chromium base metal alloy, 30% had an allergic reaction within 48 hours.[18] Interestingly, it was found that intraoral exposure in the sensitive patient can result in an exasperation of previous reaction sites elsewhere on the body, even in the absence of intraoral symptoms. [18] These symptoms subsided within one or two days, after removal of the intraoral base metal alloys. Immunologically, sensitivity to a substance is a systemic phenomenon not confined to one tissue even though it could be expressed in just one tissue.[18] With saliva acting as an electrolyte to leach out metal ions from the appliance, it should be expected that metal-sensitive patients would also have a positive response.[18] On the basis of available evidence and the potential risks that might be anticipated with intraoral exposure to nickel and chromium containing alloys, the use of these alloys is contraindicated in sensitive patients or in patients with suspected sensitivity.[18]

The outcome of this study is the significantly higher release of Nickel ions in radiation exposed generic bracket samples and significant Chromium ions release in all radiation exposed bracket samples. The result suggests the positive effect of mobile phone radiation on metal ion release in orthodontic patients.

Although the mobile phone radiation did not have much effect on the general level of nickel concentration of saliva in all bracket groups, it cannot be ignored that minor amounts of nickel leached out from appliances could be of significance in cases of hypersensitivity to nickel.[23] Minor concentrations of nickel on the oral mucosa might be sufficient to elicit allergic reactions, though the increased nickel ion concentration in the saliva may not be quantifiable. The clinician should be aware that release of nickel and chromium from orthodontic appliance composed of these metals, might sensitize patients and may cause secondary hypersensitivity reactions in patients with a prior history of hypersensitivity to these metals.[23] Moreover, there exists a possibility for induction of immunological tolerance to nickel and chromium through prolonged presence of orthodontic appliances in oral cavity.[23]

The question which remains unanswered is whether long-term intraoral exposure to a nickel containing dental alloy can result in induced nickel sensitivity.[18] On the basis of the study by Prystowsky, there is presumptive evidence to indicate that increased exposure to a potential sensitizing agent can result in an increased sensitivity.[17] Of particular importance was the positive finding that piercing of ears, or the insertion of a transcutaneous implant, resulted in a 6 to 33 fold increase in the incidence of nickel sensitivity. It would appear that the liberation of nickel ions directly into the human system may be responsible for the dramatic increase in the incidence of nickel sensitivity. The release of metal ions from base metal alloys has also been reported as detectable in tissues after implantation, as reagents causing positive cytotoxicity in vitro, and from some corrosion-susceptible nickel-chromium alloys. It may be envisioned that the placement of a nickel-containing dental alloy into the gingival sulcus, as in the case of a fixed prosthesis, would, in a similar manner, enhance the liberation of nickel directly into the human system via the crevicular fluid flow mechanism. As has been well documented, the crevicular fluid flow increases significantly with gingival inflammation, which is common in association with ill-fitting fixed prostheses. In addition, there is minimal cornification of the crevicular epithelium, which, on the basis of other observed nickel sensitivity elsewhere on the body, would also leave that tissue more susceptible to sensitization.[18]

Saghiri et al. (2015) found that mobile phone use has a time dependent effect on Nickel ion release.[13] A similar study conducted by Nanjannawar et al in 2017 concluded that longer the exposure to RFER emitted by a mobile phone, the greater the concentration of nickel in saliva.[56] These researchers have attributed their findings to alteration in physical characteristics of saliva, variations in pH and temperature differences.

The effects of using mobile phones on the salivary flow characteristics and parotid glands have been studied by other researchers. Goldwein reported significantly higher saliva secretion rate in the dominant mobile phones handheld side compared with that in the non-dominant side.[41] Lower total protein concentration was obtained in the dominant compared with the non-dominant handheld mobile phones side among the right dominant users.[41]

The anatomic location of the parotid gland (at the anterior border of the external ear and between the mandibular ramus and the sternocleidomastoid muscle, 4- to 10-mm deep under the skin surface) makes it a conceivable candidate to be influenced by exposure to radiofrequency electromagnetic radiation (RFER) on the side of the head where the mobile phone is held.[13] Heavy users of mobile phones demonstrated increased rates of salivary flow and blood flow, and greater volumes of the parotid glands.[49] The increase in salivary flow rate is known to have a diluting effect, mostly on salivary macromolecules and to a lesser extent on ions, since the ions diffuse relatively easily along with the watery secretions.[13] Kalati FA et al., showed that cell phone usage decreases total antioxidant capacity of saliva.

The heating of biological tissue is a result of microwave energy absorption by the water content of the tissues.[24] Specific energy absorption rate (SAR) is the rate at which energy is absorbed in body tissues, in watt per kilogram (Wkg^{-1}).[70,71] When electromagnetic waves propagate through the human tissues, the energy of these waves is absorbed by the tissues. Interaction of electromagnetic fields with biological tissues can be defined in term of specific absorption rate (SAR). The specific absorption rate is defined as power dissipation rate normalized by material density. It is found that the SAR distribution pattern in the human head is depended on the effect of the frequency and the dielectric properties of human tissues. With penetration into the head, the SAR values decrease rapidly along the distance. For the human head exposed to the mobile phone radiation, the temperature within the human head increases corresponding to the specific absorption rate.[50] An increase in temperature affects the resistance to localized corrosion by reducing the ability of the material to repassivate.[13] Temperature can also affect the nature of the environment by changing the solubility of a constituent that can affect the corrosion behavior of a material.[13]

It was also claimed that, mobile phone radiation can change the pH of the saliva. A temporary decrease in pH of saliva in patients exposed to mobile phone radiation were reported in previous literatures.[48, 60] All these changes in physical properties of saliva and temperature might increase the corrosion rate of orthodontic appliances and influence the passive layer on the metal surface.

An in-vitro study may not be able to reflect all the highly complex and dynamic properties of oral environment. In experimental condition, the rate of corrosion depends on the composition of material, process of manufacturing, alloy type and the properties of the surface of these devices. But in an in-vivo study, metal corrosion and subsequent ion concentration can be attributed to the composition and flow characteristics of saliva, dietary intake, systemic conditions, activation and fiction of orthodontic appliances, and physical and chemical agents like tooth brushing, mastication that disrupts the protective oxide layer.

Three principal methods are used to manufacture brackets, namely casting, milling, and powder sintering techniques.[22] Cast and sintered brackets are manufactured in a near-finished condition, but with milled brackets, the slots and wings are machined into lengths of rolled strips that are then cut into individual brackets.[22] Variations in manufacturing technique as well as post manufacture finishing and polishing operations can have an effect on the corrosion behavior of the brackets. Studies have shown that brackets of the same composition can exhibit significantly different corrosion behavior in an in vitro artificial saliva exposure test.[68]

The microstructure of a metal is a basic parameter that affects its mechanical properties and particularly, its corrosion behavior. The microstructure is affected by alloying, heat treatment, and cold working which in turn alter the chemical and physical properties of the metal. The metallurgical structure of both cast and sintered metal brackets are influenced by the homogeneity and internal structure- both of which are determined by the alloy composition, the casting or sintering conditions and the internal particle or grain size.[22] Cold work introduced during milling and cutting of the bracket will affect the slot area of the bracket, which in turn may result in galvanic couples being established between the slot area and adjacent (unworked) areas. Furthermore, some manufacturers use steel of a different composition for the mesh or adhesive base of the bracket, which may establish galvanic couples between the mesh and the bracket material, especially cold-worked areas such as the slots and wings. Likewise, the soldering or welding of the adhesive base to the bracket may also result in corrosion couples.[22] Post manufacture surface finishing procedures will influence corrosion behavior.[22] Many manufacturers electro polish their brackets to improve the appearance and reduce corrosion susceptibility, but it is also possible for galvanic corrosion cells to be established between electropolished and nonpolished areas such as bracket slots. Some commercial brackets are available with a gold finish that is produced either by gold electro deposition or plasma arc deposition of titanium nitride (TiN) onto the metal surface. Such surface treatments may reflect esthetic considerations, and although the effects of the coatings are unknown, it is possible that the TiN coatings may improve both the corrosion and wear resistance of the bracket. It also should be noted that certain types of spring wires, namely the cobalt-chromium, nickel-titanium and β-titanium wires, should be noble to the stainless steel brackets and be protected from corrosion.[22]

Although, the level of nickel and chromium released after exposure to radiofrequency electromagnetic radiation emitted from mobile phones was far below the toxic level and the recommended dietary intake, even these low concentrations might be sufficient to induce biologic toxicity. Multiplying these values to simulate the equivalent release from a fully banded or bonded maxillary and mandibular appliance will be higher than the results obtained from this study. Hence precautions should be taken to limit the release of these metal ions from orthodontic brackets at any cost.

This study investigated the effect of RFER produced from a single device, which may affect the ion release from brackets. But there are multiple sources that emit RFER like Wi-Fi device and mobile phone base stations which in turn can increase the radiation exposure and subsequently the ion release. Therefore in an in-vivo condition, the net RFER exposure effect will be a cumulative effect from all those sources.

To avoid the release of nickel, manufacturers have designed the cobalt-chromium bracket. Because this is essentially nickel-free, it would substantially reduce the release of nickel in vivo as compared with stainless steel brackets and thus would be more suitable for the nickel-hypersensitive patient. [25]

Institute of Metallurgy of ETH Zurich developed a new type of austenitic steels. The most important feature of this steel is the complete absence of nickel as alloying element. The austenitic microstructure is obtained exclusively by adding nitrogen. Besides being nickel free, the steel is further characterized by an excellent corrosion resistance, the absence of ferromagnetism, and outstanding mechanical properties. The unique combination of these properties makes this steel most interesting for its use in items which are in direct contact with the human body. By using these new steels also, nickel allergy can be prevented.[72]

Stainless steel brackets have low nickel content (6%) and are considered safe. However, nickel free alternative brackets to stainless steel include: ceramic brackets produced using polycrystalline alumina, single-crystal sapphire, and zirconia;

polycarbonate brackets that are produced from plastic polymers; titanium brackets; and gold-plated brackets. Extra-oral metal components, including metal studs in headgear, are of greatest concern due to greater sensitivity of the skin. Plastic-coated headgear studs are available and may be a better alternative to simply wrapping a bandage around the metal component.[9]

According to the outcomes of the study, it can be concluded that mobile phone radiation, can influence the release of nickel and chromium from orthodontic brackets. This adverse effect of radiation on the release of nickel was more prominent in a generic bracket group and chromium in all bracket groups used in this study. It might be significant in high-risk patients, even though the level of the nickel released was below the toxic level to cause concern in healthy people. The biocompatibility should be the prime factor for choosing material rather than cost and availability to deliver proper and quality treatment.

Limitations of the study:

The study was conducted in an in vitro study setting where in the replication of an oral environment is a challenging task. The study tried at its level best to incorporate most of the in vivo conditions such as normal oral temperature, pH, and salivary components. Being an in vitro study, replicating enzymatic activities, microbial activities, simulation of friction between arch wires and brackets, routine dietary influence, plaque etc. which contributes to metal corrosion, was not able to recreate. Difficulty in simulating a complete in vivo environment remains as a major drawbacks of the study. Hence further in-vivo studies will give more insights in to this subject.

In this study, single brackets from different manufacturers were used. But in fixed appliance therapy, this effect has more intensity taking into consideration the number of brackets, arch wires, auxiliaries etc. Therefore the results obtained from this study have great relevance in clinical scenario, since multibracket appliance is used. Further investigations and researches have to be conducted in this subject to obtain more concrete results

CONCLUSION

CONCLUSION

1. Nickel ion release from one of the generic bracket was greater than the standardized brackets when exposed to mobile phone radiation.
2. Both Mobile phone radiation-exposed and non-exposed standardized brackets didn't show any significant difference in Nickel ion release.
3. A definite association was observed between Mobile phone radiation and Chromium release from all the four Orthodontic bracket groups.

Technological advancement has made our life easy. Today we can comprise the whole world on our fingertip. Hence a life without mobile phone has become almost unimaginable. Despite these facts, the detrimental effect of radiation from the mobile phones is always a cause of concern.

The study was an attempt to evaluate the effects of mobile phone radiation on metal ions release from different commercially available brackets. A significant difference was observed in Nickel ion concentration in irradiated generic bracket compared to other three bracket groups. The Chromium release was found to be significant in all the radiation exposed samples.

Being an orthodontist we must be concerned about the biocompatibility of every single product that we deliver to our patients. Previous literatures have reported emerging risk of radiation from mobile phones triggering the release of certain sensitive elements from the metal components and auxiliaries that we use in our orthodontic practice. This study has made an attempt to evaluate one of those detrimental effects associated with this modern gadget.

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ANNEXURES

ANNEXURES

Annexure 1. Concentration of Nickel in control groups

Group	A	B	C	D
X1	0.007	0.007	0.003	0.007
X2	0.007	0.002	0.002	0.005
X3	0.007	0.007	0.008	0.008
X4	0.007	0.008	0.006	0.007
X5	0.006	0.007	0.006	0.009
X6	0.006	0.004	0.008	0.009
X7	0.009	0.008	0.004	0.005
X8	0.005	0.009	0.01	0.007
X9	0.008	0.006	0.009	0.008
X10	0.008	0.003	0.008	0.004
Average	0.007	0.0061	0.0064	0.0069

Annexure 2. Concentration of Nickel in test groups.

Group	A	B	C	D
X1	0.01	0.005	0.005	0.006
X2	0.004	0.005	0.008	0.006
X3	0.011	0.005	0.006	0.007
X4	0.004	0.008	0.008	0.014
X5	0.007	0.004	0.006	0.009
X6	0.007	0.006	0.008	0.008
X7	0.008	0.007	0.005	0.005
X8	0.009	0.009	0.007	0.009
X9	0.006	0.008	0.009	0.008
X10	0.007	0.006	0.008	0.008
Average	0.007	0.006	0.007	0.008

Annexure 3. Concentration of Chromium in control groups.

Group	A	B	C	D
X1	0.284	0.21	0.306	0.265
X2	0.173	0.259	0.231	0.252
X3	0.231	0.228	0.231	0.301
X4	0.263	0.242	0.215	0.303
X5	0.198	0.222	0.308	0.302
X6	0.217	0.24	0.265	0.305
X7	0.211	0.239	0.253	0.313
X8	0.225	0.255	0.215	0.268
X9	0.258	0.232	0.212	0.278
X10	0.223	0.23	0.233	0.264

Annexure 4. Concentration of Chromium in test groups

Group	A	B	C	D
X1	0.465	0.768	0.496	0.466
X2	0.508	0.851	0.506	0.487
X3	0.368	0.431	0.398	0.324
X4	0.436	0.532	0.403	0.286
X5	0.495	0.527	0.516	0.383
X6	0.393	0.656	0.428	0.291
X7	0.449	0.689	0.474	0.437
X8	0.423	0.503	0.382	0.349
X9	0.417	0.516	0.546	0.374
X10	0.441	0.586	0.447	0.476

Annexure 5

ST.GREGORIOS DENTAL COLLEGE

UNDER THE MANAGEMENT OF MJSCE TRUST, PUTHENCRUZ
CHELAD, KOTHAMANGALAM, ERNAKULAM DIST, KERALA - 686681

ETHICAL CLEARANCE CERTIFICATE

SGDC/152/2017/1733/1 Date:- 20-10-2017

To,

Dr. Vincymol J
St. Gregorios Dental College
Chelad, Kothamangalam

Dear Dr. Vincymol J,

Subject: - Ethics Committee Clearance Reg.

Protocol – An in vitro comparative study on the effect of mobile phone radiation exposure on metal ion release from four different bracket systems.

After the Institutional Ethics Committee (IEC) held on 20th of October 2017, this study was examined and discussed. After the consideration, the committee had decided to approve and grant clearance for the aforementioned study.

The members who attended the meeting at which the protocol was discussed were:-

1. Dr.CKK Nair - Former BARC scientist
2. Dr.Ommen Aju Jacob - Dean, St. Gregorios Dental College, Chelad
3. Dr.Cinu Thomas A - Scientist, Senior Lecturer, Department of Pharmaceutical Sciences Centre for Professional and Advanced Studies
4. Rev. Fr. Shanu K. Paulose
5. Lissy Jose – Former Member Women's Welfare Association
6. Adv. Jose Aranjani - Advocate
7. Dr.Sauganth Paul - Senior Lecturer, Department of Biochemistry, St.Gregorios Dental College
8. Dr.Eapen Cherian - Secretary
9. Dr.Jain Mathew - Principal and Head of the Department, Department of Conservative Dentistry and Endodontics.
10. Dr. George Francis - Head of the Department, Department of Prosthodontics Crown & Bridge
11. Dr.Binnoy Kurian - Head of the Department, Department of Orthodontics & Dento-facial Orthopedics

Dr.CKK Nair
Chairman Institutional Ethics Committee
St.Gregorios Dental College, Chelad

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Dr Vincymol J

ABBREVIATIONS

Abbreviation	Description
Cr	Chromium
EMR	Electromagnetic Radiation
EMW	Electromagnetic wave
Fig	Figure
GSM	Global System for Mobile communication
ɥg	Microgram
MHz	Megahertz
ml	Milliliter
mm	Millimeter
Ni	Nickel
Ni- Ti	Nickel- Titanium
NiACS	Nickel induced Allergic Contact Stomatitis
PGT	Parotid gland tumors
ppm	Parts per million
RFER	Radio Frequency Electromagnetic radiation
SD	Standard Deviation
SS	Stainless Steel
Ti	Titanium