24th INTERNATIONAL CONGRESS ON SOUND AND VIBRATION
23–27 July 2017, London

ROLE OF ULTRASOUND IN CELLULAR PHONE HYGIENE

Meena Sharma

K J Somaiya College of Science & Commerce (University of Mumbai), Mumbai, 400 077, India

Neha Sharma

University of Salford, Acoustics Research Centre, Salford, M5 4WT, United Kingdom
email: n.sharma2@edu.salford.ac.uk

Cellular phones and its accessories often harbour various microorganisms, particularly in the regions that lack potable water and good sanitation. A constant use of such mobile phones thus serves as potential carriers of bacterial infection. The present study aims to establish the role of ultrasound in controlling microbial growth present on the surface of the mobile phones for better cellular phone hygiene.
The presence of microbial load was assessed; microbial contaminants were identified and later exposed to the non-invasive ultrasound at different frequencies and with varying time of exposure. Considering the findings of this study, it can be concluded that ultrasound does have inhibitory effect on the growth of bacterial agents present on the surface of the mobile phones. However, more exposure time at higher frequencies in continuous mode could reduce the growth of microbes to a certain extent. The future scope of this on-going research work is to carry out an in-depth controlled study for achieving a complete cleansing effect of the cellular phones.

Keywords: Cellular Phones, Microbial Load, Non Invasive Ultrasound, High Frequency, Exposure Time

1. Introduction

The global system for mobile telecommunication was established in 1982 in Europe with a view of providing and improving communication network. Today, cellular phones have become one of the most indispensable accessories of professional and social life. The dizzying pace of modern life demands that people stay in constant contact via their mobile phones. Cellular phones aren't just for talking anymore, but to send text messages, e-mails and photos, as well browse internet sites, play video games and hold hundreds of music files. Since mobile phones have become so vital to everyday life, carrying out routine maintenance tasks on these phones is just as important. Although they are usually stored on bags or pockets, mobile phones are handled frequently and held close to face [1, 2]. Countries where potable water and good sanitation are limited, inhabitants are exposed to the risk of contracting infections because these individuals carry phones, and the potential of such accessories, as cellular phones in the spread of bacterial infection is not yet clear [3, 4]. However, due to their constant use, mobile phones can also serve as a home for various microbes.

The first study of bacterial contamination of mobile phones was conducted in a teaching hospital in Turkey with a bed capacity of 200 and one intensive care unit [5]. One-fifth of the cellular phones examined in yet another study conducted in New York were found to harbor pathogenic microorganisms [6]. The contamination rate varied from 95.65 percent in mobile phones of staff members to 100 percent that of trainees in an Indian dental school [7]. For many years, physicians, dentists and other medical professionals have used different means for cleaning and sterilizing their equipment. Mobile phone users may also use some of these means including the use of alcohol or liquid ultrasonic cleaners, to remove many of the bacteria and viruses that can cling to the surfaces of their phones. In one of the studies[7], mobile phones after being cleaned with 70 percent isopropyl alcohol swabs, carried fewer bacteria. Simple cleaning of the cell phones with 70 percent isopropyl alcohol could completely disinfect only twenty-two out of forty-nine contaminated cell phones. In the remaining phones, there was a significant reduction in the number of colonies. Similar efficacy of alcohol in cleaning mobile communicating devices has also been demonstrated previously [6, 8]. Previous studies on mobile communicating devices decontamination have demonstrated no adverse events during decontamination protocols [9, 10].

Many smart phone users are opting to use ultrasonic cleaners to remove dust, sweat and other particles from these sensitive instruments. Mobile phone users also use their ultrasonic cleaners to remove many of the bacteria and viruses that can cling to the surfaces of their phones, which comprises of an electronic transducer, similar to those found in stereo speakers and amplifiers, attached to a vibration-resistant metal tank. When the user fills the tank with water and cleaning solution, the transducer produces high-frequency sound waves that agitate the water, forming millions of microscopic bubbles. These bubbles reach into the narrow crevices and tiny holes that hand-cleaning methods can't touch. When the bubbles implode (a process called "cavitation"), they loosen and carry off the contaminating particles. Yet the situation still remains confounded by the lack of guidelines available and the fact that some manufacturers advise against the use of any cleaning fluids [11, 12].

In light of these facts that the cellular phones carry a potential microbial threat not only to the individual carrying and using it but also in spreading among others coming in close contact of the mobile phone user, the present study was undertaken. One of the main objectives, therefore, was to assess the presence of microbial load on the mobile phones, collected randomly. Further, to identify the microbial contaminants found on the cellular phones under study and to be exposed to the non invasive ultrasound to establish its effect on microbial growth present on the surface of the mobile phones.

2. Methodology

In the present study, microbial load and their type were assessed in the microbiological laboratory using standard procedures. Thereafter, in the laboratory, ultrasound was used at different frequencies for varying time period to establish its effect on the microbial growth of commonly occurring microbes. *In situ* studies were then carried out wherein ultrasound was used on mobile phones to observe the effect on the growth of the microbes present on the surface of the mobile phones.

2.1 Microbiological studies:

A total of 50 mobile phones randomly collected were sampled. The samples were collected aseptically using dry sterile cotton swab by rotating over all exposed outer surfaces of the mobile phones including the keys, mouthpiece, and ear-piece. These cell phones had been used for at least two months. A new pair of latex gloves was worn while sampling each mobile phone to avoid cross-contamination. The samples were then transported within thirty minutes to the microbiological laboratory for culture and identification of bacteria. For assessment of bacterial load these were incubated at 37°C for twenty-four hours. Plates were observed for growth and colonial morphology of the isolates. Culture results were measured as mean number of colony-forming units (CFU). Isolated microorganisms were identified using Gram stain, morphology and all isolates were allocated to the appropriate genera.

2.2 Ultrasound device:

In the present study, ultrasound was delivered with DIGISONIC (HMS Medical Systems, Chennai) operating at frequencies of 1 MHz and 3 MHz, with both continuous and pulsed modes, and intensity up to 3 W/cm^2. As per the study groups shown in Table 1, the surface of the mobile phones in treated groups were insonified for 1, 5, and 10 min duration with an acoustic field produced by the 1 MHz and 3 MHz transducer, operated at an intensity of 1 W/cm^2, in the continuous mode, respectively.

Table 1: Study Groups

Group No	Exposure time	Ultrasound frequency employed
1	1 min	1 MHz
2	1 min	3 MHz
3	5 min	1 MHz
4	5 min	3 MHz
5	10 min	1 MHz
6	10 min	3 MHz

7	Untreated control

3. Results

Out of 50 samples assessed, presence of a bacterial agent was observed in 42 cases. The results showed a very high percentage (84%) of bacterial contamination of mobile phones sampled. These 42 mobile phones were then randomly grouped under seven groups such that each group (treated and untreated control) had six cellular phones.

In all, eighty bacterial pathogens were isolated. *Staphylococcus aureus* was the dominant pathogen followed by *Micrococcus luteus*, *Pseudomonas aeruginosa*, *Proteus mirabilis*, *Escherichia coli*, *Klebsiella pneumoniae*, *Enterobacter aerogenes*, *Bacillus spp*, and *Salmonella typhi*. The distribution of different pathogens isolated is as shown inTable 2.

Table 2: Pathogens isolated from the surface of mobile phones

Bacterial agents isolated	No.	%
Staphylococcus aureus	24	30
Micrococcus luteus	17	21.25
Pseudomonas aeruginosa	13	16.25
Proteus mirabilis	9	11.25
Escherichia coli	8	10
Klebsiella pneumoniae	5	6.25
Enterobacter aerogenes	2	2.5
Bacillus spp	1	1.25
Salmonella typhi	1	1.25
Total	80	100

The percent change in the CFU counts, before and after treatment, in different groups and controls are as shown in the Table 3.

The effect of ultrasound at 1 MHz and 3 MHz frequencies on CFU counts (Mean ± S.D.) of microbes isolated from the surfaces of the mobile phones, with respect to exposure time (1, 5, and 10 minutes) are represented graphically in the Figs. 1 and 2, respectively.

Table 3: Change in the CFU counts under different conditions of ultrasound exposure

Exposure time	Treatment	Frequency	
		1 MHz	3 MHz
1 min	Before	84.33±4.72	77.67±5.32
	After	81.5±4.46	71.67±5.50
	% change	(-) 3.36	(-) 7.72
5 min	Before	84.17±5.53	83.84±.62
	After	75.67±6.44	60.84±4.02
	% change	(-) 10.1	(-) 27.43
10 min	Before	73.34±4.89	85.84±5.60
	After	54.84±3.54	49.84±4.26
	% change	(-) 25.22	(-) 41.94
Control	*0 hrs*	*68.17±3.31*	
	24 hrs	*73.17±4.40*	
	% change	*7.33*	

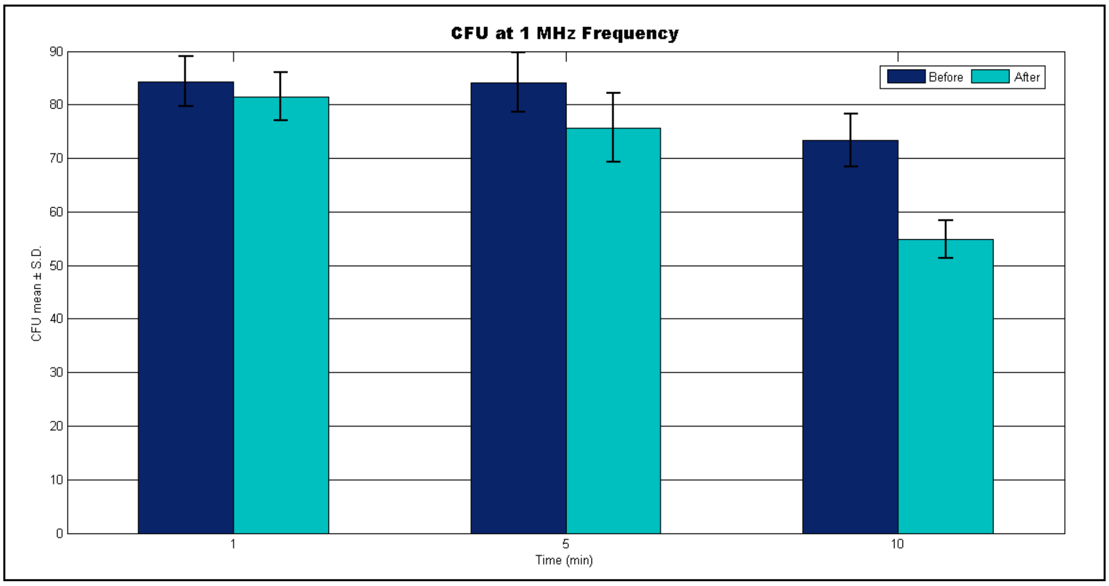

Figure 1: Change in CFU counts at 1 MHz frequency at different exposure time period

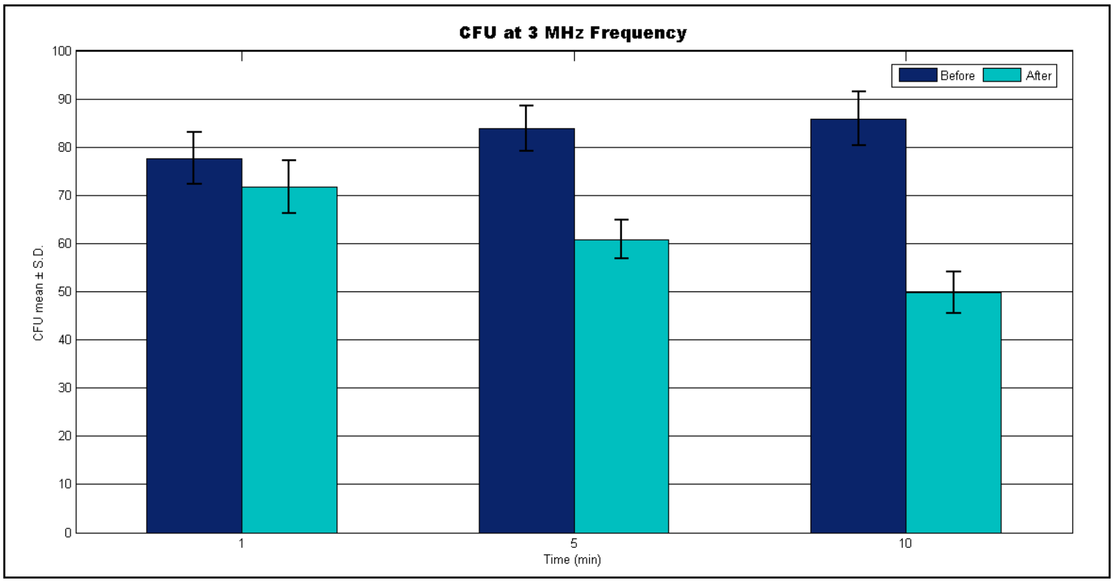

Figure 2: Change in CFU counts at 3 MHz frequency at different exposure time period

Likewise, comparison of CFU counts (Mean ± S.D.) before and after ultrasound exposure at different frequencies (1 MHz and 3 MHz) for fixed time period of 1 min, 5 min, and 10 min is shown graphically in the Figs. 3, 4, and 5, respectively.

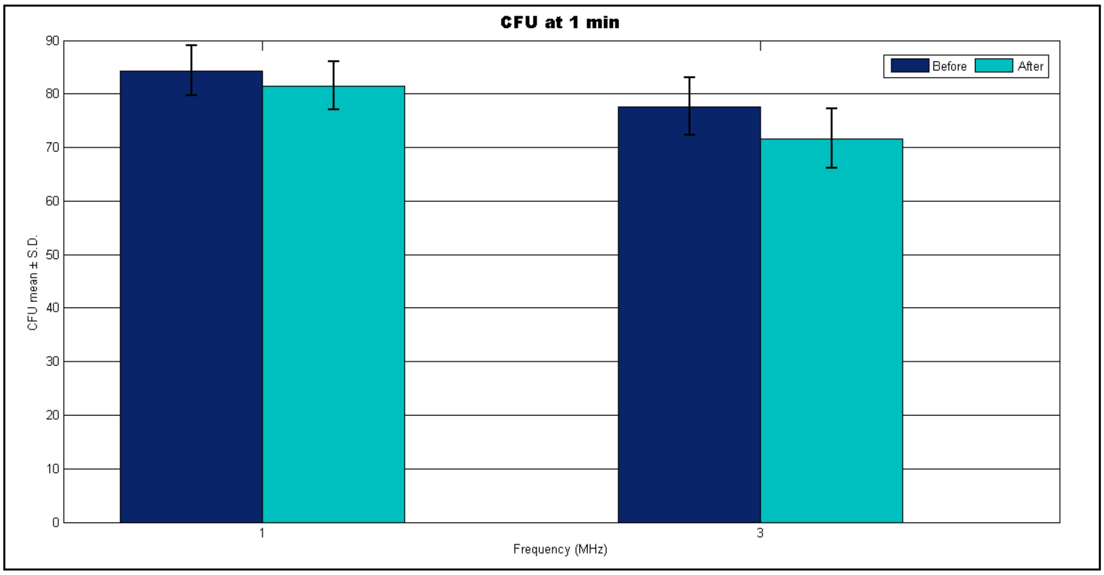

Figure 3: Change in CFU counts after 1 minute of ultrasound exposure

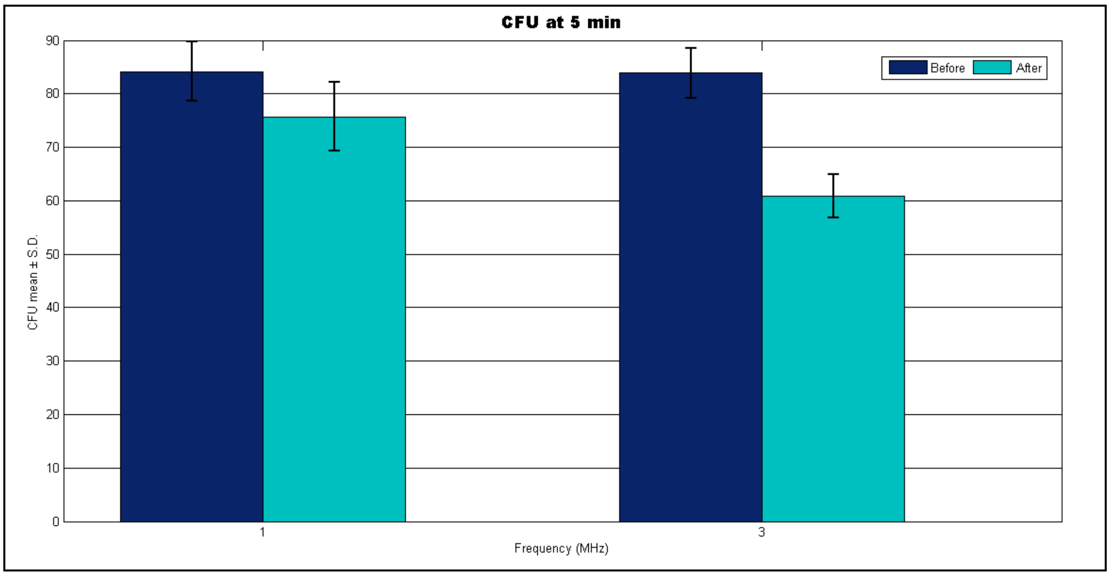

Figure 4: Change in CFU counts after 5 minutes of ultrasound exposure

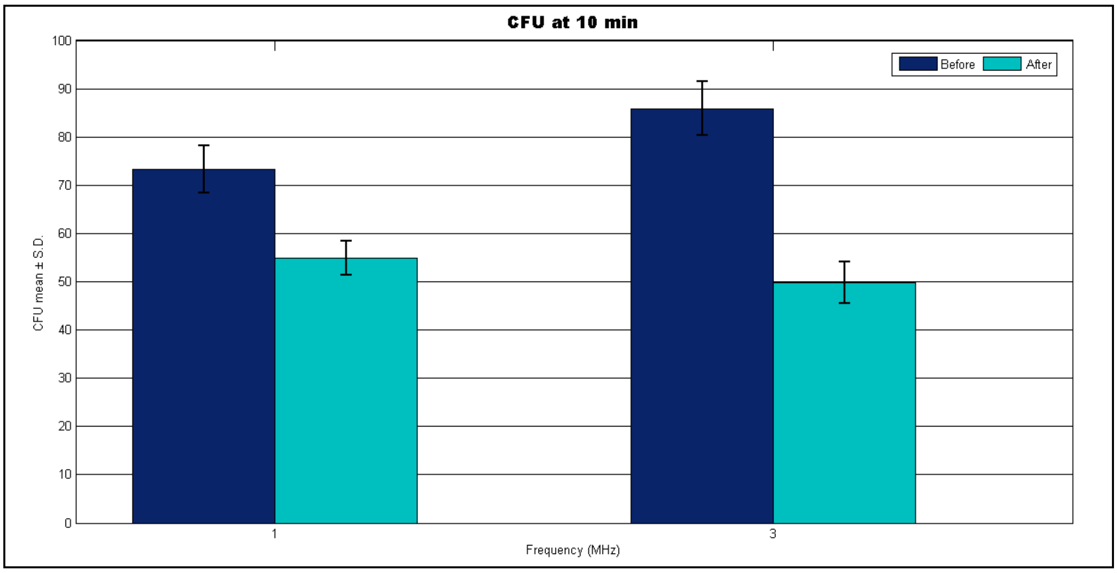

Figure 5: Change in CFU counts after 10 minutes of ultrasound exposure

4. Discussion

Ultrasound is defined as acoustic energy or sound waves with frequencies above 20 kHz. Ultrasonication is commonly thought to be detrimental to cell growth; however, cells can grow in low intensity insonation due to the following properties of ultrasound: 1) its ability to increase the transport of small molecules in solution, and 2) its inability to completely remove cells (or even non-living particles) from surfaces. High intensity (high power density, > 2 W/cm2) and low frequency (<100 kHz) ultrasound is commonly used to clean solid surfaces such as the surfaces of glassware, metallic instruments, plastic parts, and more. Ultrasonic “cleaners” are commonly found in laboratories and industrial settings for such purposes. The mechanism by which dust and particles are removed from these solid surfaces is commonly believed to be related to cavitational events and the related shear forces adjacent to the surface [13, 14, 15, 16].

Ultrasound is known to damage biological cells and tissues through two primary mechanisms, heating and cavitation. Each bubble has a sharply defined resonance frequency that depends upon the bubble size, the composition of any contaminating surface layer, and the characteristics of the surrounding fluid (e.g., viscosity). If the bubble is driven near its resonance frequency, the resulting violent collapse may be symmetrical, producing temperatures in excess of 5,000 K at the collapse point and pressures of thousands of atmospheres that can be measured as acoustic emissions. These conditions are sufficient to produce hydroxyl free radicals. If the bubble collapse is asymmetrical, however, as is the case when the collapsing bubble is within a few radii of a solid surface, a jet of liquid can form that pierces the bubble and strikes the surface at velocities up to 200 m/s. These microjets, which have been shown to be responsible for damage to both kidney and gallstones in lithotripsy, have the ability to puncture or shear cell walls. Sonication is often used by investigators as a method of lysing bacterial cells. It depends upon bubble activity, heating, and the shear forces produced by the sonicator tip itself (“jackhammer effect”). Sonicators such as the Branson W-350 model operate at ultrasonic frequencies in the range of 20 to 25 kHz in a continuous wave or slowly pulsed mode (pulse duration of several seconds). Spatial and temporal average intensities for sonicators are typically a few watts per square centimeter. In contrast, diagnostic (imaging) ultrasound is typically composed of very short pulses (a few microseconds) in the frequency range of 1 to 10 MHz, with spatial peak pulse average intensities (*I* SPPA) of tens or hundreds of watts per square centimeter [17, 18, 19].

The present study elaborates on initial findings to determine whether treatment of bacterial cultures with high-frequency pulses of ultrasound induces specific stress responses. The end product of such an investigation was to determine how much megahertz frequency ultrasound and duration of exposure is necessary to kill bacteria. The microbes present on the external surfaces of the mobile phones were directly exposed to the ultrasonic waves at 1 MHz or 3 MHz frequencies for a time period of either 1 min, or 5 min, or 10 min. The heat generated by the exposure was probably the reason to disrupt the microbial growth. However, even the higher frequency exposure for greater time period could result in a limited success.

5. Conclusion

Considering the findings of the present study it can be concluded that ultrasound does have effect on the bacterial agents present on the surface of the mobile phones. However, more exposure time at higher frequencies in continuous mode could reduce the growth of microbes but with limited success. For complete cleansing effect, an in-depth controlled study is warranted.

6. Acknowledgement

The investigators are highly indebted to the University of Mumbai for funding the present study under Minor Research Project (no. 148 of 2016). Thanks are also due to the Principal and staff of K J Somaiya College of Science & Commerce for extending whole hearted support during the conduct of the present study. Head, staff and the post graduate students of the Department of Microbiology, K J Somaiya College of Science & Commerce needs special mention for their invaluable help rendered in carrying out microbiological work related to this study.

REFERENCES

1. Neubauer G., Röösli M., Feychting M., Hamnerius Y., Kheifets L., Kuster N., Ruiz .I, Schüz J., Überbacher R. and Wiart J. Study on the Feasibility of Epidemiological. Studies on Health Effects of Mobile Telephone Base Stations – Final Report: A workshop Organized by Swiss Research Foundation on Mobile Communication Swiss Agency for the Environment, Forests and Landscape Swiss Federal Office of Public Health FSM – Project No. A2003-9 (2005).
2. Sowah L. N. The future of the Mobile Internet: How do we tap into its fullest benefits? *Technology Blogs*, 1-2, (2008).
3. Brady R. R., Wasson A., Stirling I., McAllister C. and Damani N. N. Is your phone bugged? The incidence of bacteria known to cause nosocomial infection in healthcare workers mobile phones, *Journal of Hospital Infection* **62**: 123-125, (2006).
4. Fleming K. and Randle J. Toys--friend or foe? A study of infection risk in a paediatric intensive care unit. *Paediatric Nursing* **18**: 14-18, (2006).
5. Karabay O., Kocoglu E. and Tahtaci M. The role of mobile phone in the spread of bacteria associated with nosocomial infections, *The Journal of Infection in Developing Countries*. **1**: 72-73, (2007).
6. Goldblatt J. G., Krief I., Haller T. D., Milloul V., Sixsmith D. M,, Srugo I, and Potasman I. Use of Cellular Telephones and Transmission of Pathogens by Medical Staff in New York and Israel, *Infection Control and Hospital Epidemiology* **28**: 500-503, (2007).
7. Sweta Singh, Shashidhar Acharya, Meghashyam Bhat, Sree Vidya Krishna Rao, and Kalyana Chakravarthy Pentapati. Mobile Phone Hygiene: Potential Risk Posed by Use in the Clinics of an Indian Dental School, *Journal of Dental Education*. **74**: 1153-1158, (2010).
8. Brady R. R. W., Verran J., Damani N. N. and Gibb A. P. Review of mobile communication devices as potential reservoirs of nosocomial pathogens, *Journal of Hospital Infections* **71:** 295-300, (2009).
9. Borer A., Gilad J. and Smolyakov. Cell phones and Acinetobacter transmission, *Emerging Infectious Diseases* **11**: 1160-1161, (2005).
10. Hassoun A., Vellozzi E. M. and Smith M. A. Colonization of personal digital assistants carried by health care professionals, *Infection Control and Hospital Epidemiology* **25**:1000-1001, (2004).
11. Braddy C. M. and Blair J. E. Colonization of personal digital assistants used in a health care setting, *American Journal of Infection Control* **33**: 230-232, (2005).
12. Jeske H. C., Tiefenthaler W., Hohlrieder M., Hintergerger G. and Benzer A. Bacterial contamin tions of anaesthetists' hands by personal mobile phone and fixed phone use in the operating theatre, *Anaesthesia* **62**:904-906, (2007).
13. Brennen C. E. *Cavitation and Bubble Dynamics*, Oxford University Press, New York pp 282. (1995).
14. Maisonhaute E., Prado C., White P. C. and Compton R. G. Surface acoustic cavitation understood via nanosecond electrochemistry Part III: shear stress in ultrasonic cleaning, *Ultrasonics Sonochemistry* **9**: 297-303, (2002).
15. Zips A., Schaule G. and Flemming H. C. Ultrasound as a Means of Detaching Biofilms, *Biofouling* **2**: 323-333, (1990).
16. Li J. X., Sanderson R. D. and Jacobs E. P. Ultrasonic cleaning of nylon microfiltration membranes fouled by kraft paper mill effluent, *Journal of Membrane Science* **205** (1): 247-257, (2002).
17. Vakil N. and Everbach E. C. Transient acoustic cavitation in gallstone fragmentation, *Ultrasound in Medicine and Biology* **19**: 331-342, (1993).
18. Miller D. L. and Williams A. R. Nucleation and evolution of ultrasonic cavitation in a rotating exposure chamber, *Journal of Ultrasound in Medicine* **11**: 407-412, (1992).
19. Anderson D. M., Nosenchuck D. M., Reynolds G. T. and Walton A. J. Mechanical stimulation of bioluminescence in the dinoflagellate, *Journal of Experimental Marine Biology and Ecology* **122**: 277-288, (1988).