

Hollow, Reusable Instruments: Importance of Meticulous Maintenance

—Dental handpiece asepsis and the risk of cross-infection. A review of existing scientific literature.

By Dr Mikael Zimmerman DDS, PhD, associate professor

Introduction

For a review of the current knowledge of sterile dental handpieces and the risk of cross-infection, information has been gathered by searching PubMed for relevant citations. PubMed comprises more than 20 million citations for biomedical literature from MEDLINE, life science journals, and online books.

Key words such as dental handpiece, turbines, hollow instruments, narrow lumens, cross-infection, cross-contamination, infection control, infection prevention, cleaning, decontamination, disinfection, sterilization, lubrication, longevity, life time, costs, and maintenance have been entered as search strings in relevant combinations.

This article is based on a systematic review from the point of view of general dental practitioners: 1) What are the risks? 2) Can risks be handled with available medical devices and methods? 3) Which rules and recommendations exist? 4) What are the obstacles?

Hollow instruments—a multidimensional problem

Dental handpieces, turbines, ultrasonic scalers and triplex (three-way) syringes play a key role in dentistry and require particular attention when it comes to infection control and prevention. In a great number of surgical and health care settings, hollow instruments with narrow internal lumen impose high demands on proper and meticulous maintenance⁽¹⁾. The possibilities of decontamination, disinfection and sterilization of these instruments are usually limited due to their design, available reprocessing equipment and current methods for reprocessing. This is the case with different types of endoscopes, delicate instruments for keyhole surgery as well as dental handpieces.

Rotating instruments, such as turbines and dental handpieces, require daily maintenance because of the precision mechanics, moving internal parts and the high stress on the rotating instruments. The daily maintenance of the system in the clinic is important, especially with respect to cleaning, disinfection, lubrication and sterilization. Clinical evaluations have demonstrated that cleaning and lubrication are the most critical factors in determining performance, durability and longevity^(2, 3).

No epidemiological studies exist with evidence of disease transmission through dental handpieces, turbines, ultrasonic scalers or triplex (three-way) syringes⁽⁴⁾. However, a large number of both laboratory and clinical studies strongly indicates that there is a potential for cross-contamination. This also poses an ethical dilemma.

Technical development requires altered quality procedures

The use of rotating instruments for removal of tooth substances is an art that has been known already in historical cultures. Archaeological findings suggest that dental drills were used for medical reasons in treating decayed teeth already 9000 years ago⁽⁵⁾. Findings also show that dental drills were used by Mayans some 2000 years ago⁽⁶⁾. In 1864, the first clockwork dental drill was invented by the British dentist George Fellows Harrington. The improvement made the possibility of filling teeth a practical alternative to extractions. The very first electrical drill was patented by Dr Green in 1875⁽⁷⁾. Dr John V. Borden, a former U.S. Navy dental officer, solved the engineering problems with an air-operated turbine handpiece. In 1956, he demonstrated his high-speed drill, and in 1957, the S.S. White Company introduced the Borden Air rotor, the first successful air-operated handpiece, which ran at about 300,000 rpm⁽⁸⁾.

With more technically advanced and delicate instruments follow demands on proper maintenance to guarantee functionality. The continued development of dentistry and the introduction of new possibilities to treat oral diseases put new demands on how dental procedures can be carried out under safe conditions. Today's outpatient nature of dental practice, with a large turnover of patients and a wide range of treatment of varying difficulties, requires well-functioning and carefully integrated hygiene routines. With increasing knowledge about the risk of transmission of infection and about hygiene, dental care can be provided under safe, hygienic conditions which minimize the risk of transmission of infection.

Already in 1939, dry-heat sterilization and relubrication of dental handpieces were suggested, not merely because of the risk of cross-infection, but also because of unhygienic techniques. Steam sterilization, autoclaving, at 120°C for 20 minutes were recommended in 1940⁽⁹⁾.

Risk of cross-infection—Where is the evidence?

Micro-organisms from the oral cavity are drawn into dental handpieces, triplex (three-way) syringes and ultrasonic scalers in several ways. It has been demonstrated in multiple studies that contamination of the insides of this equipment occurs and that bacteria as well as viruses may remain infectious when expelled during subsequent use. It is a well-known fact that the oral cavity represents the most colonized area in the human body with a large variety of micro-organisms, bacteria, viruses and fungi – whether residual or transit flora.

Dental handpieces, turbines and ultrasonic scalers will become contaminated with organisms from the oral cavity during usage and also with micro-organisms contained in the water supply of dental units⁽¹⁰⁾. Micro-organisms commonly found in the oral cavity have been demonstrated in dental unit water lines. Fluids and biological material will be drawn into the narrow lumens of hollow instruments and then back to the air and water hosing system due to physical retraction forces⁽¹¹⁾

It is very difficult to evaluate the degree of risk of cross-contamination within dentistry for patients, personnel and others, simply because there are no systematic records, and eventually acquired infections are not reported and registered as HCAs (Health Care Associated Infections). For hospitalized patients, reliable figures on HCAI, number of cases, number of deaths attributable to HCAI, high risk procedures, costs for additional care etc. are of great importance to infection prevention in health care institutions. In the dental profession, we can, so far, only make estimates from various case reports or local outbreaks of cross-infections. In most cases, legislation, recommendations and routines are based on logical assumptions and probability calculations based on risk analysis.

The Dr David Acer case is a well-known fact. The Florida dentist, who infected six of his patients with the AIDS virus. The case has become one of the most disturbing unsolved mysteries in the annals of medicine⁽¹²⁾. There are other reports where hepatitis B-virus, hepatitis C-virus, herpes virus and methicillin-resistant staphylococcus aureus (MRSA) have been transmitted to patients during dental treatment, but none of them has become as well known, among dental professionals, as the so-called Florida case.

In 2007, a case with patient-to-patient transmission of hepatitis B-virus has been reported. This is the first time ever when an identical DNA match has been identified between two patients on the same day, in the same dental office, treated by the same dental team, with tooth extractions on both patients⁽¹³⁾. This is thus the first documented case of patient-to-patient transmission of a blood-borne pathogen in a dental setting.

Viruses are some of the most serious pathogens potentially transmitted through dental procedures. Hepatitis B-virus viral DNA and HIV proviral DNA have been detected in samples taken from inside rotary dental instruments in both laboratory and clinical studies. Genetic material was found in internal mechanisms of handpieces after treatment of patients known to be virus positive⁽¹⁴⁾.

Firstly, therefore, the dosage of biological material released from dental turbines and handpieces while doing a minor dental restoration could be compared with the equal risk of unprotected oral intercourse. Secondly, large dental preparations involving minor marginal gingival injuries through cutting rotation forces from the drill and the high-pressure flow of water from turbines and handpieces will have the same effect as getting multiple injections including biological material from unclean injection needles⁽¹⁵⁾.

It has been demonstrated that HIV in whole-blood samples and pseudomonas aeruginosa in blood and plasma survive high-level disinfection when entrapped in lubricants used in dental handpieces and endoscopes⁽¹⁶⁾.

For a great number of reasons, the use of a sterile handpiece on each patient should be considered mandatory⁽¹¹⁾.

In 1992, ADA (American Dental Association) reached a consensus that handpieces should be sterilized between patients⁽¹⁷⁾. This was later stated by CDC (Centres for Disease Control and Prevention): handpieces should be sterilized between patients with methods that ensure internal as well as external sterility^(18, 19).

Corresponding legislation and recommendations have been enforced in a great number of nations. All health care must be carried out under safe conditions for patients, personnel and others; this is one of the core statements in the European Medical Devices Directive. Safe conditions should of course also include infection prevention perspectives.

Sterilization will not work without thorough cleaning and disinfection!

It has been demonstrated in several studies that contamination of the insides of high-speed dental turbines occurs and that bacteria as well as viruses may remain infectious when expelled from such turbines during subsequent use.

Great care must be exercised in the cleaning of equipment prior to moist heat sterilization⁽²⁰⁾.

Adequate external cleaning and disinfection can be achieved in a washer-disinfector complemented by some kind of internal cleaning and disinfection. Internal cleaning of handpieces is best done with the aid of specially designed cleaning apparatus, which as well as cleaning also lubricates the handpiece.

If internal lumens and crevices are not ultra-clean, the sterilization process will only succeed in sterilizing the surface of the biofilm/bioburden in the internal lumen and crevices. This means that when using a dental handpiece with only surface-sterilized biofilm, the interior moving parts of the dental rotating instruments will break the surface-sterilized biofilm apart, which will result in viable micro-organisms from the interior of the biofilm to be liberated and sprayed into the patient's mouth.⁽¹⁵⁾

It is of great importance to keep the bioburden inside dental handpieces at the lowest possible level in order to achieve elimination of viable micro-organisms. All hollow instruments must be subjected to a flushing procedure as well as autoclaving after treatment of each patient⁽²¹⁾. Instruments should be processed directly after use, handpieces left to dry before cleaning have been shown not to be sterilized by otherwise effective autoclaving⁽²²⁾.

The thermal effect of autoclavation of high-speed turbines without prior cleaning and lubrication tends to hasten malfunction of these instruments⁽²³⁾.

Autoclaving supplemented by prior cleaning and lubrication resulted in an elimination of growth in all autoclaves tested⁽²⁴⁾.

Cleaning, disinfection and lubrication makes B-class sterilization much safer

When cleaning and lubrication were omitted, small autoclaves without vacuum could not kill all micro-organisms consistently. None of the tested small, non-vacuum autoclaves could consistently kill all endospores. Vacuum autoclaves left no viable endospores. Cleaning before sterilization is essential for safe use of high-speed dental turbines. Small, non-vacuum autoclaves should be carefully evaluated before being used for the reprocessing of hollow instruments such as high-speed turbines⁽²⁴⁾. Dental instruments are extremely difficult to clean, inspect and sterilize due to the small size and length of lumens, intricate working parts and their inability to be readily dismantled. For sterilization of dental handpieces to be effective it should be performed after cleaning which, if inadequately performed, will compromise the sterilization process⁽²⁵⁾.

Due to internal contamination, it is necessary to clean the handpieces internally before sterilization; otherwise the efficacy of the sterilization is dubious: many functional problems of sterilized handpieces are due to heat treatment of dirt accumulated inside⁽²⁶⁾.

The sterile processing of hollow and reusable instruments needs staff well trained in sterile supply. Disinfection with aldehydes before cleaning the interior hollow parts (lumina) of instruments must be avoided because protein coagulation will occur⁽¹⁾.

Surgical instruments contaminated by heat-stable endotoxin that remained in the bioburden on the instruments through the autoclave process caused severe inflammatory reactions in the immediate post-operative period. Even when dentists follow the manufacturer's recommended fluid-changing procedures, some models of ultrasonic instrument cleaners could result in endotoxic contamination of surgical instruments⁽²⁷⁾.

Commonly used items in dental clinics should not be sterilized in the gravity steam autoclave (type N process) or unsaturated chemical vapour sterilizers. Dental instruments require high-vacuum steam autoclave processes^(28, 29, 30).

Sterilization must be carried out in specific, secure and validated processes

For steam sterilisation of hollow objects with long and narrow lumens, procedures with either several pre-vacuum pulses to a defined (=pre-set) vacuum level or specially designed medical devices for reprocessing of specified instruments must be used. The number of evacuation cycles necessary highly depends on the degree of vacuum in relation to the number of vacuum pulses. One single vacuum pulse is in general insufficient for wrapped, hollow and porous loads⁽³¹⁾.

Dental handpieces, turbines and ultrasonic scalers are difficult instruments to sterilize. Such instruments have several moving parts protected from the sterilization medium by outer castings⁽³²⁾.

Steam sterilization in downward displacement autoclaves is not sufficiently effective to safely sterilize dental handpieces⁽³³⁾. Steam sterilizers without any pre-vacuum and post-vacuum process show great variations. In various studies, up to 60% does not result in sterile instruments^(34, 35, 36).

Considerably more energy (time and heat) is required to convert water to steam than to convert chemical solutions in chemiclaves to vapour. The higher specific heat of steam would most likely account for greater penetration⁽²⁸⁾.

Dry heat will destroy delicate instruments. Moist heat in the form of saturated steam under pressure is by far the most reliable medium, known for the destruction of all forms of microbial life. Steam sterilization is the most economical and effective method for sterilization⁽³⁷⁾.

Current recommendations are that dental handpieces should be sterilized between patients. Despite this, studies report non-compliance with regulations⁽²⁵⁾.

Retraction of biomaterial cannot be avoided

Through the negative pressure formed when turbines stop rotating, biological material will be retracted into various lines of dental handpieces and further into couplings and instrument tubing. Even if no patient case can be proved, it is an ethical dilemma that microbes are transferred into the patient's mouth⁽³⁸⁾.

The main variable affecting the influx of contaminating fluid into the air chamber of the turbine head was represented by the shape of the bur. The number of stops set on the turbine was irrelevant. The expulsion of contaminant from the turbine head showed 2 different exponential rates: a very rapid-elimination phase within 30 seconds and a slow-elimination phase between 60 and 300 seconds. In order to remove 99% of the contaminant from the air chamber, a turbine had to run for more than 4-7 minutes. The average amount of contaminant fluid was 30µl, with a drop of liquid containing millions of bacteria or viruses, which in turn corresponds to approximately 10-20µl⁽²⁶⁾.

In a study on low-speed handpieces and prophylaxis angles, movement of bacteria both inwards and outwards was shown in 61.4% of 420 specimens⁽³⁹⁾.

The overwhelming majority of anti-retracting devices did not prevent retraction when the turbine stopped running, leading to a contamination of the water lines, and a consequent possible cross-contamination of the patients⁽⁴⁰⁾.

Lubricants must be of good quality and used with great care

The choice of lubricant is also very important for proper maintenance of the rotating instruments. The lubricant should have a good wetting capacity in order to cover all internal moving parts, but at the same time not being able to leak out.

Lubricating oil should be applied before sterilization, but has been proved to be both an impediment to and favourable for the sterilization process^(33, 41, 42).

Petroleum-based lubricants are not easily removed by washing with aqueous cleaners. Contamination from patient bacteria in dental devices may be hindered by lubricants⁽¹⁶⁾. The use of non-water-soluble, oil-based lubricant could prevent steam from killing bacterial endospores⁽²⁵⁾, especially if there is an excess use of lubricant⁽⁴¹⁾.

The effect of sterilization on longevity of instruments.

In the last decades, there has been great focus on potentials for cross-infection from dental handpieces. One of the major arguments against sterilization between patients has been the longevity of rotating instruments. Sterilization of handpieces evokes visions of higher cost, damage to handpiece sheaths and turbines, and increased staff involvement. The introduction of fast turn-around steam autoclaves reduces the number of handpieces required and helps lower costs. The damage can be contained by using high-quality handpieces and by simple, adequate maintenance standards⁽⁴³⁾.

If properly maintained, dental handpieces can be expected to endure at least 500 clinical use-sterilization cycles, or approximately one year⁽⁴⁴⁾.

In a study from Japan, handpieces were shown not be influenced by sterilization until having gone through 900 cycles. Handpieces are sterilized 2-3 times per day and five days per week at a typical Japanese dental clinic. Turbine handpieces were subjected to the equivalent of more than two years of sterilization⁽⁴⁵⁾.

From the above, it seems quite reasonable that dental handpieces should go through professional service and maintenance and possibly replacement of worn-out parts. All rotating dental instruments are very delicate and complicated devices, and are not made to last forever without service, maintenance and replacement. It seems reasonable to question if sterilization per se shortens the life span of dental handpieces and turbines or if this is merely just regular wear. A service interval of 12-18 months must be considered as quite normal for a sophisticated medical device.

One could suspect that if proper maintenance is carried out at the clinic, this will actually increase the lifespan of the rotating instruments, even if sterilizing itself actually is a life-shortening factor.

Discussion

With increasing knowledge about the risk of transmission of infection and about hygiene, dental care can be provided under safe, hygienic conditions which minimize the risk of transmission of infection.

All existing facts from the reviewed scientific literature prove that hollow instruments with narrow lumens, such as dental handpieces, turbines, ultrasonic scalers and triplex (three-way) syringes, pose a possible risk of cross-infection, which can be prevented through proper decontamination and sterilization between every patient.

Today, dental handpieces, turbines and ultra-sonic scalers available on the market withstand steam sterilization processes. Safe reprocessing, cleaning, decontamination and sterilization of turbines, dental handpieces and ultra-sonic scaling devices can be made with specially designed medical devices, which fulfil the European Medical Devices Directives, which are valid in the EU and EEC. The validation and verification of the intended purpose of such medical devices must be declared by the manufacturer in the Declaration of Conformity included with every individual medical device. In the Declaration of Conformity, the manufacturer must precisely describe the intended purpose, how this purpose is validated and verified and according to which laws and regulations, norms and standards.

This means that the Declaration of Conformity written by the producer for each and every machine supplied is a legal and binding document where the producer guarantees (and can prove by validating and verifying the intended purpose) the quality and functionality of the product. Therefore, any dentist or customer must make sure that the acquired product holds a Declaration of Conformity

All these factors leave no choice; appropriate infection control techniques must be implemented. The lifetime cost of effective infection control is far less than that of one malpractice settlement⁽⁴⁶⁾.

Malpractice settlement does not only include a cost issue, but the more important issues of individual suffering, badwill and the loss of confidence in dentistry. The continued use of old medical equipment as well as outdated routines is very difficult to justify on professional, moral, ethical or economical grounds.

References:

1. Fengler TW, Pahlke H, Kraas E. Sterile and economic instrumentation in laparoscopic surgery. Experiences with 6,000 surgical laparoscopies, 1990-1996. *Surg Endosc.*, 1998 Oct;12(10):1275-9.
2. Andersen HK., Fiehn NE., Larsen T. Effect of steam sterilization inside the turbine chambers of dental turbines. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*, 1999;87:184-8
3. Leonardo DL., Charlton DG. Performance of high-speed dental handpieces subjected to simulated clinical use and sterilization. *J Am Dent Assoc*, 1999;130:1301-11

4. Miller CH. Evidence-based handpiece asepsis. Infection Control Report, Handpiece Sterilization., *Dental Products Report*. August 2008. Online, December 2010 at http://www.dentalproductsreport.com/articles/show/dpr0808_ic_handpiece-sterilization/1
5. Avasthi A: 9,000-Year-Old Drilled Teeth Are Work of Stone Age Dentists. *National Geographic News*, April 5. 2006. Online, December 2010 at http://news.nationalgeographic.com/news/2006/04/0405_060405_teeth_drill.html
6. Mayan roots of cosmetic dentistry. *British Dental Journal* 193, 187-190 (2002) Online, December 2010 at <http://www.nature.com/bdj/journal/v193/n4/full/4801520a.html>
7. British Dental Association Museum. Clockwork drill and dental engine. Online, December 2010 at www.bda.org/museum/collections/dental-equipment/clockwork-drill-dental-engine.aspx
8. Hyson JM. The air turbine and hearing loss - Are dentists at risk? *J Am Dent Assoc*, Vol 133, No 12, 1639-1642. Online, December 2010 at <http://jada.ada.org/cgi/content/full/133/12/1639>
9. Harvey W., LeMay C.H., Shuttleworth C.W. The Sterilization of Dental Handpieces. *Proceedings of the Royal Society of Medicine* Vol XL, January 27, 1947 p 507-511. Online, December 2010 at <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2183586/pdf/procrsmed00532-0025.pdf>
10. Kellet M, Holbrook W.P. Bacterial contamination of dental handpieces. *J Dentistry* 8, No 3, 1980, pp 249-2539.
11. Berlutti F., Testarelli L., Vaia F., De Luca M., Dolci G. Efficacy of anti-retraction devices in preventing bacterial contamination of dental unit water lines. *Journal of Dentistry* 2003;31:105-110.
12. CDC – Centres for Disease Control and Prevention. Investigations of Patients Who Have Been Treated by HIV-Infected Health-Care Workers. *MMWR Morb Mort Wkly Rep*, May 15, 1992 / 41(19);344-346.
13. Redd JT., Baumbach J., Kohn W., Nainan O., Khristova M., Williams I. Patient-to-patient transmission of hepatitis B virus associated with oral surgery. *J Infect Dis.*, 2007 May 1;195(9):1311-4.
14. Lewis DL., Arens M., Appelton SS., Nakashima K., Ryu J., Boe RK., Patrik JB., Watanabe DT., Suzuki M. Cross-contamination potential with dental equipment. *The Lancet* 1992, Nov 21, Vol 340, p 1252-1254.
15. Lewis DL., Boe RK. Cross-Infection Risks Associated with Current Procedures for Using High-Speed Dental Handpieces. *J Clin Microbiol*, 1992(30) Febr 2:401-406.
16. Lewis D.L., Arens M. Resistance of microorganisms to disinfection in dental and medical devices. *Nature Medicine*, Vol 1 No 9, Sept 1995, p 956-958.
17. Sterilizing dental dental handpieces. *JADA* 1992;123(10):44-7.

18. ADA Council on Scientific Affairs, ADA Council on Dental Practice. Infection control recommendation for the dental office and dental laboratory. *JADA* 1996;127:672-80
19. Centres for Disease Control and Prevention. Recommended infection-control practices for dentistry. *MMWR Morb Mortal Wkly Rep*, 1993;42 (RR-8):1-12.
20. Hammond L. Office sterilization. *Aust Fam Physician*. 1990 May; 19(5):693.
21. Larsen T., Andersen H.K., Fiehn N-E. Evaluation of a new device for sterilizing dental high-speed handpieces. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*, 1997;84:513-6.
22. Hegna I.k., Kardel K., Kardel M. Autoclaving of lubricated dental instruments. *Scand J Dent Res*, 1978;86:130-4.
23. Angelini E. Corrosion. *Quintessence International*, 1992;23:215-22.
24. Andersen H-K., Fiehn N-E., Larsen T. Effect of steam sterilization inside turbine chambers of dental turbines. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*, 1999;87:184-8.
25. Smith GWG., Smith A., Creanor S., Hurell D., Bagg J., Lappin DF. Survey of the decontamination and maintenance of dental handpieces in general dental practice. *British Dental Journal*, 2009;207:E7.
26. Checchi L., Montebugnoli L., Samaritani S. Contamination of turbine air chamber: a risk of cross infection. *J Clin Periodontol*, 1998;25:607-611.
27. Richburg FA., Reidy JJ., Apple DJ., Olson RJ. Sterile hypopyon secondary to ultrasonic cleaning. *J Cataract Refract Surg.*, 1986 May;12(3):248-51.
28. Kolstad RA. How well does the Chemiclave sterilize handpieces. *J Am Dent Assoc*, 1998 Jul;129(7):985-91.
29. Palenik CJ., Cumberlander ND. Effects of steam sterilizers on the contents of sharp containers. *Am J Infect Control*, 1993 Feb;21(1):28-33.
30. Palenik CJ., Burke FJ., Bose M., Altweis ML. Sterilization of slide sheath anesthetic injection systems placed within sharp containers. *J Indiana Dent Assoc*, 1997 Spring;76(1):45-50; quiz 52.
31. Peters J., Schwebke I., Simon PG., Bönisch M. (1997): Zum Einsatz von Hohlkörper-Prüfmodellen bei VDV-Verfahren zur Dampfdesinfektion bzw. -sterilisation. *Hyg. Med.*, 22: 444-462.
32. Kellet M, Holbrook W.P. Bacterial contamination of dental handpieces. *J Dentistry*, 8, No 3, 1980, pp 249-253.
33. Edwardsson S., Svensäter G., Birkhed D. Steam sterilization of air turbine dental handpieces. *Acta Odontol Scand*, 1983, 41, 321-326.
34. Skaug N., Kalager T. Comparative thermo-resistance of two biological indicators for monitoring steam autoclaves. „Comparison performed at 134 degrees C in hospital

- prevacuum steam sterilizers. *Acta Pathol Microbiol Immunol Scand B.*, 1985 Apr;93(2):151-6.
35. Skaug N., Lingaas E., Nielsen O., Palenik CJ. Biological monitoring of sterilizers and sterilization failures in Norwegian dental offices in 1985 and 1996. *Acta Odontol Scand*, 1999 Aug;57(4):175-80.
 36. Coulter WA., Chew-Graham CA., Cheung SW., Burke FJ. Autoclave performance and operator knowledge of autoclave use in primary care: a survey of UK practices. *J Hosp Infect.*, 2001 Jul;48(3):180-5.
 37. Nagpal AK., Shriniwas AK. Principles of steam sterilization. *Health Popul Perspect Issues*, 1978 Jan-Mar;1(1):40-50.
 38. Ojajärvi J. Prevention of microbial contamination of dental unit caused by suction into the turbine driven air lines. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.*, 1996;81:50-2.
 39. Herd S., Chin J., Palenik C.J., Ofner S. The in vivo contamination of air-driven low-speed handpieces with prpphyllaxis angles. *JADA* 2007;138(10):1360-5.
 40. Berlutti F., Testarelli L., Vaia F., De Luca M., Dolci G. Efficacy of anti-retraction devices in preventing bacterial contamination of dental unit water lines. *Journal of Dentistry*, 2003;31:105-110.
 41. Frostell G., Hesselgren SG. Smittrening av hand- och vinkelstycke (Del III): Oljefilmens inverkan på sterilisationsresultat vid autoklavering av lagerförsedda instrument. *Sven. Tandlaek. Tidskr.*, 1964, 57, 543-551.
 42. Hesselgren SH., Frostell G., Linder F. A new method of sterilizing handpieces and contra-angles, *J Oral Therapeut. Pharmacol.* 1967, 8, 340-353.
 43. Clappison RA. Cross contamination control and the dental handpiece. *J Prosthet Dent.*, 1995 May;73(5):492-4.
 44. Daniel L.L., Charlton D.G. Performance of high-speed dental handpieces. *JADA*, Vol 130, Sept 1999: 1301-1311.
 45. Nagai M., Takakuda K. Influence of Number of Dental Autoclave Treatment Cycles on Rotational Performance of Commercially Available Air-Turbine Handpieces. *J Med Dent Sci.*, 2006;53:93-101.
 46. Terezhalmay GT., Gitto CA Today's minimal requirements for a practical dental office infection control and exposure control program. *Dent Clin North Am.*, 1998 Oct;42(4):629-42.