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Front Cover: Panoramic view of a patient with Cleidocranial dysplasia (see case report).
Editorial Notices

The New Zealand Endodontic Journal is published twice yearly and sent free to members of the New Zealand Society of Endodontics (Inc). The subscription rates for membership of the Society are $35 per annum in New Zealand or $45 plus postage for overseas members. Graduates of the University of Otago School of Dentistry enjoy complimentary membership for the first year after graduation. Subscription inquiries should be sent to the Honorary Secretary, Dr Mike Jameson, 2 Granville Terrace, Dunedin.

Contributions for inclusion in the Journal should be sent to the Editor, Tina Hauman, PO Box 647, Dunedin. Deadline for inclusion in the May or November issue is the first day of the preceding month.

All expressions of opinion and statements of fact are published on the authority of the writer under whose name they appear and are not necessarily those of the New Zealand Society of Endodontics, the Editor or any of the Scientific Advisers.

Information for Authors

The Editor welcomes original articles, review articles, case reports, views and comments, correspondence, announcements and news items. The Editor reserves the right to edit contributions to ensure conciseness, clarity and consistency to the style of the Journal. Contributions will normally be subjected to peer review.

It is the wish of the Editor to encourage practitioners and others to submit material for publication. Assistance with word processing and photographic and graphic art production will be available to authors.

Arrangement

Articles should be typewritten on one side of A4 paper with double spacing and 3cm margins. The author’s name should appear under the title and name and postal address at the end of the article. If possible, the manuscript should also be submitted on computer disc, either Macintosh or PC compatible.

References

References cited in the text should be placed in parenthesis stating the authors’ names and date, eg (Sundqvist & Reuterving 1980). At the end of the article references should be listed alphabetically giving surnames and initials of all authors, the year, the full title of the article, name of periodical, volume number and page numbers.

The form of reference to a journal article is:

The form of reference to a book is:

Illustrations

Illustrations should be submitted as clear drawings, black & white or colour photographs and be preferably of column width. Radiographs are acceptable. However a black & white photograph is preferred. Illustrations must be numbered to match the text and bear the author’s name and an indication of the top edge on the back. Legends are required for all illustrations and should be typewritten on a separate page.
President’s Report

Welcome members to 2009. Here’s hoping it’s going to be a fruitful and pleasant year for you all, I just can’t believe that the last one has finished already.

Well, the Inaugural Trans Tasman Endodontic Congress has been and gone and what a busy two and a-half days that was! Thank you to all those members who attended and helped make it a very successful event. With almost 400 attendees I believe it was the largest endodontic meeting outside the US and UK last year. I hope you all enjoyed it and took home some helpful information.

We are in the early stages of planning the next one, in 2010, hopefully to be hosted somewhere in New Zealand. Any feedback about the Hobart meeting would be much appreciated, as we want to make the next one even better. Please feel free to email me, or any of the other members of our committee with your comments.

I would like to welcome back our executive for 2009. Deborah has indicated that she will continue with the mantle of treasurer and Mike has also said he will give us another year as secretary. Hani, is currently working hard at finalising the societies new web site, and Robyn, James and Craig are all on board again. Heartfelt thanks to you all for giving your precious time and energies into helping run the society. This year we have managed to rope in a new member to the committee, Dr Jackie Pahl. Jackie trained in Melbourne and has run an endodontic practice on Auckland’s North Shore for a number of years. She will bring with her valuable experience and knowledge not only of endodontics but also how to manage the Australians!

Thanks again to Tina for continuing to look after the journal. There has been a lot of discussion over the past year regarding an amalgamation of our journal with that of the Australian Endodontic Society Journal. After a lot of thought, on both sides, it was decided to keep the status quo. The journal is primarily aimed at the general dentist not the endodontic specialist. Keeping it local enables us to have full editorial control along with keeping the price of membership very low. If members would like to discuss this matter further please contact me.

At our AGM in Rotorua last year, kindly chaired by Dr Deborah Creagh, Honorary Life membership of the New Zealand Society of Endodontics was bestowed upon Professor Robert Love. The society wishes to thank Professor Love for all his hard work over the years not only on behalf of the society but also for his commitment to improving endodontic education throughout the profession. Many thanks Robert.

Points also discussed were a possible name change to The New Zealand Society of Endodontics and Dental Trauma. The consensus at that time was to retain the current name but that further discussion at committee level should be looked at. There was also a suggestion that the new edition of Dr Jim Gutmann’s book “Problem Solving in Endodontics” be distributed to all current members and the committee will look into this in the coming year.

Our subscription rates for this year are to go up to $40. This includes the journal, which I know is much appreciated by our members. Here is to another exciting year.

All the best, Sara Jardine
Honorary Life Membership

Professor Robert Love was granted Honorary Life Membership of the New Zealand Society of Endodontics in recognition for his long and committed service to the endodontic profession and the New Zealand Society of Endodontics.

Professor Love joined the New Zealand Society of Endodontics in 1986. He acted as committee member, secretary and regional sub-committee member between 1987 and 1994. He became assistant editor of the New Zealand Endodontic Journal in 1994 and the editor in 1996, a position he kept until 2003. In addition to his role as editor of the journal he was president of the Society between 2000 and 2003.
Editorial

I hope you all had a very happy and relaxing Christmas and New Year.

The year 2008 ended on a high note on the endodontic front with the Trans-Tasman Endodontic conference in Hobart in November. The presentations from Australian and New Zealand speakers were informative and of high standard while the keynote speakers, Professor Ove Peters from the University of the Pacific, San Francisco and Professor Markus Haapasalo from the University of British Columbia, Canada lived up to their international reputations. Professor Ove Peters addressed the current status and future challenges of root canal preparation and periapical biology, while the focus of the presentations by Professor Markus Haapasalo was a new perspective into root canal irrigation and persistent endodontic infections. Congratulations to the organising team on a well organised, successful and enjoyable event.

While we all focus on eliminating bacteria from root canals during endodontic therapy we sometimes forget about the possible environmental hazards associated with this treatment. In his review paper “Air quality in the endodontist’s surgery”, Osama Alothmani addressed these environmental risks.

Perforations are undesirable but, unfortunately, common occurrences during endodontic therapy. Artika Patel reviewed the etiology, management and predicted prognosis of perforations and perforation repair in her article.

The case presentation by Abdul Aziz emphasised the need for taking a thorough medical and dental history to enable us to provide the best treatment plan and options for the patient’s future well-being.

Thank you Osama, Artika and Abdul for your valuable contributions to the Journal.

I wish you all a very happy and successful 2009.

Tina Hauman
Air Quality in the Endodontist’s Dental Surgery

Osama Alothmani

Introduction
The working environment of the dental team is intricate. Advances in techniques, instruments and materials used in dentistry have improved the quality of treatment. Meanwhile, the undesirable events that occur with the utilisation of contemporary technologies warrant attention. For example, the shift towards using high-speed handpieces in the 1950’s was accompanied with new setbacks including heat generation and auditory complications (Stevens 1963). To eliminate heat, water spray was recommended. However, the aerosol generated was hazardous. As a response, a new area of investigation was introduced; the field of dental aerobiology. This is concerned with airborne particles in the dental office and dental laboratories and the relationship of these particles to the health of personnel and patients (Micik et al. 1969). The excellent clinical outcomes of amalgam restorations were opposed by anti-amalgam advocates due to the continuous emission of mercury which is a known poison (Dodes 2001). Endodontic evolution has been moving along the same track. The efficiency of chloroform was weighed against its potential carcinogenicity (McDonald and Vire 1992). Laser application inside root canals was successful in cleaning but the generated plume was infected (McKinley and Ludlow 1994).

In this review, I will address the factors which influence the air quality inside the endodontic clinic, the morbidity and mortality linked to them (if any) and the diverse schemes to maintain acceptable air quality in the clinic. Factors can be common among different dental disciplines (aerosol and splatter, mercury and allergies) or can be specifically related to endodontics like chloroform and laser.

Aerosol and splatter
The combination of a high-speed handpiece with water spray proved to be an effective tool. While the former reduces the working time needed to finish the procedure, the latter takes care of the frictional heat. Heat was found to be harmful to the pulpal tissue of teeth if not dissipated (Mohammed and Monserrate 1970). However, the mixture of air and water projects under pressure from the handpiece and blends with the patient’s saliva to form a cloud (or aerosol) in the immediate vicinity of the dentist, the dental assistant and the patient. This aerosol contains tooth debris, saliva with its microbial flora and water from the handpiece (Travaglini et al. 1966). The possibility to inhale this mixture cannot be disregarded nor could the potential for acute or chronic respiratory reaction be excluded (Micik et al. 1969). Furthermore, these particles were found to strike the operator and the assistant and settle on adjacent objects. As a result, an infected environment is created in which the dental team performs tasks for extended periods of time (Miller et al. 1971). Depending on their size, these particles can be divided into aerosols and splatter.

Aerosols are particles with a diameter of 50 microns or less. They are invisible to the naked eye, have the ability to remain suspended in air for long periods of time and they can travel with air currents. Importantly, aerosol particles can be recovered from the waiting areas in dental offices and distributed via the air conditioning system. Bacterial aerosols, consisting of particles in the range of 0.5-10 microns, were found to penetrate deep inside the lungs to the level of the terminal bronchioles where they promote an inflammatory reaction. Particles with a range of 10-50 microns are usually trapped in the upper respiratory tract. Smaller diameter particles penetrate deeper into the lungs (Miller and Micik 1978).

Splatters are particles with a diameter greater than 50 microns and are visible to the naked eye. These particles retain sufficient mass and kinetic energy to acquire a ballistic character and travel in a trajectory, striking and splattering objects in their path. They may target the exposed mucous
membranes of the eye, nose and mouth. In addition, eye glasses, operating lights and other surfaces are not guarded against them (Miller et al. 1971). Some of the splatter particles were found to evaporate during their trajectory and become suspended into the air, and might be inhaled at a later time (Muir et al. 1978). Moreover, re-dispersion of the settled particles on floors into the air has been noted (Gabbay et al. 1990).

Many studies demonstrate the presence of viable microorganisms (bacteria, viruses and fungi) in dental aerosols. Culture samples showed that the origin of these organisms is either from the patient or from the dental unit waterline (DUWL). Hence, the composition of an aerosol, and thus its contagions, is affected by two factors namely patient’s medical status and the quality of the DUWL.

The availability of bacteria driven from patients into the dental aerosol was proven in several studies (Stevens 1963; Belting et al. 1964, Larato et al. 1966, Travaglini et al. 1966, Pelleu et al. 1970, Cochran et al. 1989, Samaranayake et al. 1989, Bennett et al. 2000, Toroglu et al. 2001). The bacterial count was increased during the cavity preparation (Larato et al. 1966) and the length of the procedure was proportional to the amount expelled (Travaglini et al. 1966). These findings drew attention to the possibility of cross-infection of airborne diseases when using high speed handpieces. In the past, tuberculosis (TB) was seen as a potential occupational hazard of dentistry (Belting et al. 1964). The confirmed method of TB transmission is in droplet nuclei. Since droplet nuclei are produced during dental procedures, concerns regarding their composition and the probability of cross-infection to the dental team were accentuated. One of the earliest attempts to investigate this possibility was conducted by Belting et al. (1964). They captured M. tuberculosis particles at a distance as far as four feet in front of TB-active patients when the air turbine was operated inside the patient’s mouth without actual cutting and without water coolant. However, the use of water reduced the amount to almost half. They concluded that the use of water is necessary to assure the dentist’s health. This was consistent with the recommendation of an earlier study by Kazantzis (1961). These findings were opposed by others (Madden and Hausler 1963, Hausler and Madden 1966, Micik et al. 1969) who confirmed that the amount of aerosol generated is directly proportional to the quantity of water coolant used with the handpiece. Nevertheless, they stressed the potential risk of inhalation of this aerosol particularly if it was infected. Despite the fact that Belting and co-workers confirmed the presence of tubercle bacilli in the aerosol, Duell and Madden (1970) failed to reproduce this observation. They analyzed the aerosol produced from the prophylaxis procedure on patients with active pulmonary TB but the air sampler did not detect any tubercle bacilli. However, the authors attributed this to many shortcomings in their study design and recommended further studies to investigate this problem. Due to a lack of reported cases in the literature, the significance of dental aerosols as a source of cross-infection or respiratory sickness has been questioned. Nevertheless, the potential for cross-infection was not denied and the importance of infection control was emphasized (Toroglu et al. 2003). A retrospective study to correlate patients’ exposure to dental aerosols and the frequency of consequent illness revealed no relationship (Shreve et al. 1972). A more recent study targeted dental students at three dental schools in the United States. No association was established between the dental school year and the prevalence of the respiratory diseases. Based on these results, it was concluded that the short-term exposure of healthy dental personnel to a dental environment is not associated with an increased risk of respiratory illness (Scannapieco et al. 2004). Miller, a pioneer in the field of dental aerobiology, declared that the threat of infection from inhaled dental aerosols may be a great commotion over a small problem (Miller 1976). A case of Chlamydia trachomatis infection is the only reported case in the literature with suspected bacterial cross-infection via dental aerosol (Midulla et al. 1987).

Viral cross-infection was not neglected. Many researchers evaluated this likelihood and accusations were directed at handpieces and air syringes due to their inherent character of retracting water. The turbine handpiece rotates using compressed air; its momentum causes it to continue rotation for some time even after the supply of air is cut off. Consequently, a negative pressure is created inside the handpiece which sucks in some of the patient’s oral fluids. When such a handpiece is re-used without adequate sterilization, contaminated water coolant is expelled into the next patient’s mouth
(Lewis et al. 1992, Matsuyama et al. 1997). If this problem is not addressed contamination might spread into the internal waterline of the dental unit (Abel et al. 1971, Martin 1987). Similarly, air syringes suck back some water to provide a dry field, once the operator’s finger pressure is released (Ernst 1979).

In a mixed *in vitro* and *in vivo* experiment, the existence of human specific DNA, HIV pro-viral DNA and HBV DNA inside the handpiece and in the projected water was confirmed (Lewis et al. 1992). Toroglu and colleagues illustrated the presence of blood in aerosols generated with the use of a handpiece. In addition, they discovered HBsAg and HBV-DNA in the aerosol while operating on Hepatitis B-infected patients (Toroglu et al. 2003). Cross-infection between patients needs to be eliminated via proper heat sterilisation of handpieces (Lewis et al 1992). Nonetheless, sterilisation of handpieces will not affect the potential for exposure to pathogens originating from the DUWL (Atlas et al. 1995). An assessment of the risk of exposure to TB, HIV and Hepatitis B to dental care providers was carried out by Bennett and co-workers (Bennett et al. 2000). Results from this study showed a small risk of dental aerosol cross-infection with TB which could be minimized with simple infection control procedures. Cross-infection with HIV or HBV via dental aerosols was found to be extremely unlikely.

How do we prevent or manage this health threat? Fortunately, this is simple. Of prime importance is the vaccination of dental care givers against many potent microbes (Bennett et al. 2000). The use of physical barriers such as gloves, masks, protective eyewear and gowns is worthwhile, provided that they cover the exposed skin. Since contamination involves many surfaces in the operatory, protective covers can be used and disposed of between patients (Reams et al. 1995). The competence of masks in filtering aerosol particles was evaluated in several studies (Travaglini and Larato 1965, Micik et al. 1971, Belkin 1996, Derrick et al. 2006). For a mask to be effective, it should have a high filtration capacity, and be properly fitted and worn as long as the practitioner is in the aerosol vicinity. The efficiency of masks against splatter is more obvious (Micik et al. 1971). Replacement of the mask is crucial when it gets wet (Reams et al. 1995). To further reduce the risk of cross-contamination, a preoperative anti-septic mouth rinse is recommended to reduce the microbial count, (Litsky et al. 1970, Mohammed and Monserrate 1970, Wyler et al. 1971, Muir et al. 1978, Glenwright 1980). A ten-fold to a hundred-fold reduction in the bacterial count of aerosols was obtained via the use of a preoperative anti-septic mouthwash (Wyler et al. 1971). The use of rubber dam was reported to reduce the number of microbes in aerosols by 90-98% (Cochran et al. 1989) and 88% (Samaranayake et al. 1989), respectively. Rubber dam creates a virtual barrier against spraying into patient’s oral fluids (Hoffman 1958, Pankhurst and Philpott-Howard 1993).

Unfortunately, rubber dam cannot be used in all dental procedures (Harrel and Molinari 2004). High-volume suction (HVS) is another adjunctive and essential tool to minimize aerosol production and to reduce the bacterial count in aerosols (Micik et al. 1969, Glenwright 1980, Cochran et al 1989, Reams et al. 1995). In reality, a three-fold reduction in the bacterial load of aerosols can be achieved through the proper use of the HVS tip (Micik et al. 1969). However, the HVS was claimed to be inefficient for splatter control (Miller et al. 1971) in contrast to other results (Glenwright 1980, Cochran et al 1989).

High efficiency particulate air (HEPA) filters are also capable of diminishing the total bacterial count in dental office air (Pelleu et al. 1970, Muir et al. 1978). It involves a blower-filter element containing HEPA that filters the air at a certain rate with a specific filtration capacity (Pelleu et al. 1970). Another successful approach is the laminar air purge. This is defined as providing a confined area with highly filtered air flowing along parallel lines at a constant rate and requires installation of a full-wall-occupying laminar flow filtration system (Pelleu et al. 1970). The filtered air is produced under pressure through the ceiling and exhausted at the floor level (Glenwright 1980). Laminar air purge reduces bacterial contamination (Pollok et al. 1970, Williams et al. 1970). The latter group achieved a 99.7% reduction in airborne contamination. HEPA filters are relatively inexpensive compared to laminar flow filtration systems (Pelleu et al. 1970). In addition to these approaches, ultraviolet light radiation (UV-light) chambers in ventilation systems are promising options. These systems require a prolonged period of time to allow all the office air to circulate through them to be purified and installation will
incur additional expenses. (Harrel and Molinari 2004). UV-light is also associated with serious side effects (Beissert and Loser 2008). Ionization of the operatory air was seen to be another effective way to reduce the microbial count. A reduction of 40% was reported with apparently no side effects (Gabbay et al. 1990).

The other factor that contributes to the infectivity of dental aerosol is the quality of the dental unit waterline (DUWL). Presumably sterile, a variety of bacterial species were cultured from DUWLs (Abel et al. 1971, Clark 1974, Cochran et al. 1989, Samaranayake et al. 1989, Pankhurst et al. 1990, Atlas et al. 1995, Singh and Coogan 2005, Huntington et al. 2007). Moreover, endotoxins, which are responsible for the virulence of Gram-negative bacteria were also isolated (Szymanska 2005, Huntington et al. 2007). Furthermore, fungal species were identified (Pankhurst et al. 1990, Szymanska 2006a). The microorganisms were found to arrange as a biofilm inside the tubes that shelter them. Frequently, biofilm products are released into the water stream when the dental unit is flushed (Pankhurst and Philpott-Howard 1993). The presence of microorganisms in DUWL was attributed to the retraction effect of handpieces (Abel et al. 1971, Martin 1987), discussed previously, and to the complex design and tubing system of the dental unit. The sophisticated narrow plastic network of pipes, along with the slow flow rate of water inside them, affords a great option for microorganisms’ multiplication (Pankhurst et al. 1990). The majority of microorganisms isolated from DUWL are known to be a threat to immuno-compromised individuals (Clark 1974, Fotos et al. 1985, Martin 1987, Atlas et al. 1995). Two cases of Pseudomonas aeruginosa abscesses in immuno-compromised patients were reported by Martin in 1987. In both cases, the abscess developed after a dental visit and the pus culture showed that P. aeruginosa was the predominant microbe. The microorganism was traced to the DUWL of the clinics where the two patients were treated. Nonetheless, the effect of such microorganisms is not solely restricted to immuno-compromised individuals. Two studies compared the level of antibodies to Legionella between dental personnel and a non-medical group (Fotos et al. 1985, Reinthaler et al. 1988). Both studies showed that there was a significant difference between the two groups suggesting that dental care givers are at a higher risk of Legionella infection. Moreover, the former study established a link between the exposure time to Legionella and the antibody titre level. A third study analysed the nasal flora of dentists and their assistants and compared these with culture samples from the respective DUWL. Typical water microbes were found in the altered nasal flora. A possible explanation was that the dental aerosol modified the nasal environment to allow the survival of microorganisms not usually found in this area (Clark 1974). A high level of Legionella captured in the DUWL was the possible cause of the death of a dentist in California from legionellosis (Atlas et al. 1995).

Flushing the dental unit for three minutes early morning before treating the first patient and for 20-30 seconds between patients has been emphasized (Ernst 1979). Abel and co-workers yielded a reduction in the number of cultured bacteria by 98.6% after flushing the dental unit for two minutes. Moreover, few or no bacteria were observed when the unit was supplied through an external water tank with extra chlorination instead of through the municipal network (Abel et al. 1971). Unfortunately, chlorine has deleterious effects on the tubing system of the unit and the patients (Pankhurst and Philpott-Howard 1993). An evaluation of four different methods (separate water supply, chemical treatment, daily drainage and purging, and the use of filters) to obtain DUWL disinfection showed that independent sterile water supply with filters gave a prolonged and increased effectiveness (Murdoch-Kinch et al. 1997). However, the inefficiency of chlorination and charcoal filters was demonstrated (Pankhurst et al. 1990). The importance of anti-retraction valves was emphasized (Matsuyama et al. 1997) but Berlutti and associates found them to be unsuccessful unless replaced routinely (Berlutti et al. 2003). Besides, anti-retraction devices cannot be attached to air syringes (Ernst 1979). In order to disrupt the biofilm inside the waterline, it was suggested to wash out the unit with chemical disinfectants. Buffer-stabilized chlorine dioxide (Wirthlin et al. 2003), 0.26% peracetic acid (Montebugnoli et al. 2004) and hydrogen peroxide with silver ions (Tuttlebee et al. 2002, Szymanska 2006b) were nominated. A comparison of eight disinfectants revealed hydrogen peroxide with silver ions as being the most efficient (Schel et al. 2006). Pankhurst and Philpott-Howard (1993) recommended modification of the chair design to allow an easier maintenance.
Mercury
One of the most intensive debates in the field of dentistry is centred on the toxicity of amalgam and the issue of its continuous mercury emission. This was intensified with reports by the German chemist, Alfred Stock, who reported his own mercury toxicity symptoms. He claimed that the use of amalgam is a crime against humanity (cited in Weiner et al. 1990). Histological sections of mouse lungs exposed to amalgam dust revealed focal haemorrhage indicating an acute response (Legan et al. 1973). The dental team had been a victim of this problem and there are many reported cases of mercury poisoning in the literature. An unreported spillage of mercury in the operatory resulted in four, fortunately non-fatal, mercury toxicity cases (Merfield et al. 1976). Mantyla and Wright (1976) documented two cases of poisoning due to mercury leakage from an amalgamator. Nephrotic syndrome due to chronic mercury poisoning resulted in the death of dental assistant (Cook and Yates, 1969). Nimmo and associates (1990) claimed that the dentist is exposed to fully respirable amalgam particles when amalgam is being removed. Approximately 80% of mercury vapour was found to circulate in the blood where it remains long enough to penetrate the blood-brain-barrier (Nilsson and Nilsson 1986a). A report from Sweden revealed higher chronic mercury toxicity among dental personnel than their partners (Nilsson and Nilsson 1986b). All these mercury hazard reports along with ancient documentation of this undesirable condition have led to concerns about the safety of amalgam. Investigations focused on the quantity of mercury leaching from amalgam, the factors which might influence the amount emitted, and adverse reactions to it.

The physical and chemical properties of mercury get in the way of its secure handling. At room temperature, it is in a liquid state that vaporizes easily and penetrates into surrounding objects which then will act as reservoirs (Johnson 1978, Roydhouse et al. 1985, Brown and Sherriff 2002). Increasing the temperature facilitates the evaporation process. Even the oxidation layer that develops on the mercury surface does not completely prevent its evaporation as it is easily broken with a slight disturbance (Nilsson and Nilsson 1986a, Brown and Sherriff 2002). Being liquid helps mercury to mix easily with dust present in inaccessible areas. The high mercury density was found to break glass containers used for storage (Johnson 1978).

The endodontist and the general practitioner are prone to inhale mercury vapour when placing amalgam or removing it. Many studies have quantified the amount of mercury discharged during the different steps of providing an amalgam restoration. Amalgam’s mercury content, temperature of the amalgam and the conversion of the mechanical energy of condensation into thermal energy were factors controlling the amount of mercury released (Engle et al. 1992). Firstly, mercury was proven to leak from capsules during trituration (Nixon and Rowbotham 1971, Eames and Palmertree 1979, Engle et al. 1992, Powell et al. 1994). Secondly, the condensation action released mercury (Eames and Palmertree 1979, Pohl et al. 1988, Engle et al. 1992, Powell et al. 1994). Thirdly, carving action was active in releasing mercury (Mantyla and Wright 1976). Finally, even though done in another setting, polishing amalgam liberated mercury (Pohl et al. 1988, Engle et al. 1992, Langworth et al. 1997). Removing amalgam was also a mercury-releasing procedure (Brune et al. 1980, Richards and Warren 1985, Pohl et al. 1988, Nimmo et al. 1990, Engle et al. 1992, Powell et al. 1994, Langworth et al. 1997). The threshold limit value (TLV) is defined as the maximum amount of mercury vapour to which a worker can be exposed to for an eight-hour day, over a 40-hour work week (Powell et al. 1994). Several trials demonstrated that TLV could be exceeded during amalgam placement and removal (Eames and Palmertree 1979, Brune et al. 1980, Richards and Warren 1985) while others have verified that the captured level is below the TLV (Engle et al. 1992, Powell et al. 1994, Langworth et al. 1997). TLV is determined by occupational safety authorities worldwide to represent the maximum chronic concentration to which a worker can be exposed to a material throughout his/her career without adverse effects (Brown and Sherriff 2002). There are many variables in these studies such as background mercury levels, type of amalgam used, the methods for placement and removal and the armamentarium used. The number of amalgam fillings and replacements done daily is a significant factor to be considered when measuring the dental team’s exposure to mercury (Engle et al. 1992). Persistent exposure to mercury levels as low as 0.1 mg/m3 increases the chances of developing chronic mercury toxicity symptoms (Brune et al.)
surrounded with all these mercury sources, the endodontist and his/her team are not shielded against the risk of mercury poisoning and strict mercury hygiene is required. Proper mercury hygiene involves maintaining its vapour in low concentrations with adequate handling and disposal schemes (Powell et al. 1994). Worker education is of prime significance (Merfield et al. 1976, Johnson 1978). Ventilation was found to be an efficient tool for diluting concentrations (Nixon and Rowbotham 1971, Merfield et al. 1976, Johnson 1978, Eames and Palmertree 1979, Brune et al. 1980, Powell et al. 1994, Langworth et al. 1997). This factor was a major cause of the toxicity reported by Merfield et al. (1976), which occurred in winter when windows are not usually opened. The role of air conditioners distributing mercury vapours between different rooms should not be overlooked (Miller et al. 1974, Mantyla and Wright 1976, Johnson 1978, Brown and Sherriff 2002). In addition, clinic design and furniture are two crucial variables which might lead to mercury vapour build up inside the clinic. Battistone and colleagues (1973) concluded that a single large room containing multiple dental units would have higher mercury air levels. Mercury spills were the most common cause of elevated mercury levels in the air of dental clinics (Nilsson and Nilsson 1986a, Brown and Sherriff 2002). Carpet, tiles and the walls of the operator act as reservoirs for mercury (Johnson 1978, Roydhouse et al. 1985, Brown and Sherriff 2002) and it was recommended that all operator walls and floor as well as the working surfaces should be impermeable to mercury (Nixon and Rowbotham 1971, Mantyla and Wright 1976, Merfield et al. 1976, Johnson 1978). To detect any sudden elevation in air levels of mercury, regular air sampling is advised (Miller et al. 1974, Mantyla and Wright 1976, Brown and Sherriff 2002). Immediate mercury spillage cleaning is mandatory. Sweeping and dusting will spread the spill (Johnson 1978, Eames and Palmertree 1979). Using special vacuums with mercury vapour absorbing filters accompanied with the use of chemical mercury solvents or flour of sulphur as an adjunct are critical (Mantyla and Wright 1976). Amalgam waste storage is done in a leak-proof, plastic container filled with water until disposed according to manufacturer instructions (Nixon and Rowbotham 1971, Mantyla and Wright 1976, Johnson 1978). Habitual amalgamator checks for cracks and mercury leakage is crucial (Langworth et al. 1997, Brown and Sherriff 2002). Before autoclaving, instruments should be thoroughly inspected for remaining amalgam particles and must be cleaned (Parsell et al. 1996).

Gallium alloys were advocated as amalgam substitutes. Unfortunately, they have unsatisfactory clinical outcomes (Nayezadeh et al. 2000). The addition of indium was seen as unsuccessful (Powell et al. 1994) while palladium, due to its strong affinity to mercury, was a powerful mercury release inhibitor (Neme et al. 1999). Further reduction can be achieved with the use of HVS and water spray (Mantyla and Wright 1976, Johnson 1978, Brune et al. 1980, Richards and Warren 1985, Nilsson and Nilsson 1986a, Engle et al. 1992, Langworth et al. 1997). In addition, Engle et al. (1992) pointed out the importance of adding a disposable charcoal filter in HVS lines to act as a mercury hunter. The HVS should discharge outside the operatory boundaries (Stonehouse and Newman 2001). An evaluation of a combined mirror-suction instrument held by the dentist demonstrated its effectiveness in lowering mercury levels when the assistant was helping in the restorative procedure and unable to hold the HVS (Pohl et al. 1988). Water cools the surface temperature of amalgam hence reducing mercury release. In addition, it holds the mercury in a slurry that is easily captured with HVS (Engle et al. 1992). Nimmo and co-workers (1990) found that rubber dam isolation was an efficient adjunct to HVS and water in minimizing the emitted mercury.
during the removal of amalgam restorations. Yet, compulsory face mask wearing was recommended during these procedures. The effectiveness of rubber dam was further augmented in a later study (Powell et al. 1994). Sodium hypochlorite oxidizes amalgam and causes the discharge of mercury. To minimize this release, irrigation with EDTA together with NaOCl was claimed successful (Rotstein et al. 2001). Regarding the out-of-office bleach, it is recommended to cover all amalgam surfaces with three varnish coatings (Rotstein et al. 2000a).

Practicing adequate mercury hygiene, which is both simple and within the hands of every dental team, would minimize this risk (Battistone et al. 1973). Dodes (2001) concluded, based on a recent evidence-based analysis of the literature, that amalgam has remained a safe restoration and there is no need to change its use.

**Allergies**

Another possible risk associated with the inhalation of dental clinic air is the exposure to airborne allergens with resultant hypersensitivity. Exposure to methacrylate and natural rubber latex (NRL) allergen was considered the most common cause of respiratory diseases among dental personnel as well as their patients (Piirila et al. 2002). The presence of methacrylate in the aerosols generated during the removal of composite resins has been documented (Nayebzadeh et al. 2000, Ireland et al. 2003). The former study highlighted the risk of inhaling silica from the aerosol while the latter notified that the very small size of methacrylate particles can permit their penetration deep inside the lungs if inhaled. Another study detected methacrylate in the immediate vicinity of the dentist while a composite filling was placed (Henricks-Eckerman et al. 2001). In addition, they captured small amounts of NRL allergens present in the clinic air. However, they found that the exposure of dental personnel to airborne methacrylate and to NRL allergens was low. Nevertheless, they advised to maintain this exposure as low as possible to rule out possibilities of hypersensitivity (Henricks-Eckerman et al. 2001). Hermesch and colleagues (1999) justified the use of powder-free latex gloves to minimize NRL allergen air concentrations particularly in dental school environments.

**Chloroform**

Chloroform (trichloromethane, CHCl₃) is a colourless volatile liquid at ambient pressure with a sweet taste and a characteristic but not unpleasant odour. It has a moderately high vapour pressure, contributing to its high volatility, an appreciable solubility in water, and high lipid solubility. Inhalation is considered the primary route of uptake for occupational exposure. Chloroform was found to be a fatal toxin and a teratogen in rodents when they were exposed to it for a period of six to eight hours of daily inhalation (Davidson et al. 1982).

Gutta percha is the most common root canal filling material used in endodontics (Wennberg and Ørstavik 1989). In cases of retreatment, its retrieval may necessitate the use of a solvent. Chloroform is the most efficient solvent to perform this task (Wennberg and Ørstavik 1989, Wourms et al. 1990, Wilcox 1995). This organic solvent was a target of many queries regarding its safety to both dental personnel and patients, since the Food and Drug Administration (FDA) banned its use in drug and cosmetic products in 1976. The ban was a consequence of findings by the U.S. National Cancer Institute which demonstrated chloroform as a potential inducer of liver cancer in mice and renal tumours in rats (U.S. Food and Drug Administration, 1976). Given that, it became a trend to omit chloroform in endodontic practice (Margelos et al. 1996). Chloroform is classified as a member of group 2B by the International Agency for Research of Cancer (IARC, 1999). It is described as possessing inadequate evidence of carcinogenicity in humans but sufficient evidence of carcinogenicity in experimental animals (Vajrabhaya et al. 2004). As mentioned previously, occupational exposure to chloroform occurs mainly via inhalation due to its high volatility. Chloroform might be present in high concentrations in the immediate vicinity of the dentist, assistant and the patient when it is consumed. Taking this fact into account, organizations have determined occupational safety limits to chloroform beyond which possible damage might occur.

In endodontics, chloroform is used as a sealer component and as a solvent when retreatment is needed (Allard and Andersson, 1992). The former use was seen to be unsuccessful in improving the outcome of endodontic treatment and thus should be discontinued (Ørstavik et al. 1987, Eriksen et
Margelos and associates (1996) used a traditional use of chloroform in a Dappen dish. However, he didn’t compare his method and the syringe as a container during the procedures. Risk. Donnelly (1993) suggested the use of 1ml available for evaporation to lessen the inhalation risk. Plastic) to decrease the surface area of chloroform involving procedure is done per day. They suggested the use of closed containers (glass or plastic) instead of dishes. The use of less volatile chloroform preparations further reduced the risk. Donnelly (1993) suggested the use of 1ml syringe as a container during the procedures. However, he didn’t compare his method and the traditional use of chloroform in a Dappen dish. Allard and Andersson (1992) simulated a clinical condition in which chloroform was used in endodontic procedures. They demonstrated that exposure to high concentrations of chloroform is a possibility when cups are used as chloroform containers; especially if more than one chloroform-involving procedure is done per day. They supported the concept of reducing the surface area of chloroform available for evaporation to lessen the inhalation risk. Donnelly (1993) suggested the use of 1ml syringe as a container during the procedures. However, he didn’t compare his method and the traditional use of chloroform in a Dappen dish. Margelos and associates (1996) used an in vitro study looking at the amount of vapor exposure to dentist and the patient when using bottles or dishes with either pure chloroform or a preparation containing 5% colophonium. The outcome supported the concept of reducing the surface area of chloroform available for evaporation by using closed containers instead of dishes. The use of less volatile chloroform preparations further reduced risks (Margelos et al. 1996). In 1992, McDonald and Vire conducted an in vivo study looking at the amount of chloroform manipulation in dentistry (McDonald and Vire, 1992). They carried out a health screening evaluation on both the dentist and the assistant before the treatment appointment, five hours after patient treatment, and one year from the appointment. They used two air sampling devices placed in specific areas in the operatory and attached more devices to both the dentist and the assistant to collect employee breathing zone air samples. After that, they ensured that all clinical procedures were done with the dentist and the assistant wearing gloves, masks and eye protection, and using rubber dam isolation. They found that the chloroform concentrations in the breathing zone of the dentist and the assistant were far below the permissible limit. All health screening tests were within normal limits. They claimed that the professional and careful handling of the chloroform would ensure the safety of the dental personnel and their patients.

Many studies were directed to estimate the total amount of chloroform vapour to which dental personnel are exposed and to compare it to the permissible limits recommended by authorities. Allard and Andersson (1992) simulated a clinical condition in which chloroform was used in endodontic procedures. They demonstrated that exposure to high concentrations of chloroform is a possibility when cups are used as chloroform containers; especially if more than one chloroform-involving procedure is done per day. They suggested the use of closed containers (glass or plastic) to decrease the surface area of chloroform available for evaporation to lessen the inhalation risk. Donnelly (1993) suggested the use of 1ml syringe as a container during the procedures. However, he didn’t compare his method and the traditional use of chloroform in a Dappen dish. Margelos and associates (1996) used an in vitro study looking at the amount of vapor exposure to dentist and the patient when using bottles or dishes with either pure chloroform or a preparation containing 5% colophonium. The outcome supported the concept of reducing the surface area of chloroform available for evaporation by using closed containers instead of dishes. The use of less volatile chloroform preparations further reduced risks (Margelos et al. 1996). In 1992, McDonald and Vire conducted an in vivo study looking at the amount of chloroform manipulation in dentistry (McDonald and Vire, 1992). They carried out a health screening evaluation on both the dentist and the assistant before the treatment appointment, five hours after patient treatment, and one year from the appointment. They used two air sampling devices placed in specific areas in the operatory and attached more devices to both the dentist and the assistant to collect employee breathing zone air samples. After that, they ensured that all clinical procedures were done with the dentist and the assistant wearing gloves, masks and eye protection, and using rubber dam isolation. They found that the chloroform concentrations in the breathing zone of the dentist and the assistant were far below the permissible limit. All health screening tests were within normal limits. They claimed that the professional and careful handling of the chloroform would ensure the safety of the dental personnel and their patients.

An alternative track was to hunt for chloroform substitutes. An ideal re-treatment agent should be biocompatible to humans, easily applied and efficiently dissolve gutta percha. The best method to eliminate chloroform’s potential risk would be an alternative that would fulfill these criteria. Many studies compared chloroform with other solvents in terms of safety and efficiency in retreatment. An extensive search was conducted by Wourms and co-workers (1990) in which they chose 32 solvents based on their ability to dissolve any of the ingredients of gutta percha, or on their chemical similarity to chloroform. The sample was considered insoluble in the solvent if it took longer than 15 minutes to dissolve the gutta percha. Results showed that chloroform was the fastest solvent. Despite demonstrating results comparable to chloroform, trichloroethylene and tetrachloroethylene use was discouraged because they were suspected carcinogens. The fourth fastest agent was xylene which was known to be toxic. The fifth fastest agent was anaesthetic halothane. It dissolved the gutta percha about twice as fast as cineole, an agent used to formulate eucapercha for obturation and to remove gutta percha during retreatment. Cineole was the slowest solvent. They preferred halothane as a possible alternative to chloroform (Wourms et al. 1990). In another study, chloroform and halothane were equally effective in removing gutta percha from obturated canals but halothane was appreciably slower (Wilcox 1995). In 1991, Hunter et al. recommended the use of eucalyptol and halothane as effective substitutes for chloroform. However, halothane was significantly slower than chloroform. This was attributed to the high volatility of halothane which resulted in a lesser amount to exert the softening action. They considered the high volatility of halothane as desirable for the clinician who is concerned about residual amounts of solvent getting into the periradicular area and the patient’s systemic circulation. However, the high volatility could be a liability if the solvent evaporated before the clinician could take advantage of its softening effect. No significant difference was found between eucalyptol and chloroform in this study. On the contrary, Wennberg and Ørstavik (1989) found eucalyptol the least effective solvent among the five agents they observed. They focused on methylene chloride, methyl chloroform, tetrahydroflurane, xylol and eucalyptol but they didn’t mention the basis of their selection. The effect of the test solvent was
assessed by measuring the depth of penetration of a small indenter of fixed weight and shape into a standardized gutta percha disk covered with the test solvent. Again, chloroform was the best solvent followed by methylene chloride, tetrahydroflurane and methyl chloroform. Eucalyptol required 10 minutes of contact to produce the same softening effect as other solvents after one minute of contact. Eucalyptol is a poor solvent at room temperature. They stressed methyl chloroform as a promising substitute to chloroform. Zakariasen and colleagues (1990) appreciated the properties of eucalyptol when compared to chloroform. Accordingly, they suggested a technique that overcomes the incompetence of eucalyptol at room temperature. They recommended utilizing a self-heating instrument with the heat-potentiated solvent action of eucalyptol. In other words, heat will soften gutta percha while warming eucalyptol. The combined actions of both will guarantee the removal of gutta percha (Zakariasen et al. 1990). Meanwhile, Kaplowitz (1990, 1991) shifted away from the halogenated compounds and explored essential oils. In the first experiment (1990) he considered five essential oils including rectified white turpentine, oil of melaleuca, eucalyptol, white pine oil and pine needle oil and looked at their ability to dissolve gutta percha in comparison to chloroform. He found all of them to be effective and considered them to be good options. In his second trial (1991) he followed a more stringent procedure. He denoted the solvent to be effective only if it dissolved the gutta percha completely. He ignored the partial dissolution action that was exerted by some test oils. Only rectified white turpentine was successful under this definition and its action was comparable to chloroform. As a result, he suggested it as another substitute to chloroform. Uemura and associates (1997) compared eucalyptol and d-limonene to chloroform for their ability in retreatment of four different obturation techniques: lateral condensation, Ultraphil, Obtura II and Thermafil. They observed that both solvents were able to produce a clean canal comparable to the potentially dangerous chloroform. The latter needed much more volume in all samples than that used for d-limonene and eucalyptol. This was attributed to the volatility of chloroform. They believed that if chloroform is dangerous when inhaled, the use of d-limonene or eucalyptol will be preferred (Uemura et al. 1997). Unfortunately, in another study, d-limonene was found to be as cytotoxic as chloroform when reacted on cell line L929. The authors recommended the careful use of chloroform instead of searching for substitutes for it (Vajrabhaya et al. 2004). A different cytotoxicity study was conducted by Barbosa and co-workers (1994) investigating the consequences of the exposure of L929 cell culture to chloroform, halothane and turpentine. The latter showed the highest cytotoxicity among the solvents while chloroform and halothane had similar effects. They suggested performing retreatment without any solvents at all whenever possible (Barbosa et al. 1994).

Routine storage and disposal of chloroform must not be overlooked. It should be stored in a closed container. Pouring chloroform into the drainage system might result in contamination of soil and drinking water (Allard and Andersson, 1992). It should be kept in mind that no organic solvent is completely safe. These agents should be labelled and used under adequate ventilation (Knapp 1966).

These studies have demonstrated that there are no ideal solvents for gutta percha, and that chloroform was the superior agent regardless of its potential risk. Chloroform is not yet confirmed as a definitive human carcinogen.

Lasers
The non-stop development of new techniques and tools to improve the outcome of endodontic procedures by using lasers has received huge interest over the past 20 years (Stabholz, 2003). Laser have been claimed to be effective in diagnosing pulpal status, removing pulp tissue from canals, enlarging root canal spaces, sealing apical foramen, sealing dentinal tubules, and disinfecting root canals (McKinley and Ludlow 1994, Matsumoto 2000). The application of laser light leads to the production of a laser plume. This is a result of the dehydration of the tissue and heating of the residual solid matter to temperatures sufficient for combustion. After that, oxygen, present in ambient air, will combine with tissue elements to form a variety of by-products, many of which are unsafe (Miserendino and Robert, 1995). Hence, ablation of infected tissue can create susceptibility to cross-infection due to the possible presence of viable intact infectious agents in the laser plume. Garden and co-workers found viable DNA of papilloma virus in the laser plume.
produced after irradiating verrucae (Garden et al. 1988), while Baggish and his colleagues declared the presence of HIV pro-viral DNA in laser smoke originating from concentrated tissue culture pellets infected with HIV (Baggish et al. 1991). Both studies used a carbon dioxide laser. Frietag and associates accomplished an in vivo study that stressed the danger underlying inhalation of Nd:YAG laser smoke. In the light of their results, they concluded that the muco-ciliary function of the lung was significantly depressed and that this depression was dose-dependent (Frietag et al. 1987).

Little attention was devoted to the inhalation of laser smoke during dental procedures. Based on a Medline search one paper by McKinley and Ludlow (1994) was found which considered this risk and investigated it. Although there are several papers on laser hazards they are not in English. In this experiment by McKinley and Ludlow, root canals of five extracted teeth were inoculated with a specific strain of E. coli and then subjected to an argon laser. Culture results of the captured plume were positive for the growth of the strain inoculated. They concluded that at least some of the bacteria are expelled out of the root canal with the plume, posing a substantial health risk to the dental team and the patient in case this plume is inhaled.

Bahn considered some dental laser safety requirements that included the use of high volume suction to capture laser smoke, especially if a CO₂ laser is used (Bahn 1994). An in vivo study examining laser plumes produced by carbon dioxide lasers during laparoscopic treatment for endometriosis and/or adhesion demonstrated that the use of a smoke evacuator system with a high-efficiency multistage filter during plume-generating laser vaporization procedures was useful. In addition, a significant portion of the particles in the laser plume were in the size range of 0.5-5.0 microns. These particles are too small to be effectively filtered by the currently available surgical masks (Nezhat et al. 1987). It should be kept in mind that the evacuator system used is not the same as the suction units used in dental clinics. Studies evaluating the potency of dental suction units in eliminating plumes are needed.

Conclusion

The endodontist’s setting can be a threat to the well-being of the dental care providers and their patients. Modern instruments and materials may be considered to be double-edge swords. They do provide determined outcomes but the potential hazards of their use should always be kept in mind.

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Introduction
Perforations are mechanical or pathologic communications between the root canal system and the external tooth surface (American Association of Endodontists 2003). Perforations have long been considered one of the leading causes of failure in root canal treatment. Earlier reports listed root perforations as the second highest cause of root canal treatment failure, approximating 2-12% of failed cases (Ingle 1961; Nicholls 1962; Seltzer et al. 1967). More recently, the Toronto study also identified root perforations as the second most significant factor in predicting treatment outcome of endodontic retreatment (de Chevigny et al. 2008).

Perforations are a common complication of endodontic treatment, caries or root resorption. Perforations during root canal treatment arise from instrumentation, post space preparation and lack of knowledge of canal anatomy and its variations. Calcified canals and the close proximity of the chamber roof and the pulpal floor predispose teeth to procedural errors. Theoretically, a perforation into the supporting tissues may not necessarily cause irreversible inflammation and failure (Fuss & Trope 1996a). However, when the perforated regions are exposed to saliva, microorganisms or some restorative materials, it can initiate a series of events. Downward proliferation of epithelium to the perforation site leads to inflammation, bone necrosis and resorption. The periodontal attachment and fibres are replaced by granulation tissue resulting in pocket formation (Seltzer et al. 1970; Petersson et al. 1985). Thereafter, recurrent infection is commonly encountered hindering the healing process (Fuss & Trope 1996a). Perforations can lower the prognosis of the endodontic treatment and can lead to extraction of the tooth (Petersson et al. 1985; Gorni & Gagliani 2004). Prompt diagnosis and management of perforations is thus imperative.

Diagnosing and Locating Perforations
Diagnosis of perforations is dependent on a combination of symptoms and clinical observations.

Signs and symptoms
The first evidence of a perforation is often persistent or sudden bleeding into the pulp space (Alhadainy 1994). Sudden bleeding during canal preparation is often a result of stripping. Paper points are useful tools to diagnose perforations. The location of the staining on the paper point is indicative of the site of perforation. For example, blood staining on the side of the paper point indicates lateral stripping whereas paper point tip staining indicates apical bleeding.

Symptoms of perforation include sudden pain in cases with inadequate or no local anaesthetic and taste of irrigating solution in cases with perforations near the cervical margin. Untreated existing perforations present themselves as tooth sensitivity to percussion, chronic inflammation of gingivae, pockets (where the perforation penetrates the alveolus) and sinus tracts.

Diagnosis
Radiographs are important diagnostic aids. When perforations are suspected, a radiograph should be taken with a small file placed in the suspected perforation. Perforations on the buccal and lingual aspect of a tooth are difficult to diagnose as these perforations are superimposed on the root surface. The bucco-lingual orientation of the perforation can be detected on a radiograph by shifting the cone horizontally. Apex locators can be helpful clinical aids in detecting root perforations. However, the location of the perforation in relation to the crestal bone can only be confirmed by radiographs (Fuss et al. 1996b).

Prognosis
Many suggestions have been made to help predict the prognosis of perforations (Seltzer et
in the apical and middle third of the root have a good prognosis while perforations in the coronal third or on the floor of the pulp chamber have a doubtful prognosis (Seltzer et al. 1970).

Fuss & Trope (1996a) further specified the location of the perforation by relating perforations to the critical zone rather than along the root. The critical zone is defined by the level of crestal bone and epithelial attachment. By assessing the location of the crestal bone in relation to the perforation, one can predict the prognosis more accurately.

### Table 1. Classification of root perforations according to factors which affect prognosis (Fuss & Trope 1996a)

<table>
<thead>
<tr>
<th>Time</th>
<th>Good Prognosis</th>
<th>Poor Prognosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh</td>
<td>Old</td>
<td></td>
</tr>
<tr>
<td>Small</td>
<td>Larger</td>
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</tr>
</tbody>
</table>

**Time**

It is well established that the longer a perforation is left untreated, the worse the prognosis. Lantz and Persson (1967) found the best results when perforations in dogs were sealed immediately. Seltzer et al. (1970) treated perforations in monkeys and got the worst results in cases with no treatment, followed by delayed perforation repair (Seltzer et al. 1970). These studies demonstrate that the best time to repair a perforation is immediately (Sinai 1977; Beavers et al. 1986).

**Size**

Smaller perforations respond to repair better than larger perforations. Himel et al. (1985) highlighted this in their experiment with dogs and found that larger teeth with proportionally smaller perforations showed a better healing response.

Generally, small perforations are associated with less tissue destruction and inflammation. These perforations (ISO size 15, 20) are also more likely to occur under aseptic conditions with an overall better prognosis. Extrusion of repair material into surrounding tissues is minimal when sealing smaller perforations (Nicholls 1962).

**Location**

The location is probably the most important factor affecting perforation prognosis. The location of perforations is often categorised into apical, middle or coronal/cervical third. Root perforations...
Perforation Repair

Perforations have a significantly lower success rate (Stromberg et al. 1972). Apical perforations generally have a good treatment success rate. Perforations of the apical third or midroot without any communication to the oral cavity have a good prognosis given the main canal is accessible, adequate endodontic treatment is undertaken and an immediate seal is provided (Lantz & Persson 1967).

Treatment outcome is also affected by the seal and the sterility of the perforation site and the biocompatibility of the material used to repair the teeth (Lee et al. 1993; Arens & Torabinejad 1996). These are important factors that should be considered when predicting the prognosis of a perforation.

Management of Perforation

Management of perforation repair has been repeatedly addressed from as early as 1893 (Evans 1893; Smale & Colyer 1893). The core essence of treating perforations has not changed since Peeso recommended a treatment course for apical, middle (crestal) and coronal perforations in 1903. Even then, he recognised the need for root resection and the importance of avoiding overfill (Peeso 1903).

The management of perforations includes a thorough examination, especially periodontal examination. If there is no disease associated with the defect or tooth, then no treatment is required (Roda & Gettleman 2006). However, if there is evidence of periradicular pathosis, repair is indicated (Roda 2001). Perforations can be managed intracoronally or extra-coronally. Intracoronal access is achieved internally through the tooth. Extra-coronal access is achieved surgically or through rapid extrusion of the tooth using orthodontics.

The approach taken is determined by the ability to achieve a good seal between the tooth and the material. The ability to achieve a good seal is determined by the location, the size of the perforation, operator skills, and the physical and chemical properties of the sealing materials (Lantz & Persson 1967; Seltzer et al. 1967; Sinai 1977; Lee et al. 1993).

Generally a nonsurgical approach should be chosen. A conventional coronal approach is less invasive, reduces periodontal tissue damage, improves isolation from microbes and enhances disinfection (Roda & Gettleman 2006). In their earlier studies on dogs, Lantz & Persson (1970) found combined endodontic-surgical treatment showed superior healing compared to conventional endodontic treatment alone in the management of perforations. However, with the introduction of better magnification, illumination and sealing materials, the prognosis of what would have been considered hopeless teeth is now manageable with non-surgical repair and conventional root canal treatment.

Supracrestal perforations

Supracrestal perforations can generally be managed non-surgically. Traditional restorative materials such as amalgam, gold, composite or cast metal restorations (margins extended to include defect) can be utilised for repair (Regan et al. 2005). The material of choice is generally driven by aesthetics.

Sometimes it may be necessary to expose the defect before repair. This can be achieved orthodontically by extruding the tooth (Ivey et al. 1980; Smidt et al. 2005) or surgically by crown lengthening (Allen 1993). This exposes the perforation site supragingivally making repair simple.

Crestal perforations

Crestal perforations are often associated with poorer treatment outcomes. They are challenging to repair because of their proximity to epithelial attachment. They are very susceptible to epithelial migration and rapid periodontal pocket formation. The three broad categories of crestal perforations include strip perforations, furcation perforations and perforations related to external cervical root resorption (Rankow & Krasner 1996).

Surgical intervention should be avoided when possible, especially with furcal and strip perforations, to preserve any periodontal attachment, thus increasing the long-term success of the treatment (Fuss & Trope 1996a). However, intracoronal access to the repair site is challenging and often adequate access is only achieved through an extracoronal approach. External cervical resorption cases may require management from an external approach to maintain the vitality of the tooth. However, it may be necessary to carry out root canal treatment in cases where pulpal
Perforation Repair

exposure is unavoidable or in the presence of irreversibly inflamed or necrotic pulps.

In cases of single-rooted teeth, orthodontic extrusion of the perforation site on the tooth may allow adequate access for external repair. Despite predisposing the tooth to a poor crown-root ratio, it maintains the tooth in the arch, eliminating the need for extraction (Smidt et al. 2007).

Apical perforations
These are treated as a routine endodontic procedure. Small and fresh lesions can be treated in one visit and sealed with gutta percha. Small and older lesions should be treated with intracanal antibacterial medicament and sealed in the second visit. Large perforations should be treated like teeth with immature apices (Fuss & Trope 1996a). If the defect cannot be managed conventionally, apical surgery may become necessary (Gutmann & Harrison 1991; Regan et al. 2005).

Non-Surgical Management of Perforations
The first step in non-surgical perforation repair is locating the perforation and preparing the coronal flare to prevent blockage when restorative material is placed in the canal (Roda & Gettleman 2006). The infected dentine from the walls and the perforation site should be mechanically removed. Depending on the size of the perforation, sodium hypochlorite or saline is used as an irrigant. If the perforation is large, saline is used as sodium hypochlorite is known to have detrimental effects on the soft tissues (Hülsmann & Hahn 2000).

Access to and cleaning of the perforation site induces haemorrhage. Achieving haemostasis is a critical step in perforation repair, mainly to allow visualisation of the perforation site. Materials used for perforation repair also depend on adequate moisture control to achieve a good seal and ultimately success. Haemostasis can be achieved by applying pressure or by using haemostatic agents such as collagen-based materials, Surgicel (Ethicon, New Jersey, USA), Gelfoam (Johnson & Johnson, Ethicon Inc, New Jersey, USA), bone wax, ferric sulphate, calcium sulphate, calcium hydroxide and epinephrine pellets (Johnson & Witherspoon 2006). The use of ferric sulphate has been questioned as it is a necrotising agent which results in haemostasis within 5 minutes but, if left behind in the osseous defect, can induce a foreign body reaction with impaired healing (Lemon et al. 1993).

Following successful haemostasis the entrance to the apical portion of the root canal should be temporarily blocked off to prevent repair material entering and blocking future access to the apical terminus. Various materials have been recommended for this purpose such as cotton pledges, gutta percha cones, paper points, shredded collagen and severed files. Severed files should be used with caution. Materials interlocking into the flutes of the file make removal difficult once the repair material is in place (Johnson & Witherspoon 2006).

The tissue surrounding the defect should be assessed. Large osseous defects often result in extrusion of repair material into the periradicular space. This is known to impair the healing process. In 1992, Lemon first discussed the use of a “matrix” in large defects for perforation repair. This internal matrix concept included placing a resorbable material in the osseous defect against which repair material can be packed without causing an overfill of the defect with restorative material and thus resulting in faster and superior healing (Lemon 1992; Rafter et al. 2002).

Matrix materials include collagen, freeze-dried demineralised bone allograft, hydroxyapatite (Rafter et al. 2002), Gelfoam, calcium sulphate (plaster of paris) (Johnson & Witherspoon 2006), calcium hydroxide, calcium phosphate and Atrisorb GTR membrane (Atrix Laboratories, Fort Collins, CO) (Salman et al. 1999). Use of calcium hydroxide in furcal areas has been questioned, as the initial inflammatory response to these materials could lead to periodontal breakdown with periodontal pocket formation (Himel et al. 1985). Encouraging outcomes have been reported when internal matrices have been used in non-surgical repairs of large perforations (Lemon et al. 1993; Rafter et al. 2002; Bargholz 2005; Bramante et al. 2007). One of the limitations of using internal matrices is the need for direct access and visualisation of the perforation site (Lemon et al. 1993). However, once a matrix has been placed, placement of repair material is simplified. This can be followed by completion of the root canal therapy.
Surgical Management of Perforations
Surgical repair of perforations has received sporadic attention in the dental literature. Existing knowledge is primarily attributed to case reports and limited studies. It is postulated that surgical repair of a perforation is more difficult than root-end resection (Gutmann & Harrison 1991). Indications for surgical intervention include the following:

- the defect is better accessed surgically
- a satisfactory restoration exists which, if disassembled to access the site would be time-consuming and costly (Sinai 1977; Johnson & Witherspoon 2006)
- large perforations
- perforation as a result of external resorption which cannot be accessed through the root canal (Tsesis & Fuss 2006)
- failure of healing after non-surgical repair (Nicholls 1962)
- concomitant periodontal therapy is required (Gutmann & Harrison 1991)

It is imperative to take the following factors into consideration before surgical intervention (Gutmann & Harrison 1991):

- amount of remaining bone – even if only a bridge of crestal bone remains it should be preserved (Rud et al. 1998)
- extent of osseous destruction
- accessibility to the defect – buccal perforations are easy to repair whereas lateral and lingual/palatal perforations can pose technical difficulties
- duration of defect
- periodontal disease status
- soft tissue attachment level
- patient’s oral hygiene
- surgeon’s experience

Soft tissue flap design and management should take into account fraenal and muscle attachments, bony eminences and the position of the defect. Horizontal relieving incisions should include the entire papilla of the tooth to accommodate any defect which may extend interproximally (Gutmann & Harrison 1991; Regan et al. 2005). Vertical incisions are generally included to improve access and also limit the number of vessels severed. This reduces haemorrhage, which is especially desirable for vision and when bonded materials are planned for the restoration.

Hard tissue management in perforation repair is similar to that required for root-end surgery. Healthy tissue is removed to expose and remove diseased tissue. An appropriate cavity is created to place restorative material. Haemostatic techniques and materials are used to achieve a dry clear surgical site and to facilitate placement of a restorative material. The haemostatic techniques are similar to those utilized for non-surgical management. In addition cauterization (electrosurgery) can be used (Makkawy et al. 1998). Use of tri-chloroacetic acid (TCA) has been suggested for haemostasis during the treatment of cervical root resorption (Smidt et al. 2007). Care must be taken to avoid spillage of TCA as severe caustic burns can occur.

Root surface conditioning is recommended after placement of the final restoration. Conditioning removes the smear layer and provides a surface conductive to cellular adhesion and growth (Regan et al. 2005). Citric acid, tetracycline and ethylenediamine tetra-acetic acid (EDTA) are commonly used. Fifteen to 24% EDTA applied for approximately 2 min removes mineral from the dentine to expose collagen fibres without injuring adjacent tissues. However, root conditioning is contraindicated when mineral trioxide aggregate (MTA) is used as a perforation repair material or root-end filling. It was shown in an animal study that cementogenesis does not occur on MTA following root surface conditioning (Abedi et al. 1997).

Guided tissue regeneration (GTR)
Healing of the surgical site is directed by the type of cells reaching and proliferating in this site. Different types of cells repopulate the site at different rates. Epithelial cells travel and proliferate faster than the more desired periodontal ligament and bone cells. This can result in unfavourable healing such as the formation of a long junctional epithelium which may break down with a resultant periodontal pocket.

The concept of guided tissue regeneration (GTR) is to impose a barrier between the gingival tissue and the exposed root tissue. This barrier prevents colonisation of the root surface by epithelial cells and “guides” other slower growing periodontal ligament and osteogenic cells to invade and proliferate at the surgical sites. This promotes favourable healing by the formation of connective tissue attachment and bone formation. This barrier
Perforation Repair can be resorbable or non-resorbable. A resorbable barrier is recommended for endodontic surgery to avoid a second surgical procedure. GTR should be considered as an adjunct to periradicular surgery in cases of apicomarginal bone loss (Dietrich et al. 2003). It can be used in cases deemed to have poor prognosis due to bone loss from furcal or crestal perforations as osseous healing following repair is compromised (Duggins et al. 1994; Rankow & Krasner 1996).

Intentional Replantation
This procedure involves atraumatic tooth extraction to avoid damage to periodontal ligament and cementum. The tooth and perforation site are then carefully inspected using a dental operating microscope and repaired appropriately. The tooth is very carefully handled with forceps and rinsed with saline and replanted in the shortest time possible to avoid complications such as external cervical resorption or ankylosis.

This treatment can be considered when orthograde or surgical options are not viable or have failed. With proper case selection and clinical procedures a reasonable success rate can be expected (Grossman 1966; Bender & Rossman 1993; Raghoebear & Vissink 1999).

Materials used in Perforation Repair
Material selection for perforation repair is critical for the success of treatment. With proper sealing of perforations, a fair prognosis can be expected. An ideal material should have the following properties:

- prevent leakage of bacteria and bacterial by-products from and to periradicular tissues
- non-toxic
- biocompatible
- dimensionally stable in tissue fluids and insoluble
- easy to use

Various materials have been suggested for perforation repair. These include Cavit (3M ESPE), zinc oxide-eugenol, calcium hydroxide, amalgam, gutta-percha, tricalcium phosphate and hydroxyapatite, freeze dried bone, MTA, intermediate restorative material (IRM®, Dentsply Caulk, Milford, DE), glass ionomer cements (GIC), resin modified glass ionomer cements, composites and a number of materials combining the properties of GICs and composites (Hartwell & England 1993; Lee et al. 1993; Main et al. 2004; Torabinejad 2004; Regan et al. 2005).

Despite numerous studies, conflict still exists with respect to a “best” material. A lack of methodological standardisation between studies leads to conflicting results. Balla et al. looked at histological sections of perforation repairs with tricalcium phosphate, hydroxyapatite, amalgam and Life (Dentsply Caulk). At 6 months, none of the repair materials resulted in hard tissue formation, with amalgam showing the most favourable response with minimal inflammation (Balla et al. 1991). On the other hand Pitt Ford et al. (1995) looked at histological sections of perforations repaired with amalgam and MTA and found severe inflammation associated with amalgam at 6 months. The majority of the teeth repaired with MTA were found to have cementum over the MTA.

Amalgam has been commonly used in perforation repairs. However, it has poor sealing ability when compared to other available materials. It is also designed to be condensed into a cavity. Thus in a furcation, which can be a bottomless cavity, the amalgam is not well condensed and tends to be extruded into the surrounding periradicular environment (Alhadainy & Himel 1993; Rafter et al. 2002). When amalgam is used with an internal matrix, unintentional extrusion can be controlled and superior healing is expected (Lemon 1992; Rafter et al. 2002). When used as a perforation repair material amalgam had detrimental effects on cell vitality in the initial 24 hours (Makkawy et al. 1998). The use of amalgam resulted in inflammation of the periradicular tissue preventing regeneration. Amalgam was also found to be more cytotoxic than resin-modified GIC. Light-cured GIC provided a superior seal compared to Cavit and amalgam, had better flow properties and bonded to dentine (Alhadainy & Himel 1993). However, various in vitro studies on cells have shown GIC to be toxic, inhibiting cell viability (Peltola et al. 1992; Huang et al. 2002; Souza et al. 2006).

The choice of material is best determined based on the site of the perforation. Supracrestal or coronal lesions support materials that can resist
dissolution by oral fluids, abrasion and erosion. Composites, GICs, amalgam and cast restorations are best suited for these sites (Regan et al. 2005). Crestal perforations are not exposed to oral fluids and abrasion, therefore materials like IRM, Cavit or MTA are appropriate for these locations. The choice of material is critical when restoring furcal or perforations close to the crestal bone level. Histological sections from animal studies showed severe inflammation with abscess formation causing bone resorption when perforations in the coronal third were sealed with zinc oxide eugenol (Seltzer et al. 1970; Bramante & Berbert 1987). Bone resorption significantly reduces the prognosis of these teeth. Zinc oxide eugenol-containing materials like IRM should thus be used with caution as perforation repair materials in the coronal third of the root near the crestal bone.

The introduction of MTA has renewed the interest in crestal perforation repair. MTA was introduced in the early 1990s by Torabinejad & colleagues. It has since received FDA approval for use in various applications including perforation repair. MTA is a hydrophilic powder which, when mixed with water forms a colloidal gel that solidifies in 4 hours. MTA is derived from Portland cement. The difference between the two is that MTA contains bismuth and a lesser quantity of gypsum to reduce setting time with smaller, uniform particle sizes. A radiopacifier (bismuth oxide) has been added to MTA for radiographic diagnosis (Camilleri & Pitt Ford 2006).

Hydration of MTA results in the production of calcium hydroxide as a by-product. The tissue response is therefore similar to the response elicited by calcium hydroxide. Based on prior results from human (Bogaerts 1997) and animal (Pettersson et al. 1985) studies, it has been speculated that calcium hydroxide based materials e.g. MTA are not suitable for crestal and furcal perforations. This theory is based on the initial inflammatory response which could lead to periodontal ligament breakdown. However, animal studies have shown little or no inflammation, with cementum repair at the MTA-dentine interface (Pitt Ford et al. 1995; Holland et al. 2001). There are, however, insufficient human studies comparing MTA to other commonly used materials in perforation repair. However, long-term clinical evaluation of clinical cases (1 year) shows favourable results following perforation repair with MTA (Main et al. 2004; Arens & Torabinejad 1996). Nevertheless, MTA is now widely acknowledged and accepted as a biocompatible material with minimal adverse tissue reactions (Torabinejad et al. 1995a; 1998; Apaydin et al. 2004).

It is proposed that MTA can be used without an internal matrix to seal furcation perforations, as cementum will form in contact with the material and will allow regeneration of the periodontal ligament (Lee et al. 1993; Torabinejad et al. 1995b; Rafter et al. 2002). However, case reports have shown good success with matrix placement (modified matrix concept) before using MTA to repair perforations (Bargholz 2005; Bramante et al. 2007).

MTA fulfils the sealability, biocompatibility and radiopacity requirements for a good perforation repair material. It provides a good seal even when the site is contaminated with blood (Torabinejad et al. 1994; Nakata et al. 1998; Yatsushiro et al. 1998). However, its prolonged setting time is a disadvantage making it undesirable for use in supracrestal or cervical perforations.

**Conclusion**

Currently, perforations are considered to be one of the leading factors in predicting treatment outcome of endodontic retreatment. Even though the core science of perforation management has not changed since Peeso recommended perforation management in 1903, our understanding of perforation management has improved tremendously. Recent years have seen the introduction of magnification, illumination and new materials such as MTA. The impact of these are highlighted in case reports with improved treatment outcomes of teeth. However, there is a need for long-term clinical studies on the use of new perforation repair materials, especially MTA.

**References**


Perforation Repair


Peezo FA (1903) The “ABC” of crown and bridge work. Dental Cosmos 45, 274-279.


An 11-year old female was referred from the paedodontic unit at the School of Dentistry, University of Otago for the management of tooth 46. She had attended a paedodontic clinic for treatment of an acute abscess on tooth 46. She was placed on 250mg/5ml of Amoxicillin, 5ml three times a day, for 5 days. A general anaesthetic was scheduled for a single visit root canal treatment of tooth 46 and other general dental procedures. The patient was suspected to have cleido-cranial dysplasia but this was yet to be confirmed by the geneticist. Otherwise there were no other medical conditions and no known allergies.

Extraoral examination revealed mid-face hypoplasia. Intraoral examination revealed heavily filled discontinuous arches with various retained primary teeth and missing secondary teeth (Figure 1). The patient presented with traumatic occlusion to the palate, posterior crossbite on the right-hand side, edge-to-edge bite on the posterior left-hand side and a mid-line shift (Figure 2).

Tooth 46 was restored with a small, but deep and fractured Glass Ionomer coronal restoration. Secondary decay was also evident. The tooth was slightly tender to percussion, had grade 1 mobility and responded negatively to cold and electric tests. Radiographic examination showed a furcation as well as an apical radiolucency and the lamina dura was absent (Figure 3).

After discussions with the patient’s mother, it was decided that root canal treatment will be attempted during the general anaesthetic procedure. It was also agreed that if the tooth proved to have a poor prognosis that it will be extracted during the procedure.

The treatment was carried out under general anaesthesia with supplementary inferior dental block of Scandonest 2% with adrenaline to reduce
immediate post-operative pain (Gordon et al. 1997). The tooth was isolated with rubber dam and the restoration was removed with a diamond bur on a high-speed handpiece. The pulp chamber was visible on removal of the restoration and slight bleeding was observed from the canals. The access cavity was modified to obtain a straight-line access to the three root canals.

Chemomechanical preparation of the root canals were carried out with Hedstrom hand files and ProFile rotary files (Dentsply Maillefer, Ballaigues, Switzerland) and copious amounts of 2.5% Sodium hypochlorite and RC PrepTM (Premier Products Company, Plymouth Meeting, USA). The root canals were obturated with single gutta percha cones and AH Plus sealer (Dentsply Maillefer, Ballaigues, Switzerland) A Fuji IX orifice sealer was placed and extended as a thin layer onto the pulp floor, followed by the placement of a direct occlusal amalgam restoration as the final coronal restoration (Figure 4).

The patient was recalled and reviewed after 6 months. No clinical signs or symptoms were present and healing was apparent on the radiograph with the formation of a lamina dura (Figure 5). The patient will be followed up yearly for a further 4 years.

Discussion

Although minimal evidence is available, it is generally accepted that a diseased 1st molar be extracted if the neighbouring 2nd molar has a 1/3 formed root and is mesially inclined. In this case tooth 47 was favourably placed, however the patient had several retained primary teeth and several unerupted secondary teeth. When the OPG was examined, it showed that the secondary teeth did not have failure of development but rather failure of eruption. Most roots were fully developed with closed apices and the root-ends extending almost to the inferior border of the mandible (Figure 6). The most likely explanation of this anomaly is cleidocranial dysplasia.

Cleidocranial dysplasia (CD) is a hereditary congenital disorder due to mutation of the RUNX gene on the short arm of chromosome 6 (Feldman et al. 1995). CD is a skeletal dysplasia characterized by delayed closure of the cranial sutures, aplastic or hypoplastic clavicles and multiple dental abnormalities including:

- mid-face hypoplasia
- delayed eruption of secondary dentition
- failure to shed the primary teeth
- malocclusion
- deformed root formation
- hypoplastic or aplastic clavicles
Other features include – failure of fontanelles to close and bulging forehead (Anspach & Huepel 1935).

Shokier in 1974 was the first person to describe such a condition as a bona fide version of CD (Shokeir 1974). Rasmussen & Kotsaki (1997) described 5 different cases with similar conditions and in all these cases treatment planning was difficult. O’Connell and Torske (1999) published a unique case with all the primary teeth retained and none of the secondary teeth erupted.

Although some of these features were evident on Ms S, the presence of healthy clavicles and a normal skull did not suggest a true diagnosis of CD. However, at the time it was not known that her half-sister had been diagnosed with CD. The father paternal grandfather and paternal grandfather father were also known to have this condition.

It was imperative to retain as many of the erupted teeth as possible, as the fate of the unerupted teeth was, and still is, unknown. Single visit root canal treatment (Field et al. 2004; Sathorn et al. 2005) has been chosen for this patient, mainly due to the need for extraction of several other teeth under general anaesthesia. Although full coverage indirect restorations are recommended for root-filled teeth (Aquilino & Caplan 2002; Ray & Trope 1995), a direct occlusal restoration was placed, as minimal tooth structure was lost (Assif et al. 2003).

The successful outcome of the root canal treatment at the six months’ review contributes favourably to future treatment planning for this patient.

References
News from the School

Excellent news for the endodontic discipline (and others) is the purchase by the Faculty of three operating microscopes. The new machines are the same Zeiss OPMI pico type to the one purchased by the Society of Endodontics in 2002. This has proved to be a robust and reliable piece of equipment. The investment in new machines has become necessary as 8 endodontic postgraduates will be in house in 2009 and the work that they undertake is becoming more complex. Over one third of the root canals the postgraduates encounter are destined for retreatment, with many also having obstructions such as broken files or root canal posts present.

One of the microscopes will spend most of its time on the first floor of the School, where it is close to the two operating theatres and available to staff and students working there.

The School has recently become part of the Dentsply Maillefer School Grant Program. This involves the supply of 25 X-Smart endodontic motors which will allow increased teaching of rotary nickel titanium preparation techniques to our undergraduates. A protocol will be developed to allow these skills to be taught to the fourth year students in 2009. With a new curriculum being introduced it is likely that this aspect of endodontic teaching will become part of the third year experience in 2010.

Nick Chandler

Four Otago postgraduate students attended the Trans-Tasman Endodonic Conference in Hobart. They are from left: Poonam Verma, and Endodontic Clinical Doctorate students Abdul Azzizz, Artika Patel and Shalin Desai.

Associate Professor Nick Chandler was an invited speaker at the Trans-Tasman Conference.
### Statement of Financial Performance
For the Year Ended 31 March 2008

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<td>$6,612</td>
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This statement has been compiled without undertaking an audit engagement or review engagement and should be read with the compilation report - disclaimer of liability and notes to the financial statements.

BDO Spicers Auckland
Chartered Accountants and Advisers
### Statement of Movements in Equity
**For the Year Ended 31 March 2008**

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Most funds are in Term Deposit at a Bank. There are no funds with Investment Companies.

*This statement has been compiled without undertaking an audit engagement or review engagement and should be read with the compilation report - disclaimer of liability and notes to the financial statements.*

BDO Spicers Auckland
Chartered Accountants and Advisers