A SURVEY OF THE IRRIGATION PROTOCOLS USED BY DENTISTS IN BRITISH COLUMBIA, CANADA

by

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Abstract

The goal of endodontic treatment is to prevent and eliminate infection. This is achieved by mechanical and chemical cleaning of the root canal. Chemical cleaning is a process in which irrigants are introduced in the root canal to eradicate bacteria and flush out debris. A study was conducted to assess the type, concentration of sodium hypochlorite (NaOCl), volume, sequence and method of delivery system of different irrigants used by general practitioners (GP) and endodontists (ENDO) in treating teeth with vital (VP) or non-vital pulp (NVP). We hypothesized that there are no significant differences between the groups regarding the method of irrigation in root canal treatment.

Methods: 1) A total of 68 samples of bleach were collected from GP offices in Vancouver. Using titration, the concentration of hypochlorite in these bleach samples was calculated. 2) A questionnaire was sent to 150 GP and 42 ENDO registered with the College of Dental Surgeons of British Columbia.

Results: The overall response rate to our questionnaire was 70.3%. Irrigants used in treating teeth with VP were NaOCl: ENDO 93.4%, GP 89.9% ($p=0.445$), EDTA: ENDO 72.9%, GP 35.1% ($p<0.001$), and RC-Prep™: ENDO 29.7%, GP 67.2% ($p< 0.001$). Irrigants used in treating teeth with NVP were NaOCl: ENDO 95.7%, GP 94.2% ($p= 0.657$), EDTA: ENDO 76.2%, GP 36.2% ($p< 0.001$), and RC-Prep™: ENDO 31.9%, GP 71.9% ($p< 0.001$). Majority of the ENDO (82.3%) used 5-6% NaOCl whereas 55% of the GP used 3-5% NaOCl. Commonly used irrigation needle by both groups was stainless steel with a tip size of 27G (ENDO 28.0%, GP 36.0%). The irrigation needle was inserted in the pulp chamber ENDO 79.8%, GP 75.2%, the coronal/mid canal: ENDO 79.8%, GP 85.3%, and the apical area ENDO 50.3%, GP 25.2%. Except for EDTA and saline, there were no statistically

significant difference between both groups in their choice of the initial, in-between or final irrigant used.

Conclusion: The ENDO and GP followed the recommended "best practice" for irrigation regarding the use of antimicrobial agents, such as NaOCl. However, the use of demineralizing agents for removing the smear layer was less frequent, particularly among the GP.

Preface

The conduct of this research was approved by the University of British Columbia Office of Research Studies Behavioural Research Ethics Board. REB number: H09-01375.

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List of Abbreviations

BC	British Columbia
CDSBC	College of Dental Surgeons of British Columbia
EDTA	Ethylenediamine tetraacetic acid
ENDO	Endodontists
GP	General practitioners
NaOCl	Sodium hypochlorite
NVP	Non-vital pulp
UBC	University of British Columbia
VAS	Visual analogue scale
VP	Vital pulp

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Dedication

To my family…….

Chapter 1: INTRODUCTION

The success of endodontic treatment is dependent on the success in eradication and/or prevention of infection. This goal is achieved by chemomechanical instrumentation and disinfection, mainly by a variety of irrigation solutions. The importance of irrigation in endodontic treatment is widely recognized and many different irrigants and delivery systems used for root canal treatment have been developed and studied. However, little is known about how general practitioners (GP) and endodontists (ENDO) incorporate the generally accepted recommendations concerning the use of irrigants into their daily practice.

Chapter 2: REVIEW OF THE LITERATURE

2.1 Goal of endodontic treatment

Apical periodontitis is a sequel to endodontic infection and manifests itself as a host defense response to microbial challenge emanating from the root canal system (Nair *et al.* 2004).

The goal of endodontic treatment is elimination and prevention of disease from the root canal system and periapical tissue. Studies have shown that root canal treatments have success rates ranging from 64% to 96% (Strindberg 1956; Eriksen *et* al. 1990; Sjogren *et al.* 1990). Microbial eradication within the root canal system can be achieved by mechanical and chemical cleaning. Due to the complex anatomical nature of the root canal system compromising fins, apical deltas, lateral and accessory canals, effectiveness of mechanical cleaning is limited. Peters *et al*. (2001) have shown that 35% or more of the canals' surface area remained untouched after instrumentation. Chemical cleaning is recommended to debride the inaccessible surfaces and to facilitate removal of microorganisms, tissue remnants, and dentin chips from the root canal system.

2.2 Role of bacteria

Bacteria play the main role in the development of apical periodontitis (Kakehashi *et al*. 1965). Inflammation of the root canal space is most commonly a response to an advanced carious lesion (Langeland 1987). Cracks extending into the pulp chamber can also initiate endodontic infection (Cameron 1965). Any discussion of microbial entry into the root canal system should differentiate between vital and non-vital cases. Pulpal

inflammation appears to be elicited by bacterial antigens that diffuse into the pulp through dentinal tubules (Hahn 2000).

Vital pulp tissue can defend against microorganisms and is thus largely non-infected until it gradually becomes necrotic (Langeland 1987). However, vitality cannot always be predictably evaluated with current sensitivity and radiographic tests (Seltzer 1963). A positive thermal or electrical stimulation of pulp is an indication of the activity of sensory nerve fibers, not the level of blood flow. Laser Doppler Flowmetry has been suggested to be an accurate and reliable method to assess pulpal blood flow (Evans *et al*. 1999; Ingolfsson *et al.* 1994). Treatment of teeth with vital pulp emphasizes asepsis, i.e. the prevention of infection from entering a germ free environment. However, the pulp space of a non-vital tooth with radiographic signs of periapical radiolucency always contains multiple microorganisms (Sundqvist 1976), therefore endodontic treatment of teeth with non-vital pulp focuses on the removal of these microorganisms from the root canal system.

2.3 Root canal infection

Primary root canal infections are polymicrobial, typically dominated by obligately anaerobic bacteria (Sundqvist 1994). Gram-negative anaerobic rods, Gram-positive anaerobic cocci, Gram-positive anaerobic and facultative rods, *Lactobacillus* species and Gram-positive facultative *Streptococcus* species are most frequently found in the root canal system (Sundqvist 1994). Most of the obligate anaerobes are eliminated during root canal treatment.The most common bacteria identified in primary root canals are *Olsenella uli, Pyramidobacter piscolens, Eubacterium sulci, Eubacterium* spp*., Actinomyces* spp., *Dialister pneumosintes (Bacteriodes pneumosintes), Dialister invisus,Tannerella*

forsythensis (B. forsythus), Prevotella spp.*, Prophyromonas* spp.*,* and *Treponema* spp.*,* (Fouad *et al.* 2002; Haapasalo *et al*. 1986; Moller 1966; Siqueira *et al.* 2002; Rocas and Siqueira 2010).

Most of the obligate anaerobes are eliminated during root canal treatment. In contrast, facultative bacteria are more likely to survive chemo-mechanical instrumentation and root canal medication (Chavez De Paz *et al.* 2003). *Enterococcus faecalis* has been recognized as the bacteria present most frequently in cases of failed root filled teeth (Engstrom 1964; Peciuliene *et al*. 2001). Other microbes commonly isolated in retreatment cases include Gram-positive facultative organisms such as *Streptococcus* spp., *Lactobacillus* spp., *Actinomyces* spp., *Propionibacterium* spp., Gram-negative coliform rods, and the yeast *Candida albicans* (Chavez *et al.* 2003; Peciuliene *et al.* 2001; Waltimo *et al.* 2003).

2.4 Epidemiological studies

Several cross-sectional epidemiological studies in different countries have shown that the prevalence of apical periodontitis in root filled teeth is 16-65% in different populations (Soikkonen 1995, Sidaravicius *et al.* 1999, De Moor *et al.* 2000, Lupi-Pegurier *et al*. 2002, Dugas *et al.* 2003). This relatively high prevalence can be explained by multiple factors, many of which are related to the quality of the endodontic treatment. As irrigation is one of the most important parts of a root canal treatment, problems in irrigation can be regarded as one potential factor in the failure of treatment.

Sodium hypochlorite is the irrigant of choice because of its favorable properties which include antimicrobial activity (Shih *et al*. 1970, Bystrom & Sundqvist 1985) and the ability to dissolve organic tissue (Grossman & Meiman 1941, Koskinen *et al.* 1980,

Abou-Rass & Oglesby 1981, Gordon *et al.* 1981) and denature toxins (Buttler & Crawford 1982). However, sodium hypochlorite also has undesirable properties such as a foul odor: moreover, it causes severe pain if it is accidentally introduced into the periapical area of the tooth or foul taste if it leaks into the oral cavity during treatment. To prevent the latter, the tooth should be isolated with a rubber dam. The use of a rubber dam during root canal treatment in different countries has been reported to be 18.3% (Marshall & Page's 1990), less than 19% (Jenkins *et al.* 2001), less than 20% (Whitworth *et al*. 2000), 2% (Ahmed *et al.* 2000), less than 3% (Al-Omari 2004), 57% (Koshy *et al.* 2002) and 58% (Hill *et al.* 2008). In the absence of a rubber dam, a practitioner may choose not to use sodium hypochlorite and use other irrigants, such a local anaesthetic solution, which are less unpleasant to taste and avoid the risk of discomfort should the patient swallow the solution (Whitworth *et al*. 2000). A practitioner's choice to not use a rubber dam and the consequent effect on choice of irrigants and irrigation technique can directly affect the standard of root canal treatment and have a negative impact on the success rate (Elderton 1971).

2.5 Types of irrigants

The irrigants used currently during endodontic treatment can be divided into antimicrobial, tissue dissolving, and decalcifying agents. Sodium hypochlorite has both antimicrobial and tissue dissolving properties. Chlorhexidine and alcohol are considered to be antimicrobial, while EDTA, RC-Prep™ (Premier Dental: Philadelphia, PA, USA), MTAD™ (Dentsply, Tulsa, OK, USA), Smear Clear™ (Sybron Endo, CA, USA) and citric acid are considered to be decalcifying irrigants.

2.5.1 Sodium hypochlorite

Sodium hypochlorite is a halogen-releasing agent and is the only irrigant with the ability to dissolve organic tissue. A necrotic tissue dissolution capacity of 1% concentrated sodium hypochlorite was compared to 10% chlorhexidine, 3% and 30% hydrogen peroxide, 10% citric acid, 5% dichloroisocyanurate and 10% citric acid. This comparison showed that only sodium hypochlorite had any substantial tissue dissolution capacity (Naenni *et al.* 2004). The concentration of sodium hypochlorite used in endodontics today varies from 0.5% to 6%. An in vitro study has shown that the most effective irrigation regimen for removing *Enterococcus faecalis* from infected dentin cylinders is 5.25% NaOCl at 40 minutes, whereas 1.3% and 2.5% NaOCl for same time interval are ineffective (Retamozo *et al.* 2010). At low concentrations it will dissolve mainly necrotic tissue (Zehnder *et al.* 2002).

Pecora *et al*. (1999) reported that sodium hypochlorite acts as an organic, and fat solvent that degrades fatty acids, transforming them into fatty acid salts (soap) and glycerol (alcohol), that together reduce the surface tension of the remaining solution. Hypochlorous acid, a substance present in sodium hypochlorite solution, when in contact with organic tissue acts as a solvent, releases chlorine that combined with protein amino group, forms chloramines (chloramination reaction). Hypochlorous acid ($HOCl^-$) and hypochlorite ions (OCl^-) lead to amino acid degradation and hydrolysis (Estrela *et al.* 2002). Between pH 4 and 7, chlorine exists predominantly as HOCl, whereas above pH 9, OCl^- predominates (Mcdonnell *et al.* 1999). However at identical levels of available chlorine, hypochlorous acid is more bactericidal than hypochlorite (Bloomfield *et al.* 1979).

Sensitivity to sodium hypochlorite is rare and only a few cases of allergic reactions from root canal irrigants have been reported (Caliskan *et al.* 1994). The antimicrobial effect of sodium hypochlorite is based on its high pH and the amino acid chloramination reaction (Estrela *et al.* 2002). Its high pH interferes in the cytoplasmic membrane integrity just like the mechanism of action for calcium hydroxide. The amino acid chloramination reaction interferes with cellular metabolism. Oxidation promotes irreversible bacterial enzymatic inhibition by replacing hydrogen with chlorine (Estrela *et al.* 2002). Sodium hypochlorite is the most frequent irrigant used because it performs most of the desired functions of an optimal endodontic irrigant (Zehnder 2006).

2.5.2 EDTA & RC-Prep™

A 1-5µm thick smear layer is the result of the direct action of the endodontic instrument on the root canal wall (Mader *et al*. 1984). The smear layer consists of ground dentin and predentin, pulpal remnants, odontoblast processes and bacteria (Mader *et al*. 1984). The smear layer can delay or hinder antimicrobial action of irrigants in the dentinal tubules (Orstavik & Haapasalo 1990) and the ability of the sealer to penetrate the dentinal tubules (Oksan *et al.* 1993).

Hahn and Regadas in 1951 first reported on the demineralizing effect of EDTA on dental hard tissues. EDTA is a chelator that can form a stable complex with calcium. Chelator agents are chemicals that combine with metal ions and remove them from their sphere of action. When all the binding sites of EDTA are used,,equilibrium is reached and no further dissolution takes place (Hulsmann *et al.* 2003). The properties of EDTA are self-limiting and this is thought to be due to pH changes during the demineralization of dentin (Seidberg & Schilder 1974). In liquid or paste form, chelators are used for

irrigation during mechanical instrumentation; in gel form, chelators are used as lubricants. Chelators are used in narrow and calcified canals to facilitate removal of dentin (Serene 1976; Lovdahl 1997), and for removal of smear layer (Scelza *et al.* 2000). RC-Prep™ is another product containing EDTA. RC-Prep™ is a combination of 10% urea peroxide, 15% EDTA and glycol in an aqueous ointment base (Reference).

In the coronal and middle parts of the root canal, EDTA, with a neutral pH, dissolves significantly more calcium and phosphorous than RC-Prep™. RC-Prep™ has been found to mainly decalcify and remove the loosely attached parts of the superficial smear layer, but it cannot modify the subsurface dentin (Verdelis *et al.* 1999). Irrigation with 17% EDTA solution has a good cleaning effect on the root canal walls to remove the smear layer (Scelza *et al.* 2000) and the dentinal tubules are clearly recognizable following the irrigation (Ram 1977; Calt & Serper 2000). Irrigation with 17% EDTA resulted in better root canal cleanliness than the use of paste based-chelators during NiTi rotary preparation (Ahn & Yu 2000).

Use of paste-based chlelators combined with NaOCl proved to be superior in removal of the smear layer than preparation with NaOCl alone (Grandini *et al.* 2002). The urea peroxide (10%) content of RC-Prep™ is believed to be mainly responsible for its antibacterial effect. Urea peroxide is an oxidizing antibacterial agent (Block 1991), which retains its effectiveness in the presence of blood (Stewart *et al.* 1961).

2.5.3 Chlorhexidine

Irrigating teeth with open apices might allow extrusion of irrigant into periapical tissue and induce excessive inflammation. Chlorhexidine has shown to be harmless in these cases (Southard *et al.* 1989) and an alternative to sodium hypochlorite. If an

antimicrobial activity was the only requirement of an endodontic irrigant, chlorhexidine might be the irrigant of choice (Jeansonne & White 1994) as it has antimicrobial substantivity effect, i.e. the property of continuing therapeutic action (White *et al.* 1997).

Chlorhexidine digluconate (CHX) has been used for years in dentistry as oral rinse in concentrations of 0.12%-0.2% and as a 2% solution for irrigating the root canal system. It was developed in the late 1940's in England. Chlorhexidine permeates the microbial cell wall or outer membrane and attacks the bacterial cytoplasmic or inner membrane or the yeast plasma membrane (Mcdonnell *et al*. 1999). Chlorhexidine is unable to dissolve necrotic tissue remnants (Naenni *et al.* 2004) and is less effective on Gram-negative than on Gram-positive bacteria (Hennessey 1973). *Enterococcus faecalis*, a Gram-positive facultative species has commonly been isolated in failed root canals (Peciuliene *et al*. 2001). Chlorhexidine once in contact with sodium hypochlorite will develop a brownish-orange precipitate containing iron (Marchesan *et al.* 2007) and parachloroaniline, which has mutagenic potential (Basrani *et al.* 2009).

2.5.4 MTAD™

MTAD™ is a mixture of a 3% doxycycline, 4.25% citric acid, and 0.5% Tween 80. MTAD™ has the ability to the remove smear layer, disinfect contaminated root canals, and eradicate *E. faecalis* (Torabinejad *et al.* 2003; Shabahang *et al.* 2003). MTAD™ does not dissolve organic tissue and it should be used as a final soak and flush after the use of NaOCl (Shabahang *et al.* 2003). In the same study the authors reported that 1.3% NaOCl/MTAD irrigation has shown to be significantly more effective against *E.faecalis* than NaOCl with and without EDTA (Shabahang *et al.* 2003). Contrary to these results, Baumgartner *et al*. (2007) in an in vitro study concluded that 5.25%

NaOCl/15% EDTA significantly reduced intracanal bacteria levels compared with the use of 1.3% NaOCl/MTAD™.

2.5.5 Smear Clear ™

Smear Clear™ is used for removal of the smear layer. The formula contains 17% EDTA and cetrimide, which is a surfactant with antimicrobial activity. The surfactant is claimed to reduce the contact angle of the EDTA solution when placed on the dentin surface. Jantarat and Yanpiset (Mahidol University, Thailand) reported that Smear Clear™ performed better at removing the smear layer from the root canal walls when compared to 17% EDTA, water or 5.25%NaOCl.

2.5.6 Citric acid

Citric acid is a weak organic acid which has been used in periodontal surgery after instrumentation in order to enhance cementogenesis and regeneration of normal periodontal attachment (Wen *et al*. 1992). In operative dentistry citric acid is used as a mild etchant to remove the smear layer and dentin plugs (Salama 1994). In endodontic research, replacing EDTA with citric acid has been proposed. Yamaguchi *et al*. (1996) reported that 0.5 mol L^{-1} and 1 mol L^{-1} citric acid solutions can extract calcium from dentin matrix and has an antibacterial activity similar to or better than 10% EDTA. Di Lenarda *et al*. (2000) reported that there was no statistically significant difference in cleansing ability between 19% citric acid, 15% EDTA and cetrimide solution, and 5% NaOCl groups.

2.6 Mechanical-Chemical cleaning

Endodontic success is dependent on multiple factors, and of these, mechanical-chemical cleaning is a key component of a successful endodontic treatment (Orstavik *et*

al. 2004). As the limitations of mechanical cleaning are well known (Peters *et al.* 2001), the goal of chemical treatment is to complement mechanical treatment to clean the entire root canal system through removal of pulpal debris, the smear layer and smear plugs (Liolios *et al*. 1997; Calas *et al.* 1998).

2.7 Properties and choice of root canal irrigants

Ideally, an irrigant should dissolve inorganic tissue, penetrate dentin and dentinal tubules, remove the smear layer and debris, reduce instrument friction, have no adverse effects on dentin or the sealing properties of filling materials, kill bacteria and yeasts, not irritate or damage vital tissues, have no cytotoxic or carcinogenic effect, produce no tooth discoloration, and be easily available and relatively inexpensive (Haapasalo *et al.* 2010; Torabinejad *et al.* 2002). Presently, there is no single solution that can fulfill all these requirements. Use of more than one irrigation solution is therefore recommended to achieve optimal effect. Irrigants are selected based on their characteristics as listed above. Concentration, volume, order and time of use and method of delivery may all impact irrigant effectiveness in chemical cleaning.

Sodium hypochlorite is regarded as the most important irrigation solution because of its dual action. It is the only solution that dissolves organic tissue and other organic matter such as necrotic pulp tissue and biofilm (Naenni *et al.* 1987; Baumgartner *et al*. 1987; Johnson *et al.* 2009). It also has strong antibacterial activity (Radcliffe *et al*. 2004; Johnson *et al.* 2009). It is therefore recommended that sodium hypochlorite be used throughout the instrumentation for irrigating the canals thoroughly between each instrument and for leaving a reservoir in the pulp chamber. After finishing the

instrumentation and irrigation, hypochlorite is removed from the canal(s) and EDTA or citric acid are used to remove the smear layer (Zehnder 2006).

EDTA and citric acid have no or only weak antimicrobial effect, but removal of the smear layer also eliminates bacteria and bacterial antigens, which are embedded in the smear layer when the root canal has been infected (Haapasalo *et al*. 2010). Removal of the smear layer also improves the penetration of sealers into the dentin (dentinal tubules), and this will result in a better sealing of the root canal walls. In routine endodontic treatment, EDTA is often the final rinse. However, in cases where the eradication of the infection is considered particularly difficult, EDTA (or citric acid) may be followed by one more antibacterial rinse, which could be either chlorhexidine or another rinse containing sodium hypochlorite (Yamada *et al.* 1983).

2.8 Irrigant delivery system

Irrigants are commonly delivered using a syringe and needle (Card *et al.* 2002). Syringes of different sizes (1mL, 2mL, 3mL, 5mL, 10mL, and 20mL) are used to irrigate the root canal system. Emphasis has been placed on the needle depth position in relation to the apical third. It has been suggested that an irrigation needle positioned close to the working length (WL) may improve the debridement and irrigant placement (Abou-Rass & Piccinino 1982; Sadgley *et al.* 2005). It has been shown that when the irrigation needle was placed 3mm short of the WL, the irrigant was more effective in removing debris apically, whereas the same was not true when the needle tip was placed 6mm away from the working length (Hsieh *et al.* 2006).

Fear of tissue toxicity from the accidental extrusion of an irrigant may prevent a practitioner from inserting the irrigation needle tip in the apical third area. Safety

measures such as ensuring that the needle does not wedge between the root canal walls and the use of a side-vented needle reduce the risk of accidental extrusion. Stainless steel irrigation needle sizes of 27G and 30G are most commonly used to irrigate the root canals. The external diameter for a needle size of 27G is 0.42mm and the internal diameter is 0.18mm; for a needle size of 30G the external and internal diameters are 0.31mm and 0.13mm respectively.

2.9 Factors predisposing root to fracture

Root fracture is a common clinical problem affecting root canal treated teeth. Factors that may predispose a root to fracture have been identified as stemming from changes to the mechanical properties of the dentin due to the action of irrigants, medicaments or root canal filling materials, too wide canal instrumentation (Biven *et al.* 1972; Grigoratos *et al.* 2001), as well as loss of structural integrity due to caries and access cavity preparation (Blaser *et al.* 1983; Hood 1991). Sim *et al.* (2001) reported that immersion of dentin bars in 5.25% NaOCl significantly decreased the flexural strength of the dentin when compared to 0.5% NaOCl and saline. Driscoll and colleagues (2002) concluded 0.5%, 3%, and 5% concentrated NaOCl solution degrades the organic component of dentin, but has no effect on the inorganic component of dentin. Further they concluded that structural changes from degradation of the organic component of dentin result in changes to the mechanical properties of dentin.

2.10 Role of dental schools

It is the duty of dental schools and academics to train students in such a way that they will adopt best practice once they graduate (ESE 1994). However, once graduated many dentists fail to practice dentistry according to the guidelines they were taught (Pitt

Ford 1983; McColl *et al.* 1999). Specifically, Slaus & Bottenberg (2002) have demonstrated that dentists do not comply with academic teaching regarding the requirements for the quality of root canal treatment.

The University of British Columbia, BC, Canada, is the only dental school in the province. In this program, the undergraduate clinical endodontics is taught by local endodontists according to the guidelines set by the Canadian Dental Association. With regard to irrigation, the use of NaOCl throughout the instrumentation is recommended, followed by rinse with EDTA for smear layer removal. Alternatively, use of RC-Prep has been advocated in narrow canals to facilitate dentin removal. Little is known about how the teaching translates into the daily practice of dentists after their graduation.

Chapter 3: AIM AND HYPOTHESIS

3.1 Aim

The purpose of this study was to survey general dentists (GP) and endodontists (ENDO) in the province of British Columbia (BC), Canada to investigate irrigation practices in their daily clinical work. The study focused on the types of irrigants used, the frequency, volume and order of use of these irrigants, concentration of sodium hypochlorite, the size and type of irrigation needles used and the depth of needle penetration in the root canal. Comparisons were made between general practitioners and endodontists, and between the treatment of vital and necrotic teeth.

3.2 Hypothesis

- Sodium hypochlorite is the most common irrigant used by both groups in treating teeth with vital and non-vital pulp.
- There are no significant differences between GP and ENDO regarding the use of irrigation in root canal treatment.

Chapter 4: MATERIAL AND METHODS

4.1 Study population

The study population consisted of a stratified randomized sample of dentists and all the endodontists in British Columbia (BC), Canada. To identify all practitioners working in the province, a list of those registered in 2009/2010 was obtained from the College of Dental Surgeons of British Columbia (CDSBC).There were 2654 general practitioners (GP) and 42 endodontists (ENDO) registered with the CDSBC in that year.

A questionnaire was sent to 150 randomly chosen general practitioners out of the 2654 registered and to all 42 of the registered endodontists. For general practitioners, stratified random sampling was done by dividing the province into four areas: Vancouver, Vancouver Island, Central BC and Northern BC.

4.2 Exclusion criteria

Dental practitioners were excluded from the study if they worked in the province less than three days a month or if they did not perform root canal treatments.

4.3 Pilot study

A questionnaire was developed and piloted by sending it to nine general dental practitioners teaching preclinical endodontics part-time at the University of British Columbia, Canada. According to their suggestions, the questionnaire was modified for clarity and scope. The final questionnaire was approved by the UBC Research Ethics Committee.

4.4 Questionnaire

The final questionnaire consisted of 49 questions, each with several possible answers (Appendix A). Special care was taken to avoid guiding questions, i.e. questions were constructed so that respondents were not led to a particular answer.

The questionnaire included inquiries about different aspects of irrigation techniques, materials and equipment. Separate questions asked about techniques, materials and irrigants used in the treatment of teeth with vital and non-vital pulp. The questionnaire was divided into the following sections: type of irrigants, concentration of sodium hypochlorite, volume of irrigant, type and size (diameter) of irrigation needle, depth of the irrigation needle tip in the canal, and initial and final irrigant of choice during endodontic treatment.

For questions 1-20 and 37-39, participants were asked to mark their answers on a visual analogue scale (VAS) in which "never" indicated '0' and "always" indicated '100' percent of the time.

Initial contact to the dental offices selected for the study was made by telephone using a standardized script. Each receptionist was, informed of the pending arrival of the survey, and a timely response was requested. Ten offices at a time were contacted.
A two-page questionnaire and two-paragraph explanatory letter were faxed immediately following the phone call. The researcher's email address and phone number were provided in case participants required clarification of any part of the study. As an incentive, participants were given the option of receiving copies of the peer -reviewed papers resulting from the study. A week after the initial phone call, a reminder phone call was made to all practitioners who had not returned the questionnaire. Three weeks later,

another reminder phone call was made and a second questionnaire was sent to all non-respondents.

All returned questionnaires were coded by a single operator and the data was subsequently processed using the PASW statistics 18 statistical program (SPSS Inc, Chicago, IL).

4.5 Clinical assessment of hypochlorite concentration used among general dental practitioners

Through the use of stratified random sampling, a total of 68 samples of bleach were collected from GP offices in the lower mainland. The samples were kept in small air-tight, light-protected bottles. To allow rapid processing, a manageable number of samples (8-10) were collected at a time for analysis in the laboratory within one week of their collection.

Titration is a method in which a solution of known concentration is used to analyze and determine an unknown concentration of a second solution. Using the titration technique, the concentration of hypochlorite in the bleach samples was calculated. In order to calculate the amount of chlorine present, it is necessary to produce iodine because iodine is readily titrated with thiosulfate while the substance of interest, hypochlorite, is not titrated. As one mole of iodine is produced for every mole of hypochlorite in the sample, this allows one to determine the amount (molarity) of hypochlorite present (http://web.lemoyne.edu/~giunta/chm151L/bleach.html).

Dilution of the commercial bleach solution is necessary because iodine has low solubility, and it is important that all the iodine produced by titration remains in solution. Furthermore, the experimental error when measuring small volumes of liquids is usually

greater than the error made when measuring larger volumes. To improve the accuracy of data obtained from this experiment, 10-mL of commercial bleach solution (hypochlorite) was diluted to 100-mL using distilled water.

A 10-mL volumetric pipette was used to measure 10-mL of commercial bleach into a 100-mL volumetric flask and 90 ml of distilled water was added. Two parallel measurements were done from each sample.Twenty-five-mL of the diluted hypochlorite solution was transferred to a 250-mL Erlenmeyer flask, for reactions with KI and HCl solutions. A 100-mL graduated cylinder was used to transfer 10-ml of KI solution to the Erlenmeyer flask, and then 30-ml of 2M HCl solution was added. The color of the solution changed from colorless to brown due to formation of iodine (I_2). In the presence of excess (I^-) ion the amount of I_2 formed is a measure of the amount of OCl^- ion reacting (http://web.lemoyne.edu/~giunta/chm151L/bleach.html). The solution was continuously mixed by swirling and sodium thiosulfate ($Na_2S_2O_3$) solution was added from the burette to the solution until the solution turned light yellow. As the titration proceeds, the I_2 concentration in the solution decreases. This causes the solution color to change from brown to pale yellow near the end of the titration. The end point occurs when all the I_2 has reacted and the solution is colorless. Because the change from pale yellow to colorless is not very distinct, establishing the end point on the basis of the final color change is difficult. Therefore, the end point was made more distinct by adding a small amount of starch solution, which causes a deep blue complex to form. Additional $S_2O_3^{2-}$ ion reacts with the complex I_2, causing a breakdown of the complex. Disappearance of the blue color signals the end point (http://web.lemoyne.edu/~giunta/chm151L/bleach.html).

The concentration of hypochlorite was calculated as follows: (moles thiosulfate used)/2 = moles iodine titrated = moles hypochlorite titrated.

4.6 Statistical analysis

Group comparisons were made by comparing the endodontist group (ENDO) with the general practitioner group (GP). For all data analyses, PASW Statistics 18.0 software (SPSS Inc, Chicago, IL) was used. For the GP and ENDO group comparisons, independent sample t-tests, Chi-Square and Fisher's Exact test (when any of the frequency cells included less than five responses) were used. For all tests, the threshold for statistical significance was set at ($P < 0.05$).

Chapter 5: RESULTS

5.1 Demographic factors

5.1.1 Response rate

Thirty-five of the 42 endodontists returned the questionnaire; thus the response rate was 83.3%. Subsequently, two of these 35 endodontists were excluded from the study because they performed endodontic treatments less than three days a month. Of the 150 general practitioners, 100 responded; thus the response rate was 66.7%. Nine of these 100 general practitioners had to be excluded because either they did not perform root canal treatments or they were working less than three days a month. The overall response rate, combining both groups, was 70.3%.

5.1.2 Gender

In the ENDO group, 88 percent of the respondents were male, and 12% were female. In the GP group, 71% were male and 29% were female. There was a significant difference in gender between the two groups (Chi-Square test, p=0.003).

5.1.3 Years of professional activity

In the ENDO group 63.6% (n=21) of the respondents had worked more than 20 years, 12.1% (n=4) had worked 16-20 years, 12.1% (n=4) had worked 11-15 years, 9.1% (n=3) had worked 6-10 years, and 3% (n=1) reported they had worked less than 5 years. In the GP group the corresponding numbers of years of practice were 46.2% (n=36), 10.3% (n=8), 11.5% (n=9), 12.8% (n=10) and19.2% (n=15), respectively. There was no significant difference between the respondents in the two groups with regard to number of years of experience (Fisher's Exact test, p=0.202).

5.2 Box plot interpretation

The box plot provides an excellent visual summary of many important aspects of a distribution. In our study most of the results distribution will be illustrated by the box plot. The box plot should be interpreted as follows:

The box itself contains the middle 50% of the data. The upper edge (hinge) of the box indicates the 75th percentile of the data set and the lower hinge indicates the 25th percentile. The range of the middle two quartiles is known as the inter-quartile range. The line in the box indicates the median value of the data, if the median line within the box is not equidistant from the hinges, then the data is skewed.

The ends of the vertical lines or "whiskers" indicate the minimum and maximum data values, unless outliers are present in which case the whiskers extend to a maximum of 1.5 times the inter-quartile range. The points outside the ends of the whiskers are outliers or suspected outliers.

5.3 Type and frequency of irrigant used by endodontists and general practitioners in treating teeth with vital and non-vital pulp

5.3.1 Frequency of use of sodium hypochlorite

Sodium hypochlorite was the most commonly used irrigant for treating teeth with vital pulp by both endodontists and general practitioners. All but four endodontists reported using NaOCl 100% of the time. One endodontist reported not using NaOCl in treating teeth with vital pulp. The median value was 100%. More than 75% of GP used NaOCl the most of the time (≥90% of the time). The median value was 100%. There was no statistically significant difference between the two groups of clinicians in using NaOCl for treating teeth with vital pulp (independent sample t-test, $p=0.445$) (Fig. 5-1).

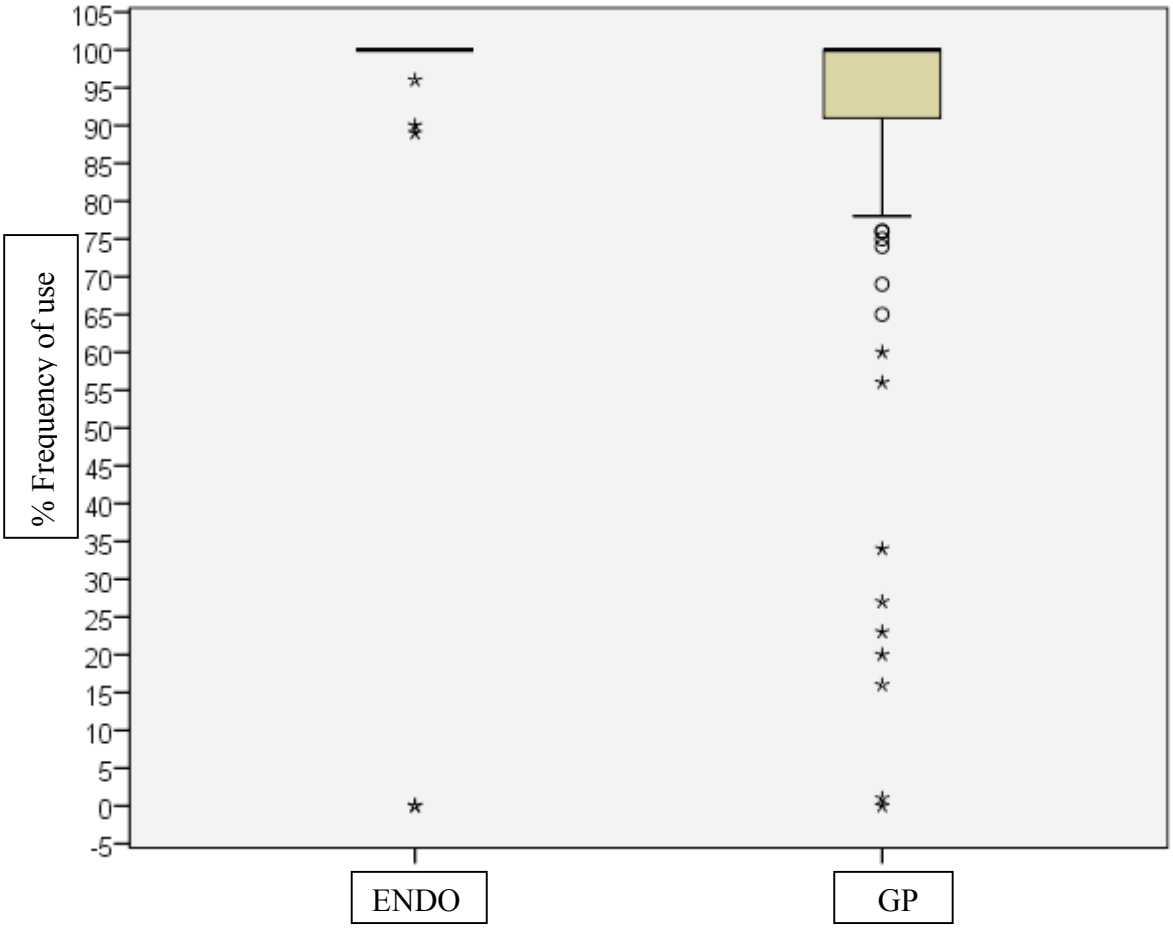

Figure 5-1. Frequency of use of sodium hypochlorite by ENDO and GP in treating teeth with vital pulp (independent sample t-test, p=0.445).

Sodium hypochlorite was the most commonly used irrigant for treating teeth with non-vital pulp by both groups of dentists. All but five endodontists reported using NaOCl all the time. One endodontist reported not using NaOCl in treating non-vital pulp teeth. The median value was 100%. More than 75% of the GP group (there were 16 outliers) reported using NaOCl almost all the time. The median value was the use of this irrigant 100% of the time. There was no statistically significant difference in mean use of NaOCl

in treating teeth with non-vital pulp between the two groups (independent sample t-test, p=0.657) (Fig.5-2).

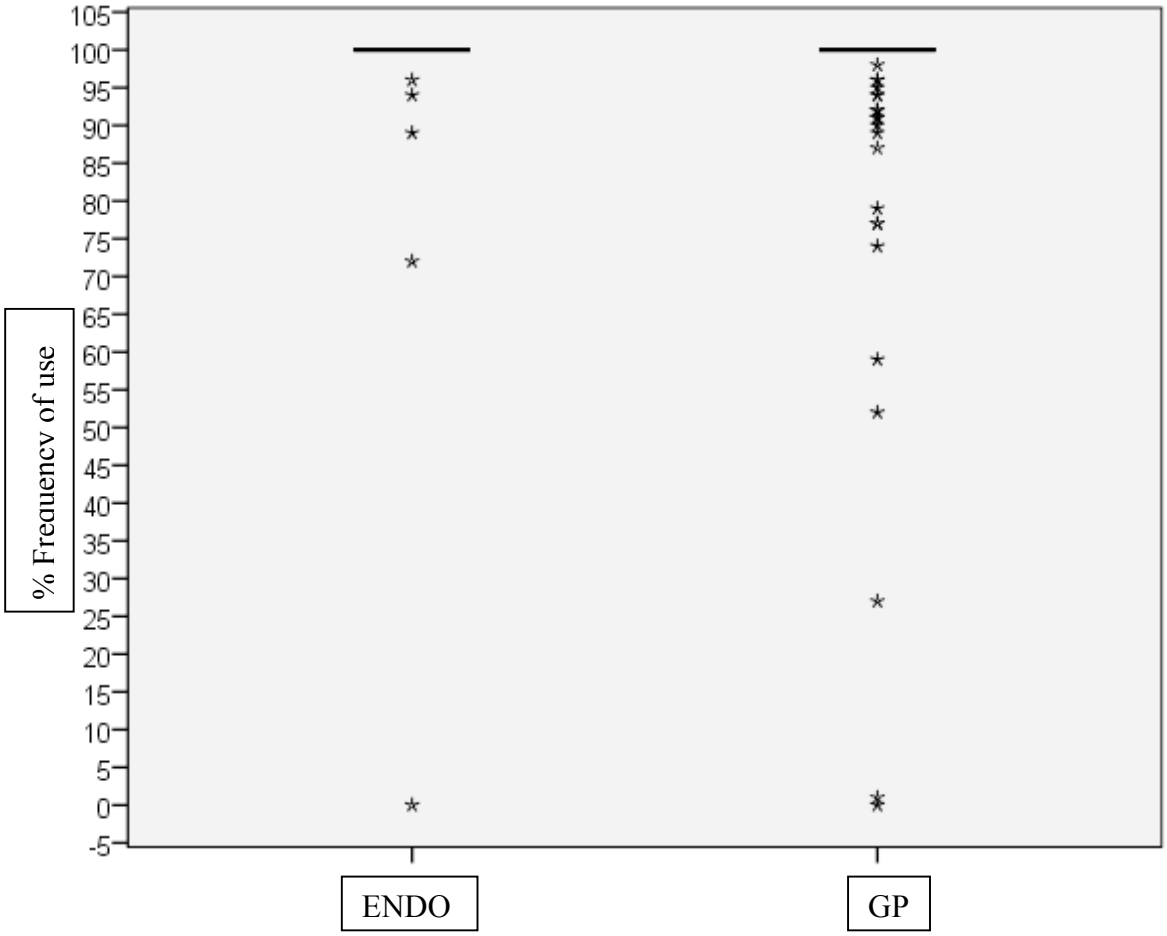

Figure 5-2. Frequency of use of sodium hypochlorite by ENDO and GP in treating teeth with non-vital pulp (independent sample t-test, p=0.657).

5.3.2 Frequency of use of EDTA

The median value for endodontists treating teeth with vital pulp using EDTA was 100% of the time, but 75% of them used this irrigant within the range of 18% of the time to always (100% of the time). Of all, 25% of endodontists reported using EDTA less than 18% of the time. In the GP group, the median value for treating vital pulp teeth using

EDTA was 10% of the time and there was a substantial variation among GP in the frequency of EDTA use. Of all, 75% of GP varied from never using EDTA (0% of the time) to using EDTA 83% of the time. There was a statistically significant difference between the two groups of practitioners in their use of EDTA for treating teeth with vital pulp (independent sample t-test, $p < 0.001$) (Fig. 5-3).

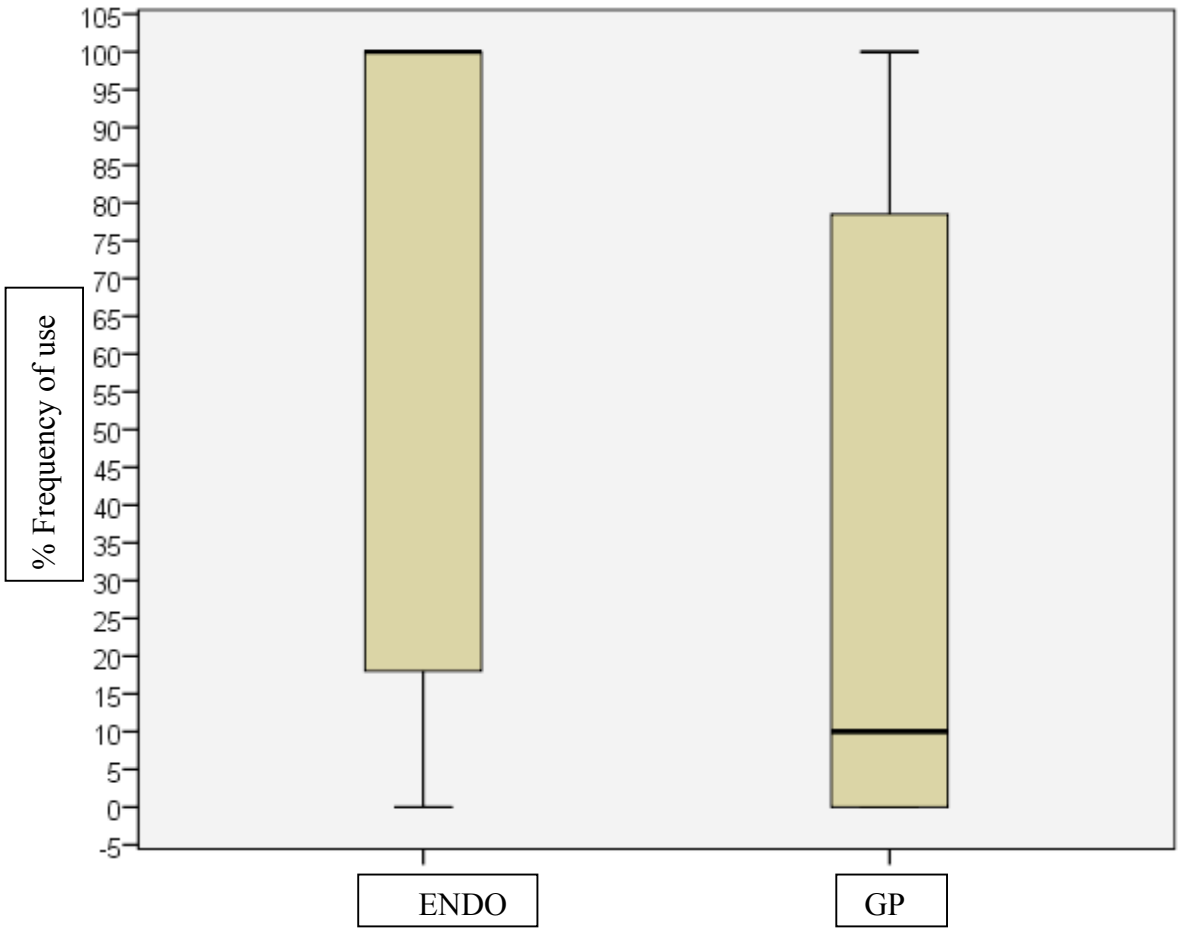

Figure 5-3. Frequency of use of EDTA by ENDO and GP in treating teeth with vital pulp (independent sample t-test, $p < 0.001$).

The median frequency value for endodontists treating teeth with non-vital pulp using EDTA was always (100% of the time), but 75% of them used this irrigant within the range of 40% of the time to always (100% of the time). Of all, 25% endodontists

reported using EDTA less than 40% of the time. In the GP group, the median value for treating teeth with non-vital pulp using EDTA was 15% of the time. However, there was a substantial variation among GP in the frequency they used EDTA. Of all, 75% of GP varied from never using EDTA (0%of the time) to using EDTA 88% of the time. There was a statistically significant difference between the two groups of practitioners in their use of EDTA for treating teeth with non-vital pulp (independent sample t-test, $p<0.001$) (Fig.5-4).

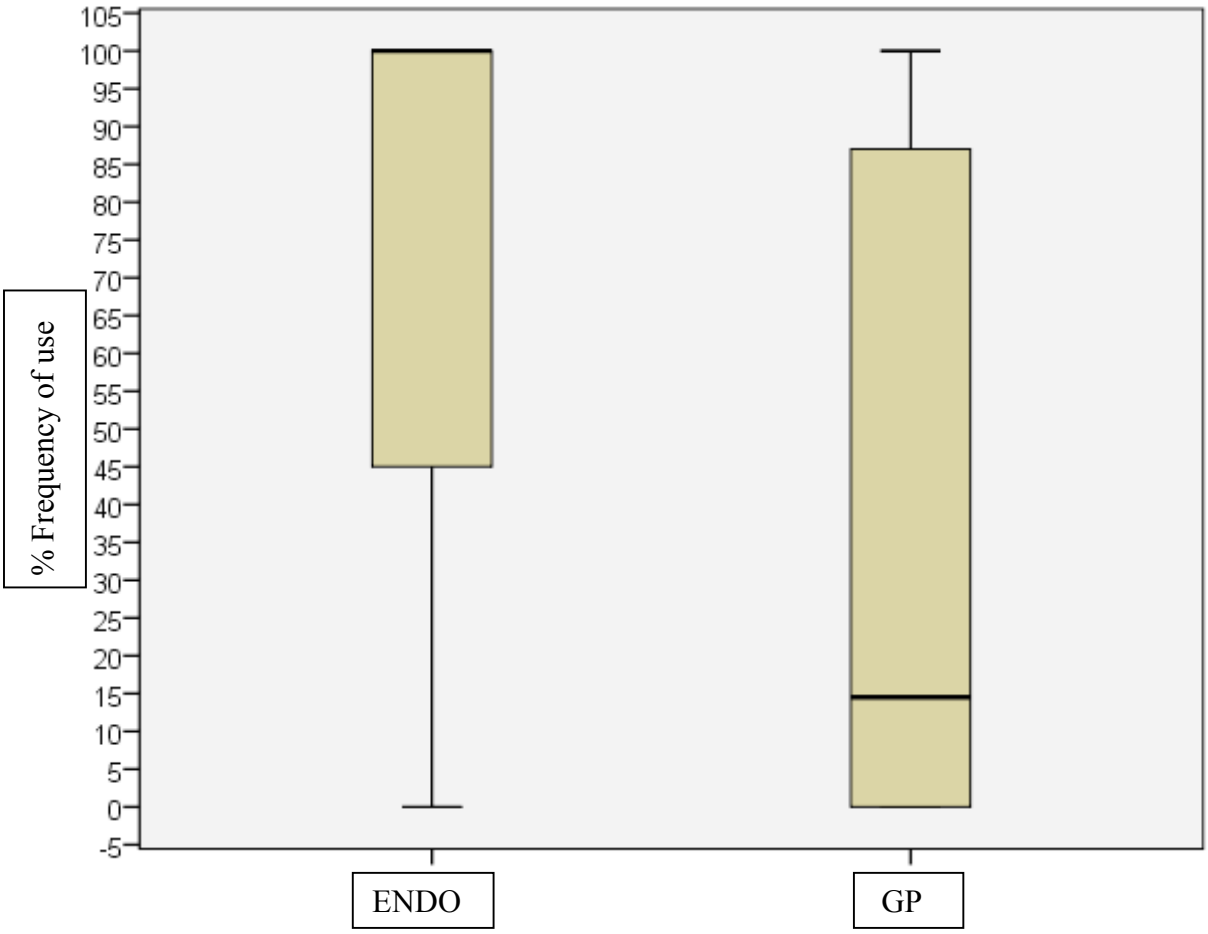

Figure 5-4. Frequency of use of EDTA by ENDO and GP in treating teeth with non-vital pulp (independent sample t-test, $p<0.001$).

5.3.3 Frequency of use of RC-Prep™

There was a substantial variation among the two groups of practitioners in the frequency they used RC-Prep™. The median value for endodontists treating teeth with vital pulp using RC-prep™ was 4% of the time, but 75% of them used this irrigant within the range of never 0% to 64% of the time. Of all, 25% of endodontists reported using RC-Prep™ more than 64% of the time. RC-Prep™ was used more commonly by GP. In the GP group, the median value for treating teeth with vital pulp using RC-Prep™ was 94% of the time. The range for the 75% of GP varied from always using RC-Prep™ (100% of the time) to using RC-Prep™ 25% of the time. There was a statistically significant difference between the two groups with GP using RC-Prep™ more commonly in treating teeth with vital pulp (independent sample t-test, $p<0.001$) (Fig. 5-5).

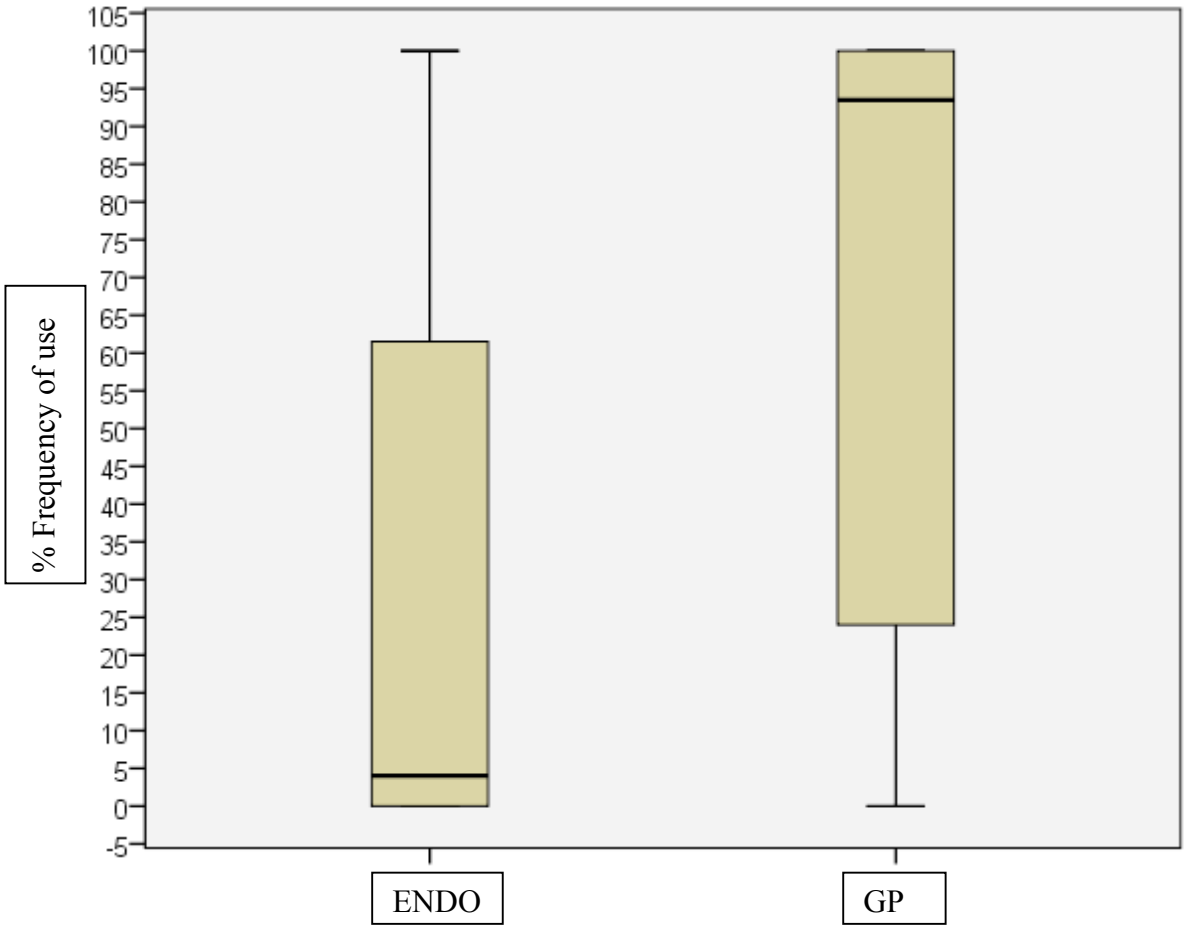

Figure 5-5. Frequency of use of RC-Prep™ by ENDO and GP in treating teeth with vital pulp (independent sample t-test, p<0.001).

There was a substantial variation among the two groups of practitioners in the frequency they used RC-Prep™ in treating teeth with non-vital pulp. RC-Prep™ was not used as commonly as NaOCl and EDTA by endodontists in treating non-vital pulp teeth. The median value for endodontists was 11% of the time but 75% of them used this irrigant within the range of never (0% of the time) to 64% of the time. Of all, 25% of endodontists reported using RC-Prep™ more than 64% of the time. In the GP group, the median value for treating teeth in non-vital pulp using RC-Prep™ was 96% of the time. Of all, 75% of GP used RC-Prep™ from always (100% of the time) to 38% of the time.

There was a statistically significant difference between the two groups with GP using RC-Prep™ more commonly in treating teeth with non-vital pulp (independent sample t-test, $p<0.001$) (Fig. 5-6).

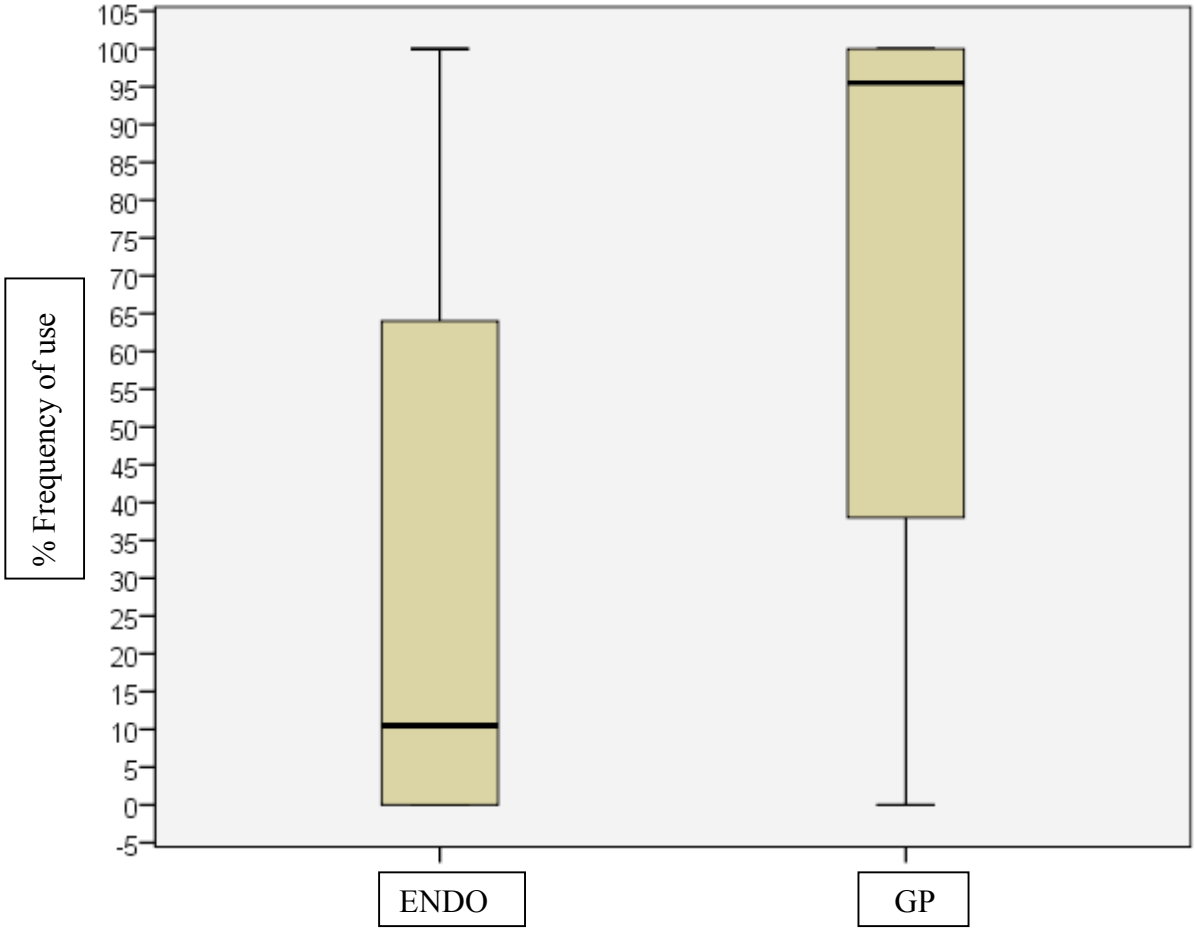

Figure 5-6. Frequency of use of RC-Prep™ by ENDO and GP in treating teeth with non-vital pulp (independent sample t-test, p<0.001).

5.3.4 Frequency of use of chlorhexidine

More than 75% of endodontists used chlorhexidine in treating teeth with vital pulp teeth within the range of never 0% to 25% of the time (there were three outliers). The median value was 0% of the time. More than 75% of GP used chlorhexidine in

treating teeth with vital pulp within the range from never (0%) to 7% of the time (there were twelve outliers). Of all, 25% of GP reported using chlorhexidine more than 7% of the time. The median value was 0%. There was no statistically significant difference between the two groups of practitioners in their use of chlorhexidine for treating teeth with vital pulp (independent sample t-test, p=0.701) (Fig. 5-7).

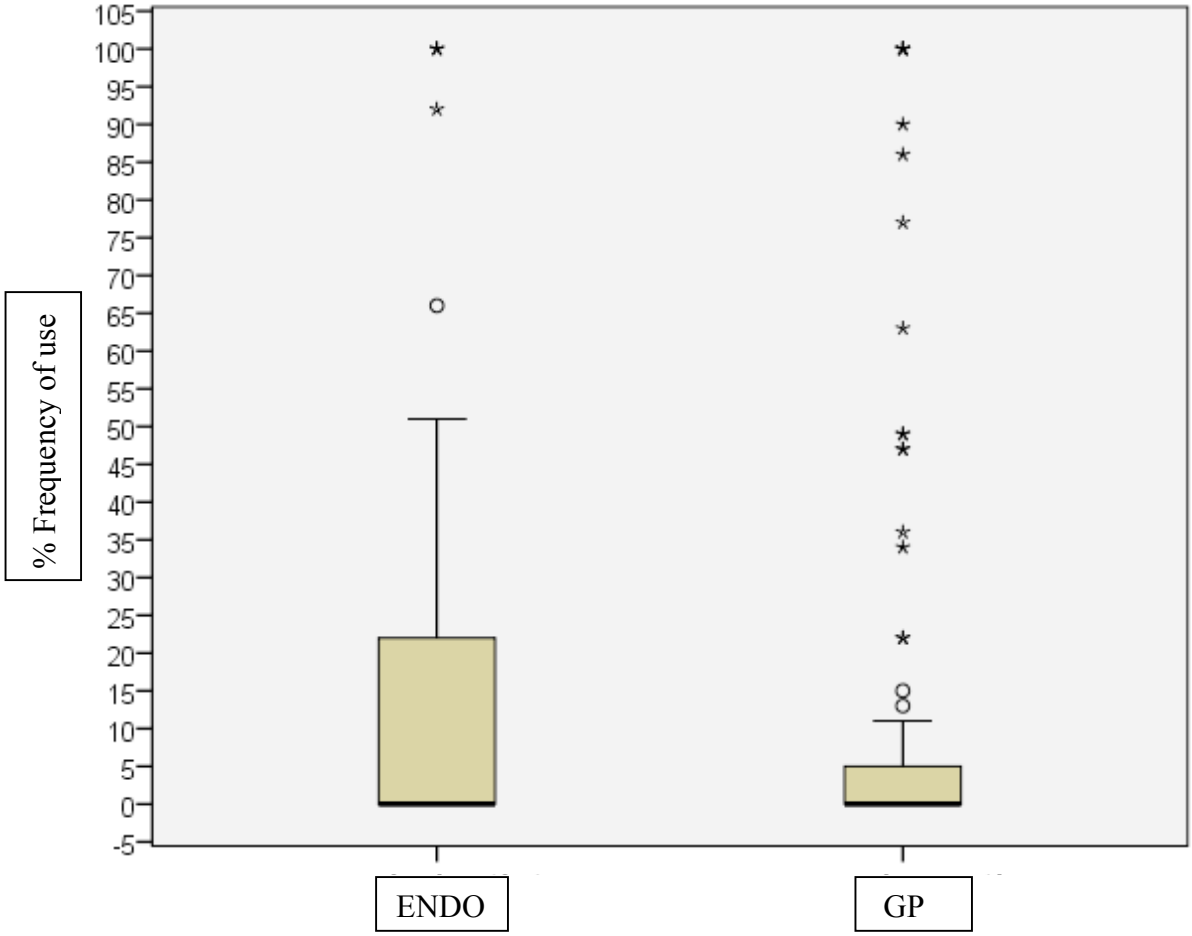

Figure 5-7. Frequency of use of chlorhexidine by ENDO and GP in treating teeth with vital pulp (independent sample t-test, p=0.701).

The median value for endodontists treating teeth with non-vital pulp using chlorhexidine was 8% of the time and 75% of them used this irrigant within the range of never (0% of the time) to 74% of the time. Of all, 25% of endodontists reported using

chlorhexidine more than 74% of the time. In the GP group, the median value was 0%. Of all, 75% of GP use of chlorhexidine varied from never (0% of the time) to 9% of the time (there were 11 outliers). There was a statistically significant difference between the two groups with endodontists using chlorhexidine more commonly than general practitioners in treating teeth with non-vital pulp (independent sample t-test, p=0.005) (Fig. 5-8).

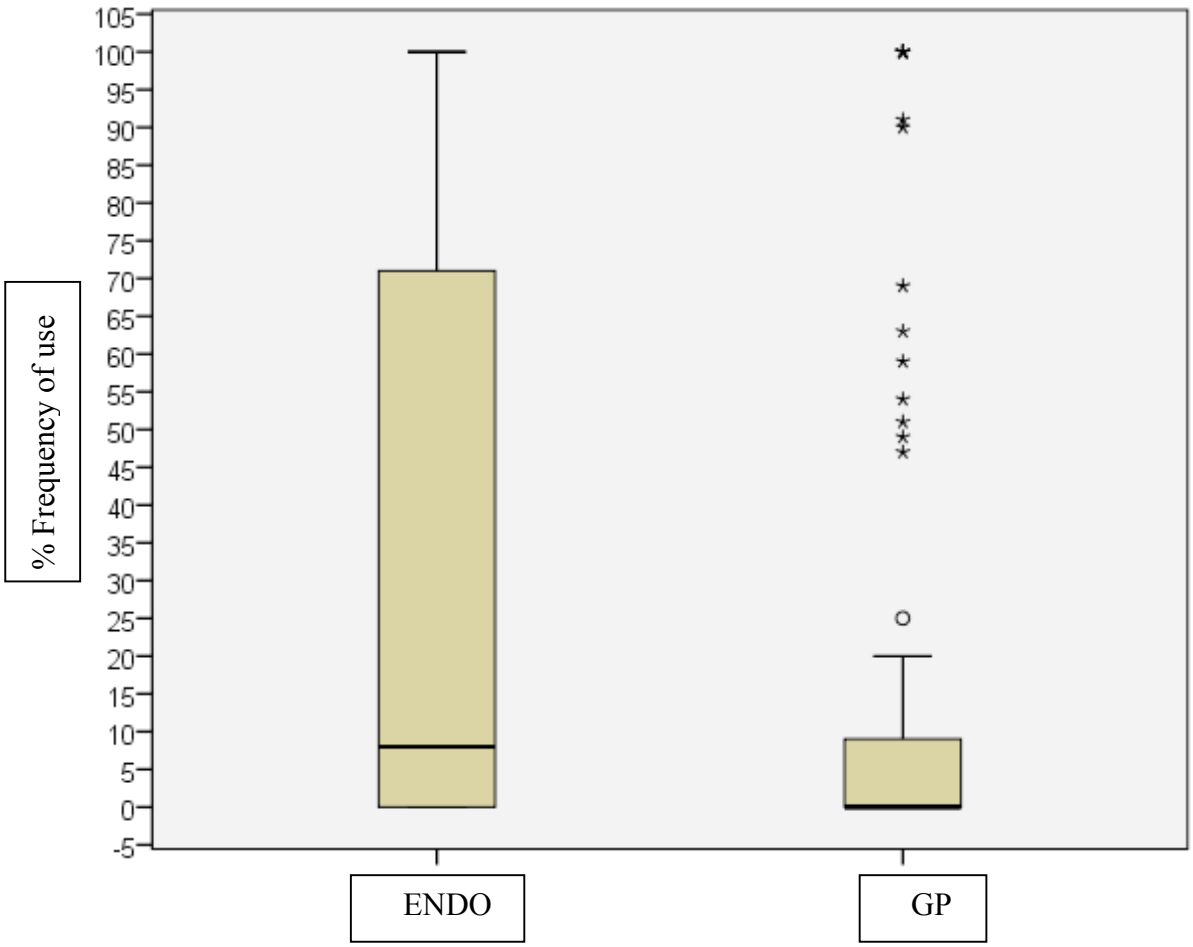

Figure 5-8. Frequency of use of chlorhexidine by ENDO and GP in treating teeth with non-vital pulp (independent sample t-test, p=0.005).

5.3.5 Frequency of use of MTAD™

MTAD™ was never used (0% of the time) by all endodontists in treating teeth with vital pulp except for one practitioner. The median value was 0%. All but four GP never used MTAD™ (0% of the time) in treating teeth with vital pulp. The median value was 0%. There was no statistically significant difference in use of MTAD™ between the two groups of practitioners in treating teeth with vital pulp (independent sample t-test, p=0.079) (Fig.5-9).

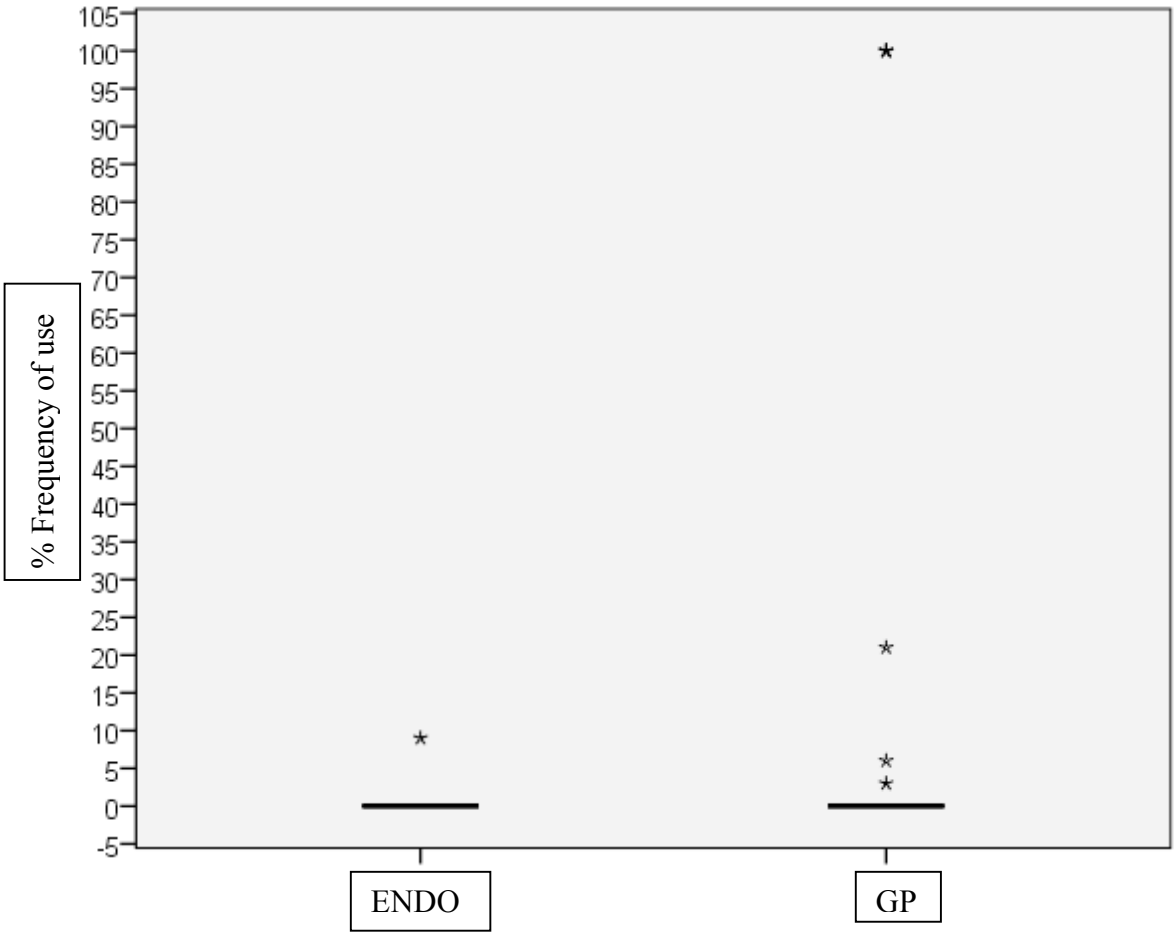

Figure 5-9. Frequency of use of MTAD™ by ENDO and GP in treating teeth vital pulp (independent sample t-test, p=0.079).

MTAD™ was never used (0% of the time) by all but four endodontists in treating teeth with non-vital pulp. The median value was 0%. All but four GP never used MTAD™ (0% of the time) in treating teeth with non-vital pulp. The median value was 0%. There was no statistically significant difference in use of MTAD™ between the two groups of practitioners in treating teeth with non-vital pulp (independent sample t-test, p=0.669) (Fig. 5-10).

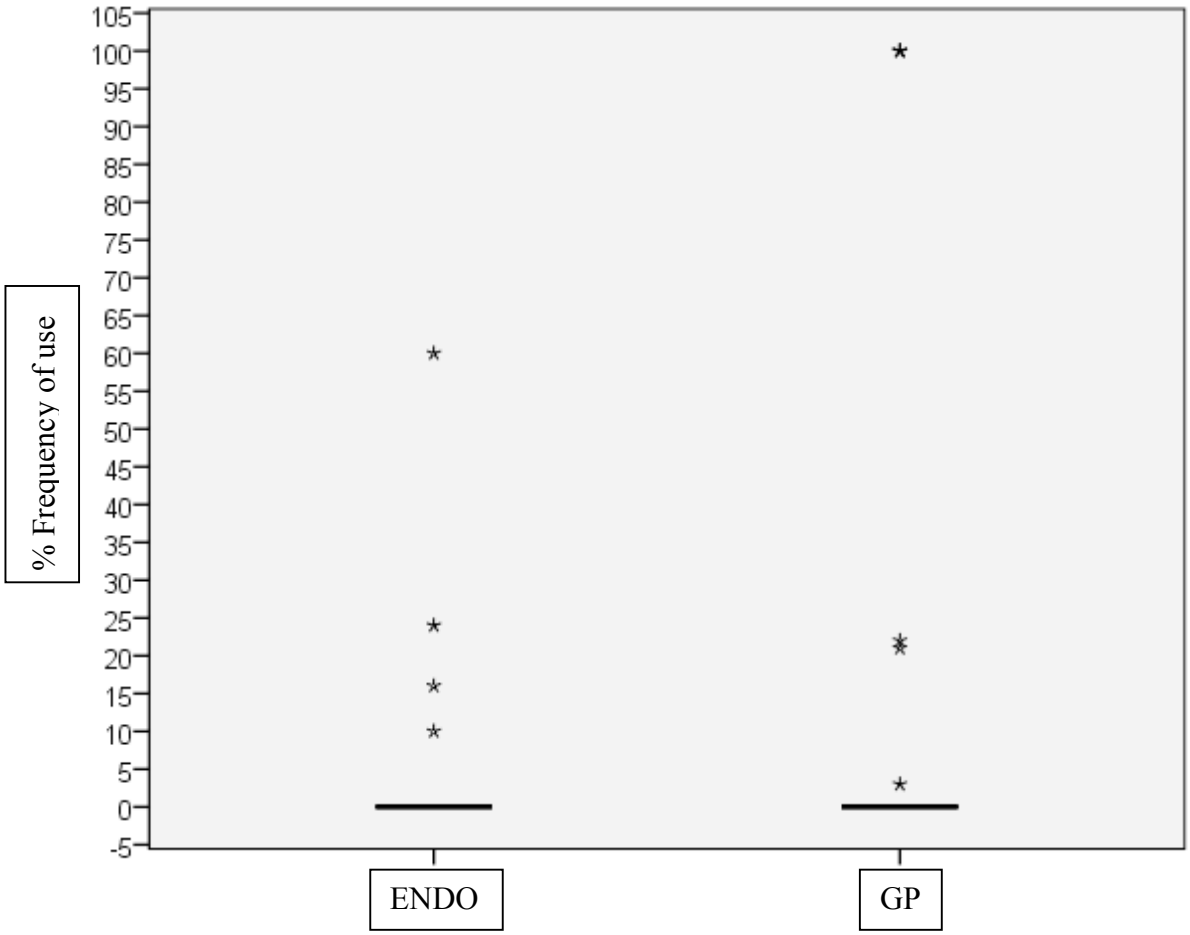

Figure 5-10. Frequency of use of MTAD™ by ENDO and GP in treating teeth with non-vital pulp (independent sample t-test, p=0.669).

5.3.6 Frequency of use of Smear Clear™

Smear Clear™ was never used (0% of the time) by all except two endodontists in treating teeth with vital pulp. The median value was 0%. All but four GP never used Smear Clear™ (0% of the time) in treating teeth with vital pulp. The median value was 0%. There was no statistically significant difference in use of Smear Clear™ between the two groups of practitioners in treating teeth with vital pulp (independent sample t-test, p=0.473) (Fig. 5-11).

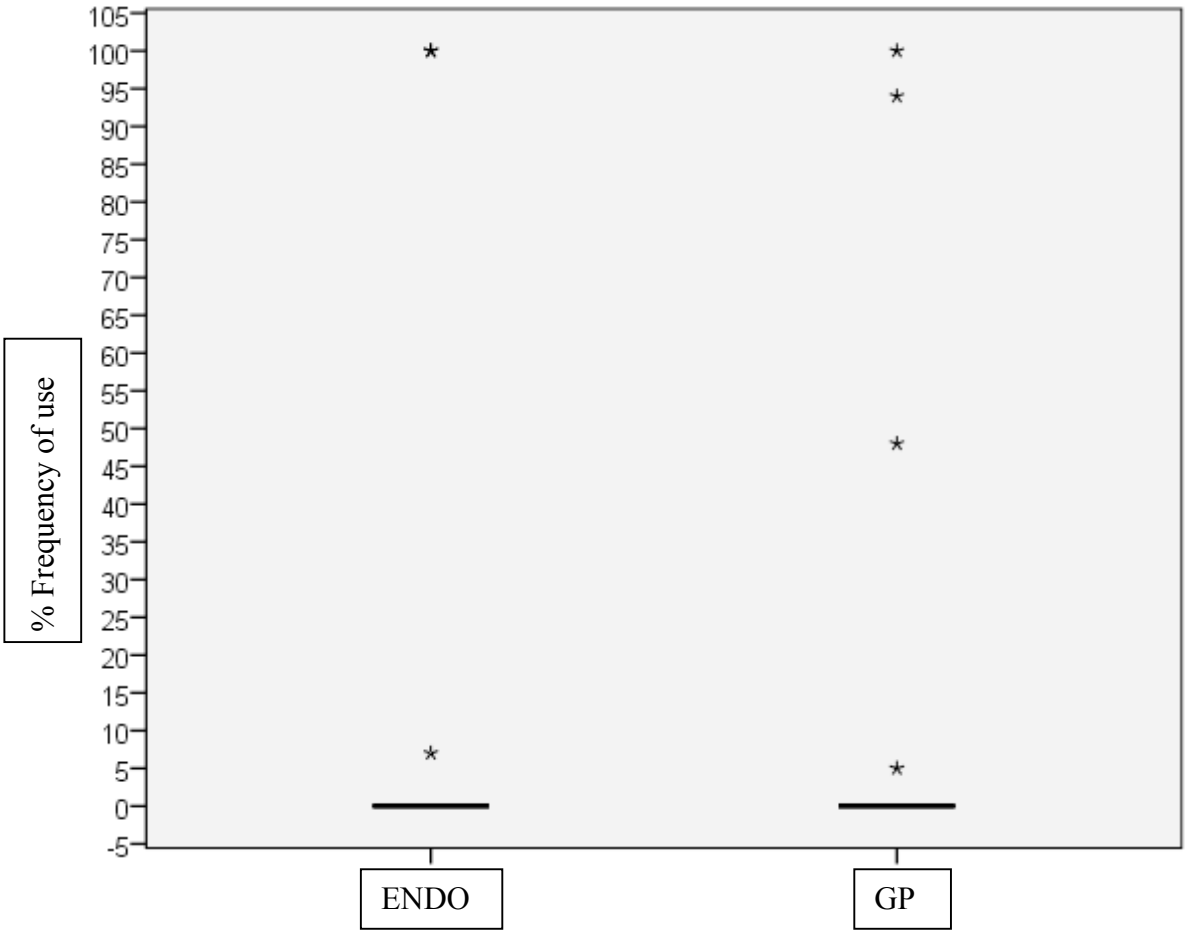

Figure 5-11. Frequency of use of Smear Clear™ by ENDO and GP in treating teeth with vital pulp (independent sample t-test, p=0.473).

Smear Clear™ was never used (0% of the time) by all except two endodontists in treating teeth with non-vital pulp. The median value was 0%. All but five of the practitioners never used Smear Clear™ (0% of the time) in treating teeth with vital pulp. The median value was 0%. There was no statistically significant difference in use of Smear Clear™ between the two groups of practitioners in treating teeth with non-vital pulp (independent sample t-test, p=0.618) (Fig. 5-12).

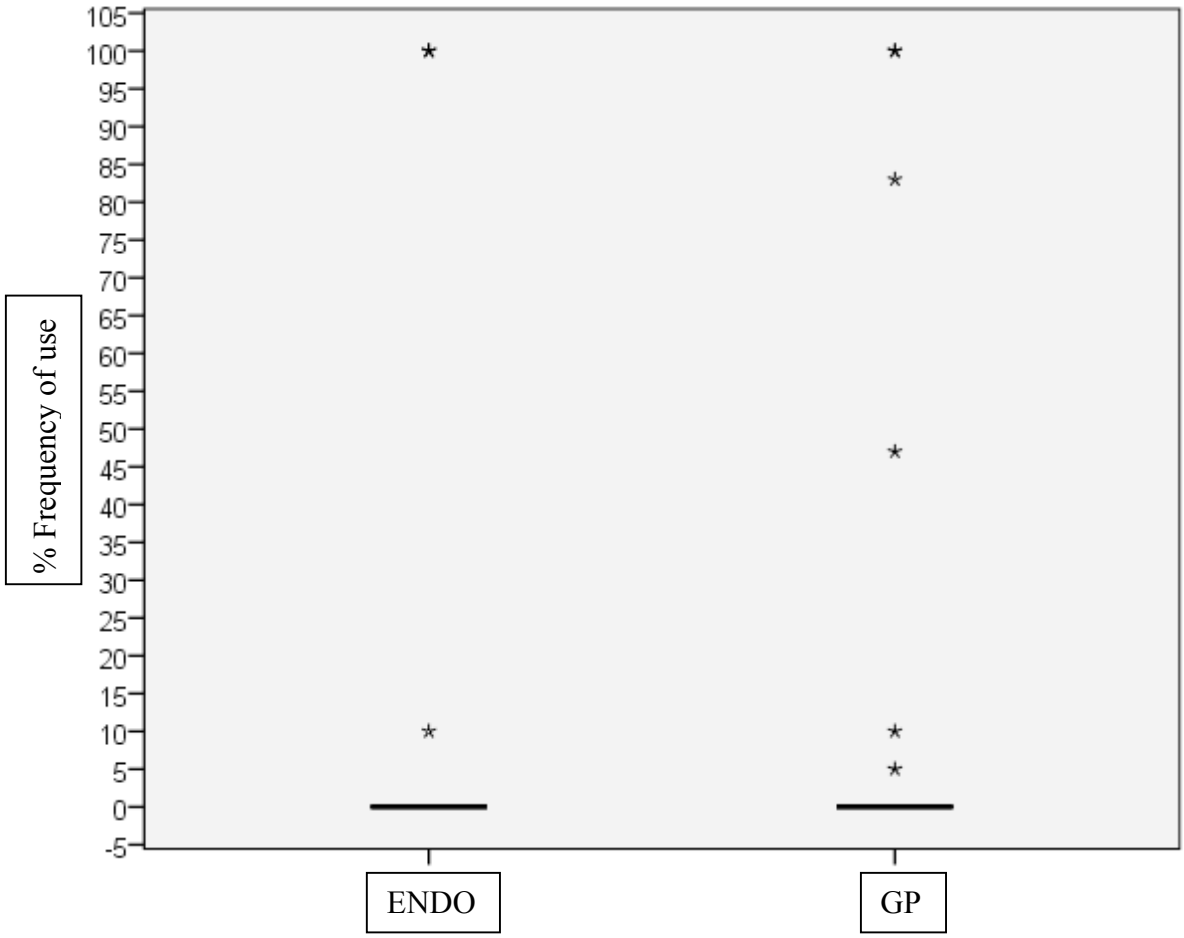

Figure 5-12. Frequency of use of Smear Clear™ by ENDO and GP in treating teeth with non-vital pulp (independent sample t-test, p=0.618).

5.3.7 Frequency of use of citric acid

Citric acid was never used (0% of the time) by all except one of the endodontist in treating teeth with vital pulp. The median value was 0%. All the practitioners in the GP group never used citric acid (0% of the time) in treating teeth with vital pulp. The median value was 0%. There was no statistically significant difference in use of citric acid between the two groups of practitioners in treating teeth with vital pulp (independent sample t-test, p=0.325) (Fig. 5-13).

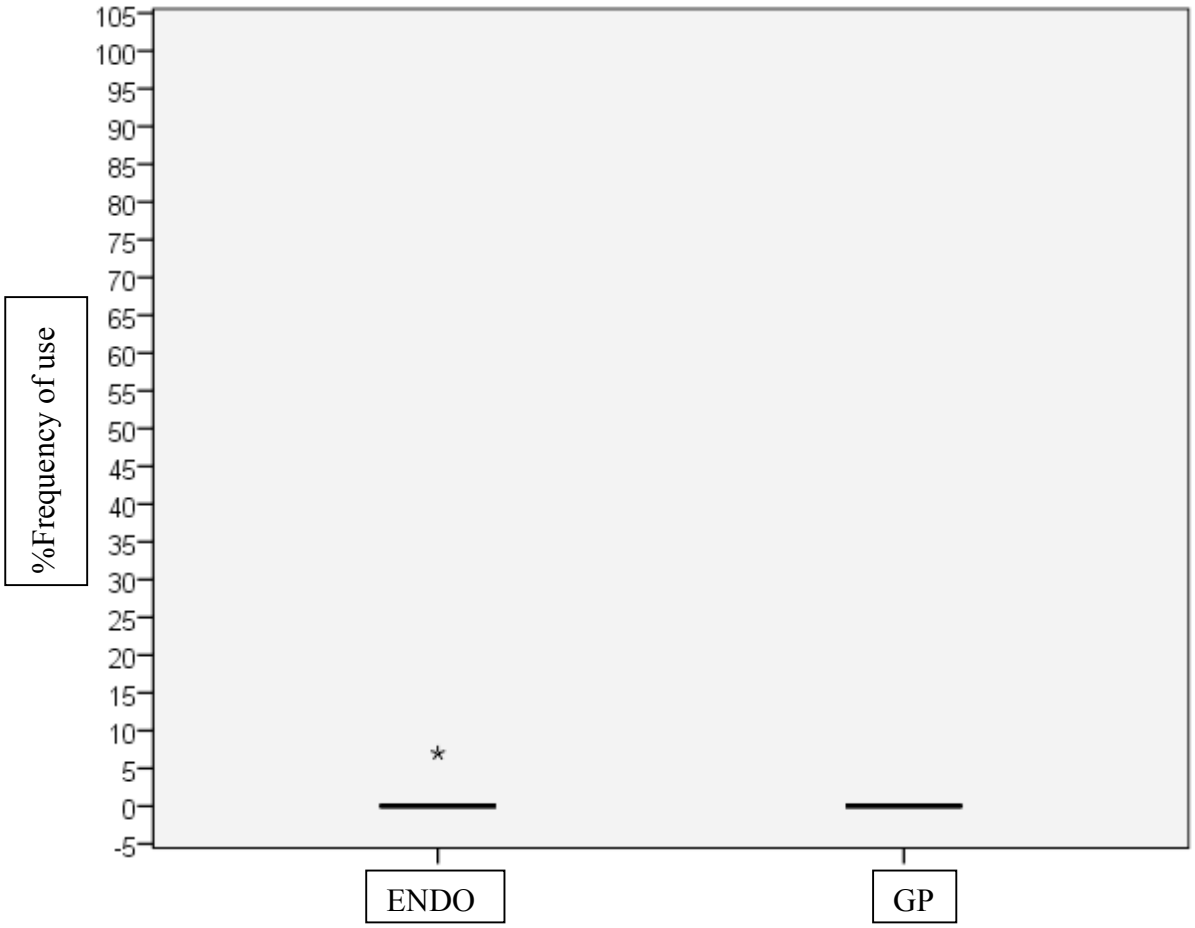

Figure 5-13. Frequency of use of citric acid by ENDO and GP in treating teeth with vital pulp (independent sample t-test, p=0.325).

Citric acid was never used (0% of the time) by all except one endodontist in treating teeth with non-vital pulp. The median value was 0%. All the practitioners in the GP group never used citric acid (0% of the time) in treating teeth with non-vital pulp. The median value was 0%. There was no statistically significant difference in use of citric acid between the two groups of practitioners in treating teeth with non-vital pulp (independent sample t-test, p=0.120) (Fig. 5-14).

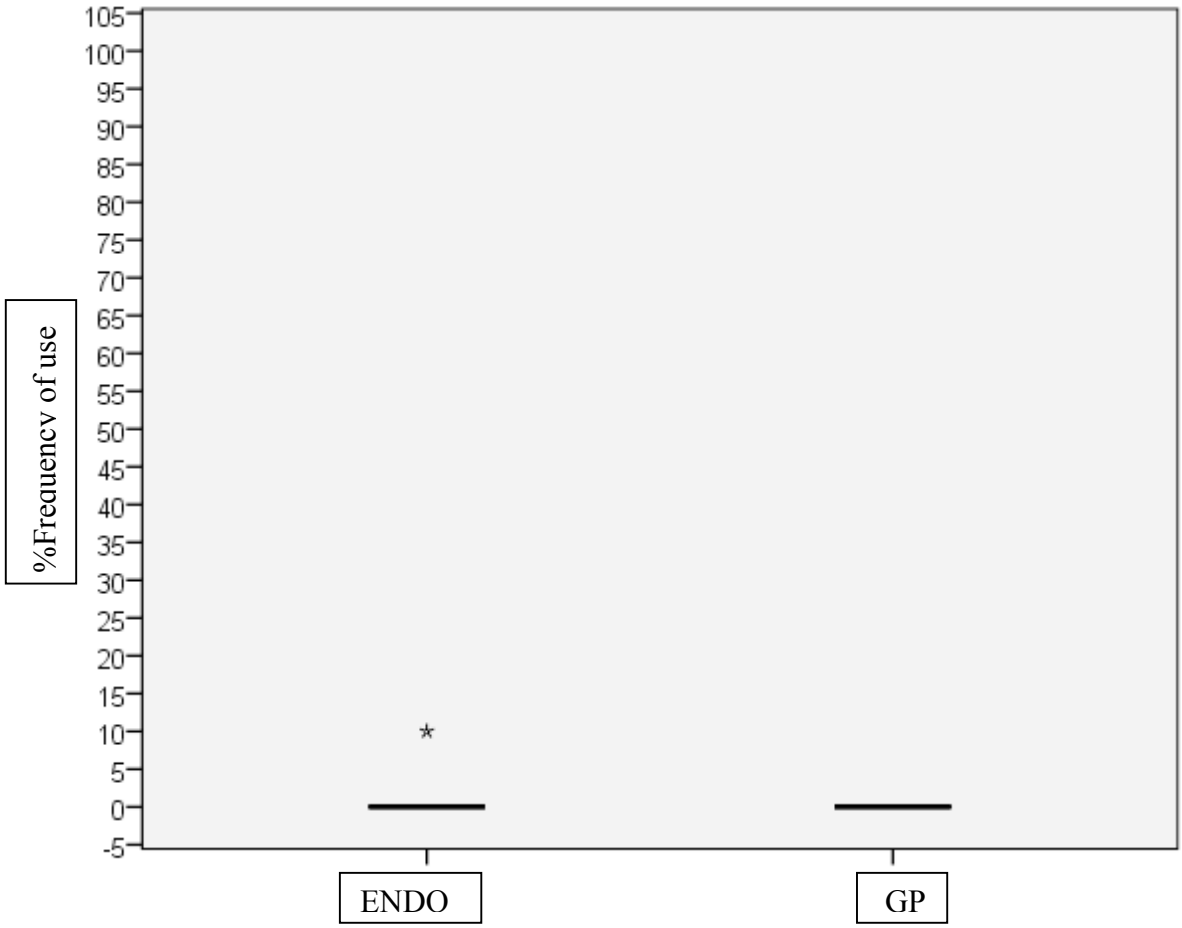

Figure 5-14. Frequency of use of citric acid by ENDO and GP in treating teeth with non-vital pulp(independent sample t-test, p=0.120).

5.3.8 Frequency of use of alcohol

The median value for endodontists treating teeth with vital pulp using alcohol was 0% of the time. Alcohol was used by 75% of endodontists within the range of 0% of the time to 11% (there were four outliers). All but eight GP never used alcohol in treating teeth with vital pulp. The median value was 0%. There was no statistically significant difference in use of alcohol between the two groups of practitioners in treating teeth with vital pulp (independent sample t-test, p=0.303) (Fig. 5-15).

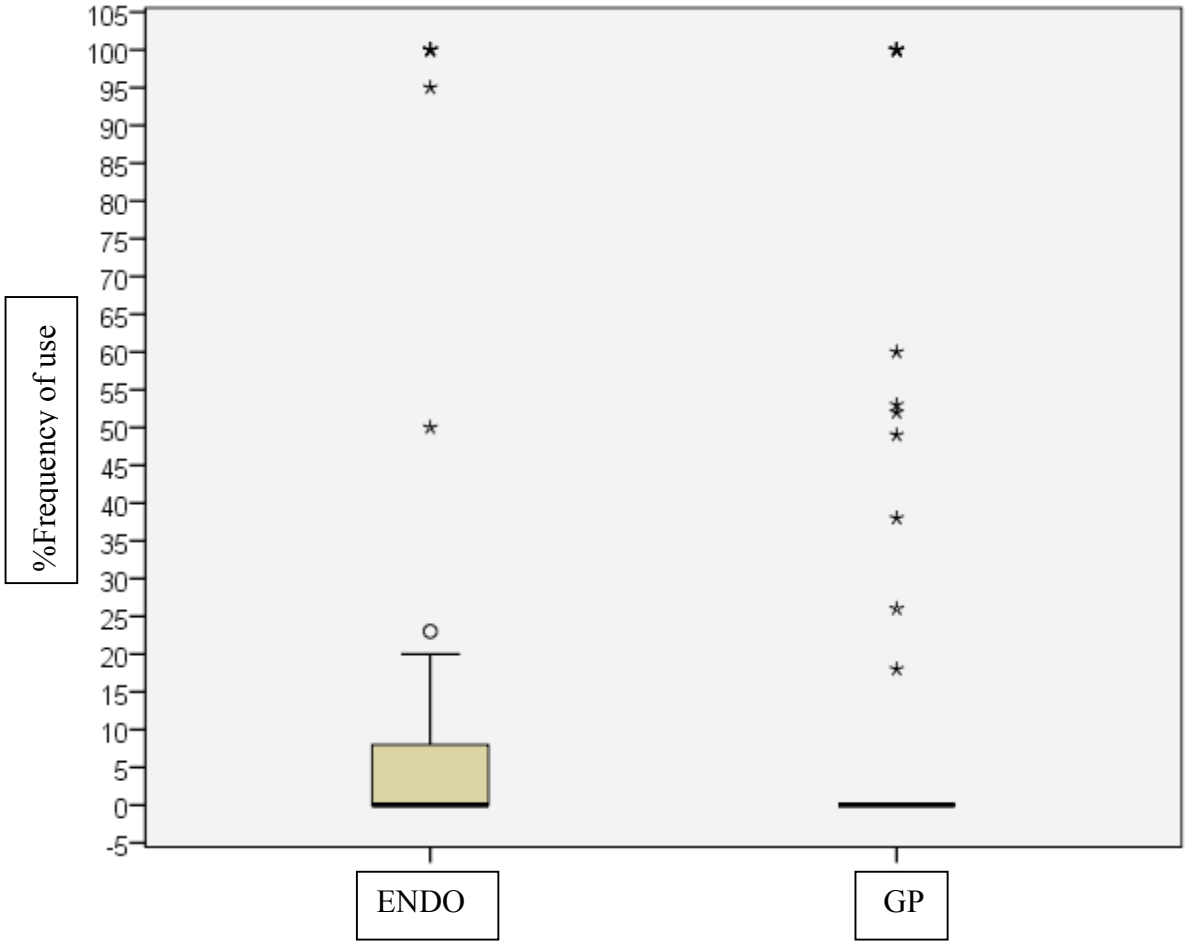

Figure 5-15. Frequency of use of alcohol by ENDO and GP in treating teeth with vital pulp (independent sample t-test, p=0.303).

The median value for endodontists treating teeth with non-vital pulp using alcohol was 0% of the time. Alcohol was used by 75% of endodontists within the range of 0% of

the time to 23.5% (there were two outliers). All but seven GP never used alcohol (0% of the time) in treating teeth with non-vital pulp. The median value was 0%. There was no statistically significant difference in use of alcohol between the two groups of practitioners in treating teeth with non-vital pulp (independent sample t-test, p=0.294) (Fig. 5-16).

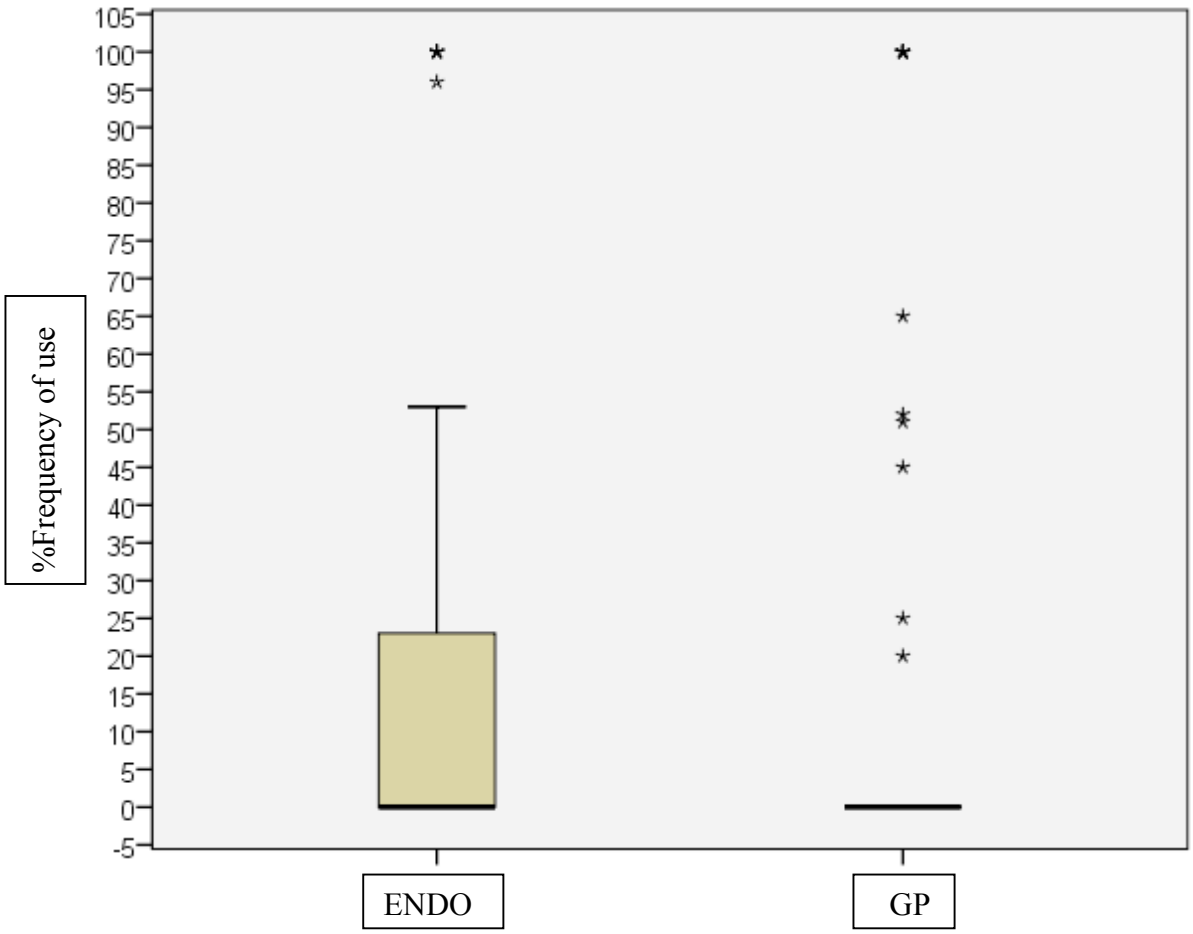

Figure 5-16. Frequency of use of alcohol by ENDO and GP in treating teeth with non-vital pulp (independent sample t-test, p=0.294).

5.3.9 Frequency of use of saline

Saline was never used (0% of the time) by all except seven endodontists in treating teeth with vital pulp. The median value was 0%. All but nine GP never used saline (0% of the time) in treating teeth with vital pulp. The median value was 0%. There was no statistically significant difference in use of saline between the two groups of practitioners in treating teeth with vital pulp (independent sample t-test, p=0.633) (Fig. 5-17).

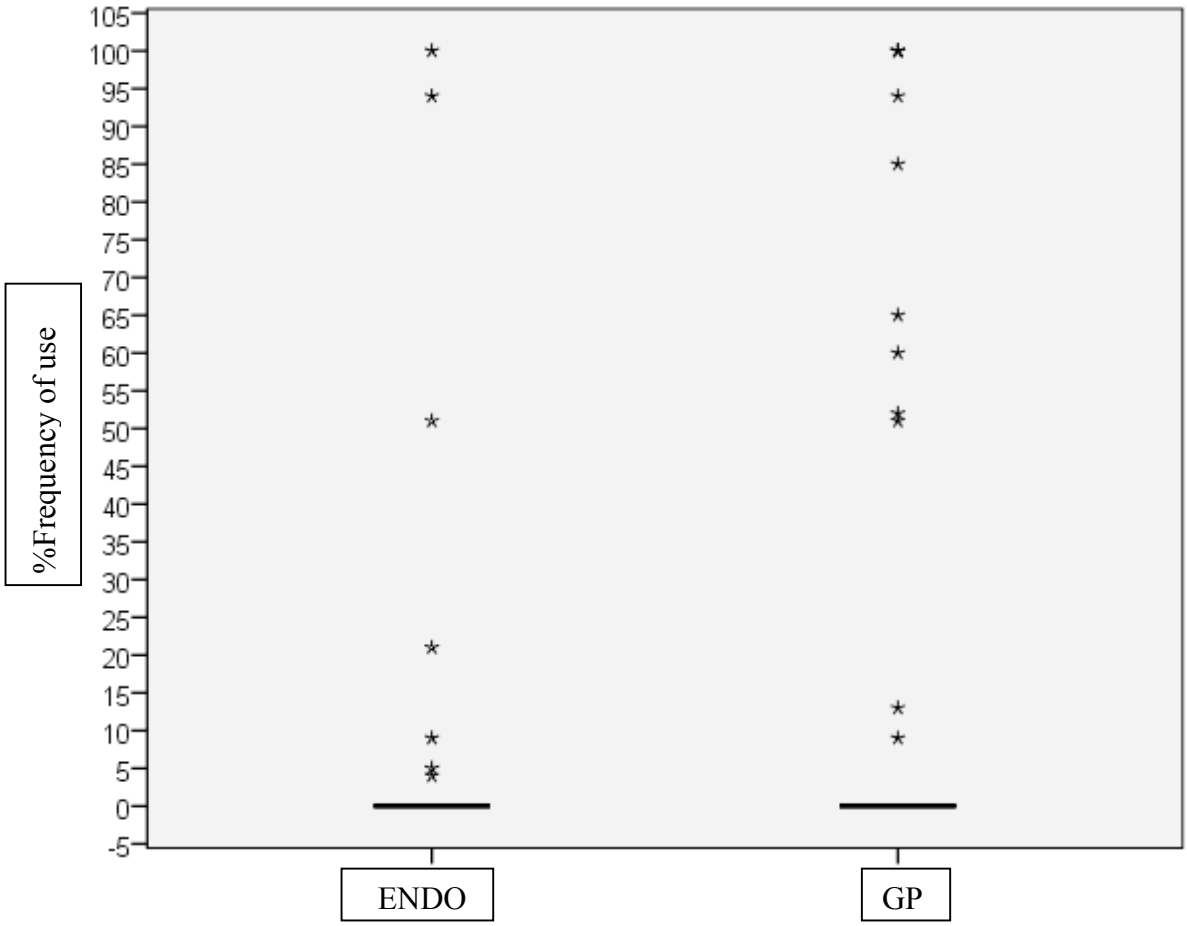

Figure 5-17. Frequency of use of saline by ENDO and GP in treating teeth with vital pulp (independent sample t-test, p=0.633).

Saline was never used (0% of the time) by all except five endodontists in treating teeth with non-vital pulp. The median value was 0%. All but eight GP never used saline (0% of the time) in treating teeth with non-vital pulp. The median value was 0%. There was no statistically significant difference in use of saline between the two groups of practitioners in treating teeth with non-vital pulp (independent sample t-test, p=0.980) (Fig. 5-18).

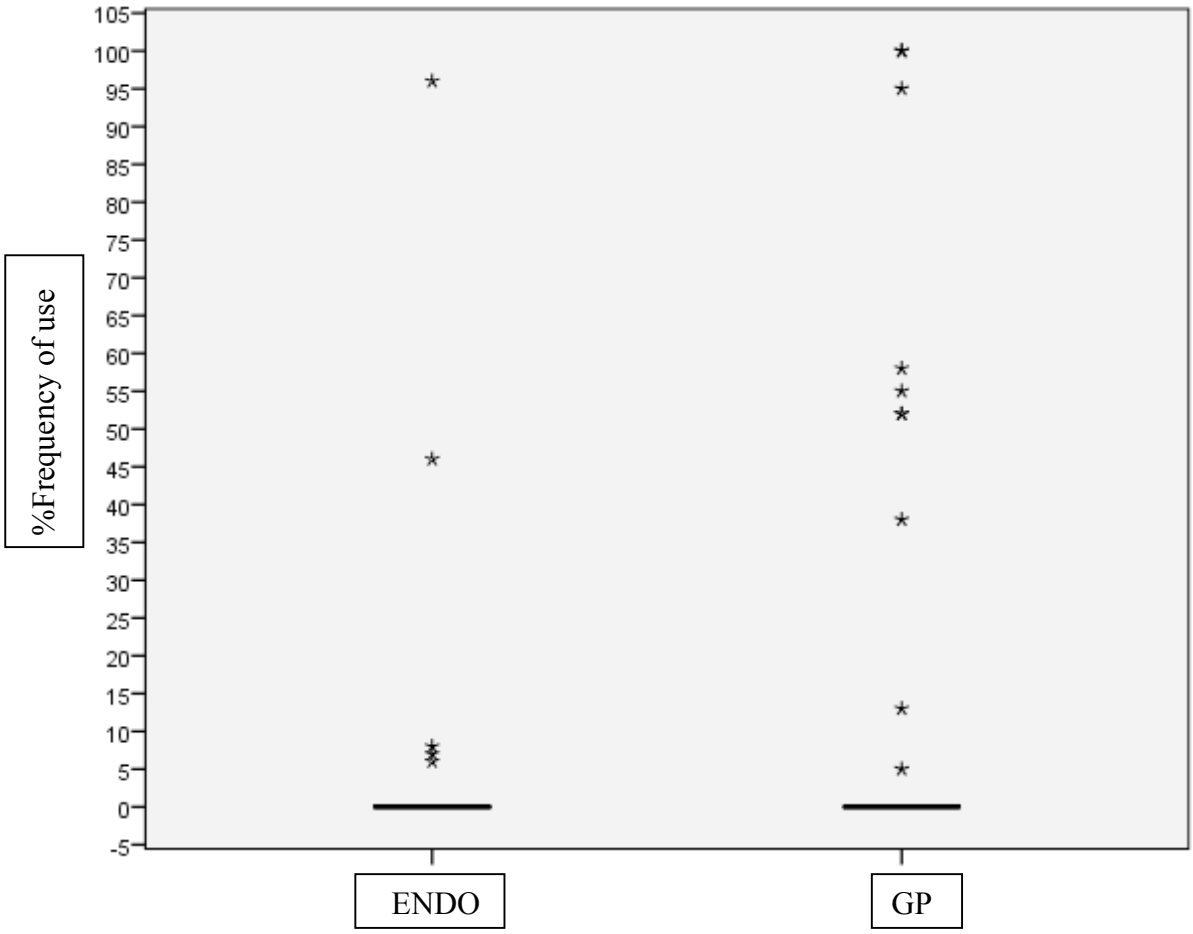

Figure 5-18. Frequency of use of saline by ENDO and GP in treating teeth with non-vital pulp (independent sample t-test, p=0.980).

5.3.10 Frequency of use of water

The median value for endodontists treating in treating teeth with vital pulp using water was never (0% of the time) and 75% of them used this irrigant within the range of never to 23% of the time (There were three outliers). In the GP group 75% of them used water in treating teeth with vital pulp within the range of never (0% of the time) to 77% of the time. Of all, 25 % of GP reported using water more than 77% of the time. The median value was 0%. There was no statistically significant difference in use of water between the two groups of practitioners in treating teeth with vital pulp (independent sample t-test, p=0.185) (Fig. 5-19).

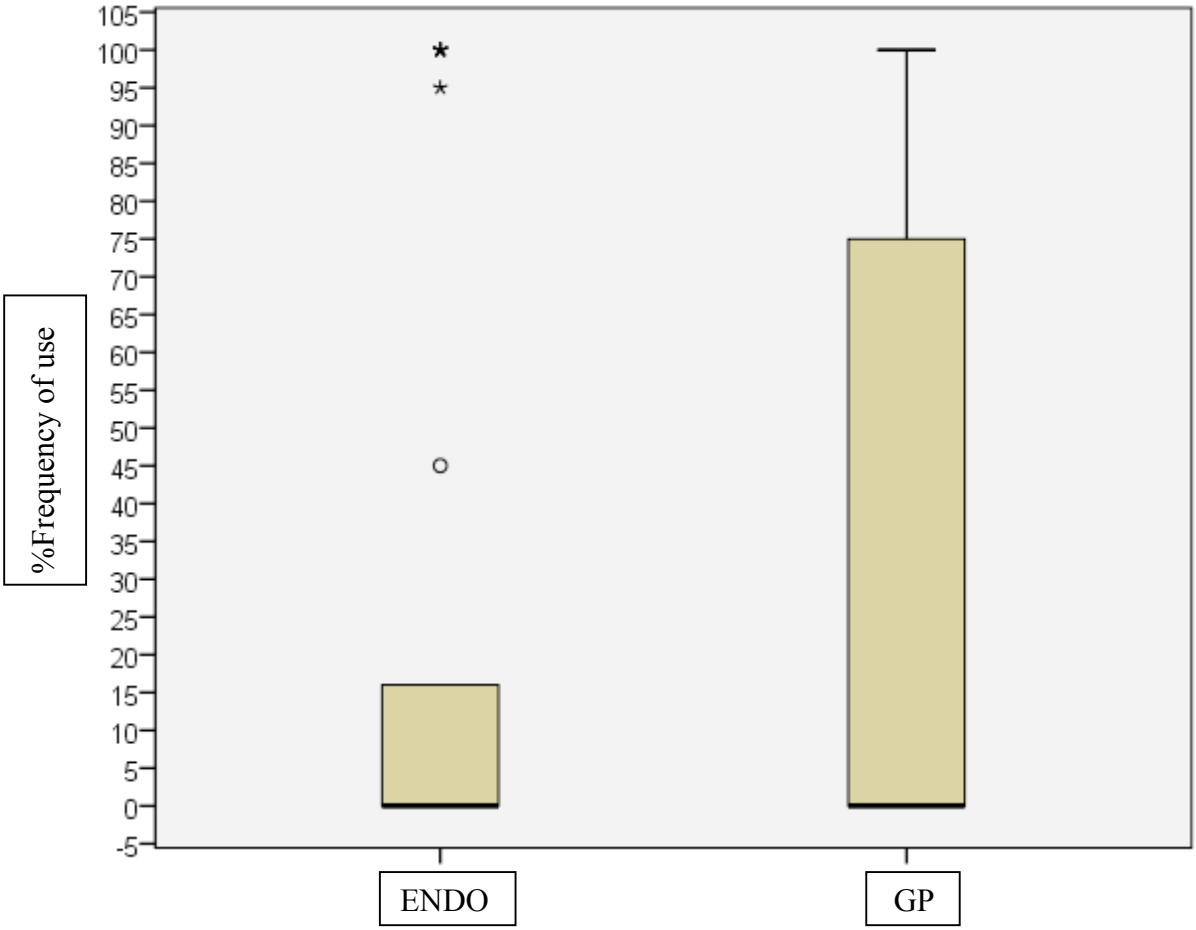

Figure 5-19. Frequency of use of water by ENDO and GP in treating teeth with vital pulp (independent sample t-test, p=0.185).

The median value for endodontists treating teeth with non-vital pulp using water was never (0% of the time), but 75% of them used this irrigant within the range of 0% of the time to 29% of the time. Twenty five percent of endodontists used water more than 29% of the time. In the GP group 75% of them used water in treating teeth with non-vital pulp in the range of 0% of the time to 79% of the time. The median value was 0%. There was no statistically significant difference in use of water between the two groups of practitioners in treating teeth with non-vital pulp (independent sample t-test, p=0.121) (Fig. 5-20).

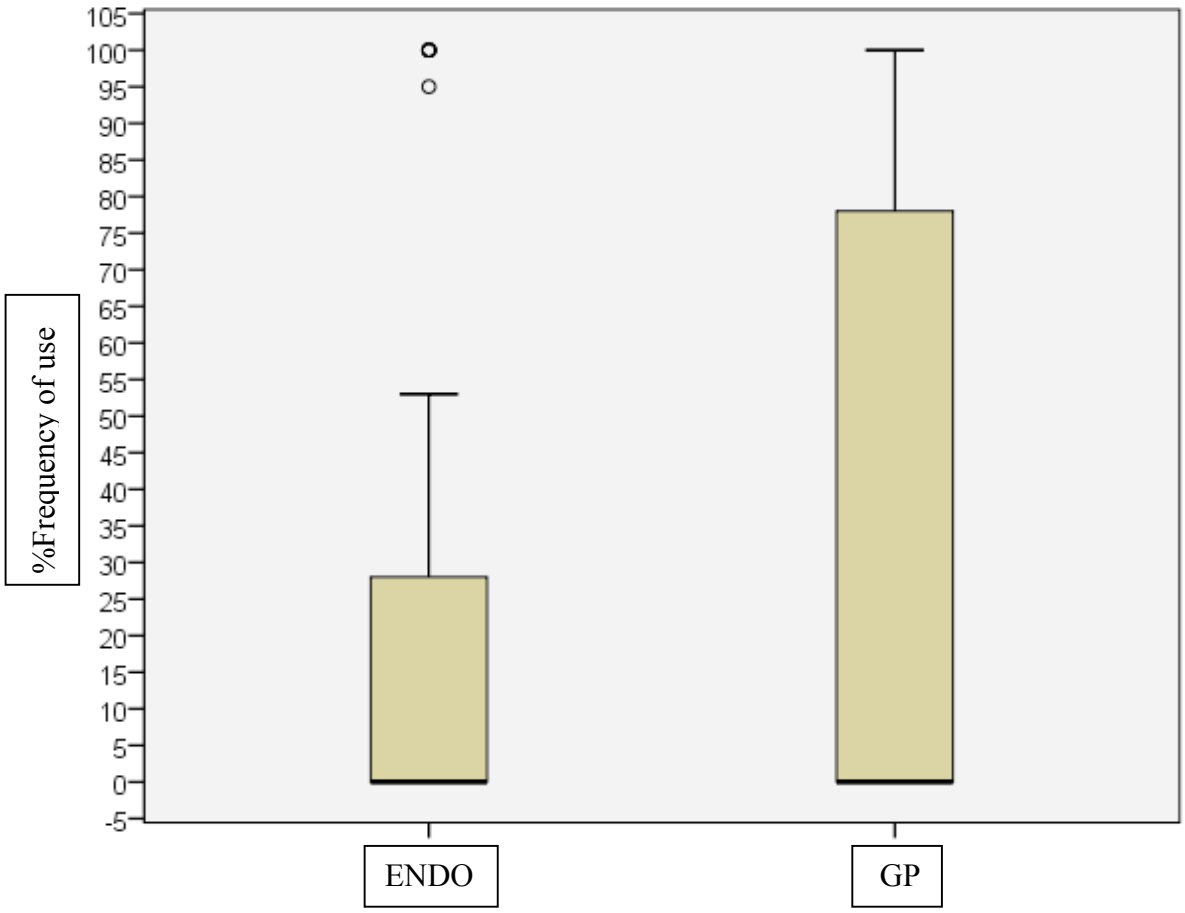

Figure 5-20. Frequency of use of water by ENDO and GP in treating teeth with non-vital pulp (independent sample t-test, p=0.121).

5.4 Concentration of sodium hypochlorite

5.4.1 Survey results of sodium hypochlorite concentration used by endodontists and general practitioners

Of all, 12% of GP did not know the concentration of the NaOCl irrigant they were using, whereas all the endodontists knew the concentration they were using. Endodontists did not use NaOCl of a concentration less than (2%) whereas 17.2% of GP used a concentration less than (2%). Only 17% of endodontists used NaOCl of a concentration (<5%) whereas 55% of GP used a concentration of (<5%). In the endodontist's group 82% used a concentration of (≥5%) sodium hypochlorite whereas 32% of GP used this concentration. There was a statistically significant difference between the two groups (Fisher's Exact test, p<0.001) with the endodontist group using a higher concentration of sodium hypochlorite during a root canal treatment (Fig. 5-21).

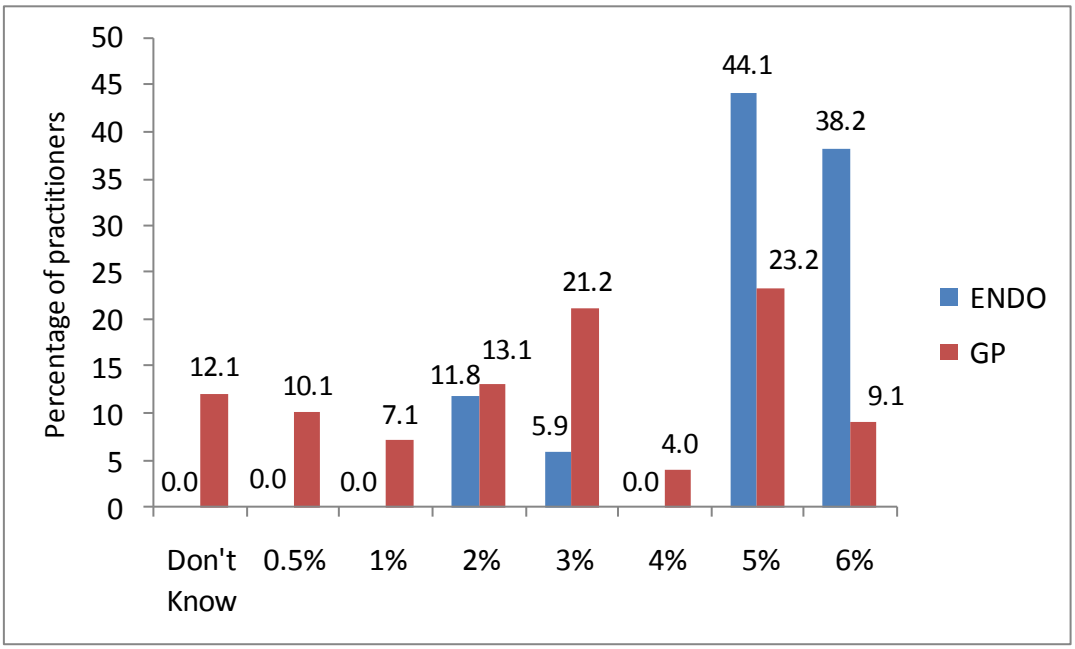

Figure 5-21. Percent of ENDO and GP using different concentrations of sodium hypochlorite (Fisher's Exact test, p<0.001).

5.4.2 Concentration of sodium hypochlorite used by general practitioners-calculated by titration

Out of 68 samples collected from the offices of general practitioners in the lower mainland, 25 percent of the group used less than (3.12%) concentrated sodium hypochlorite. Fifty percent of the group used a concentration higher than (3.12%) but lower than (4.55%). Seventy five percent of them were using lower than (4.55%) concentrated sodium hypochlorite. The median value was (3.68%) (Fig. 5-22).

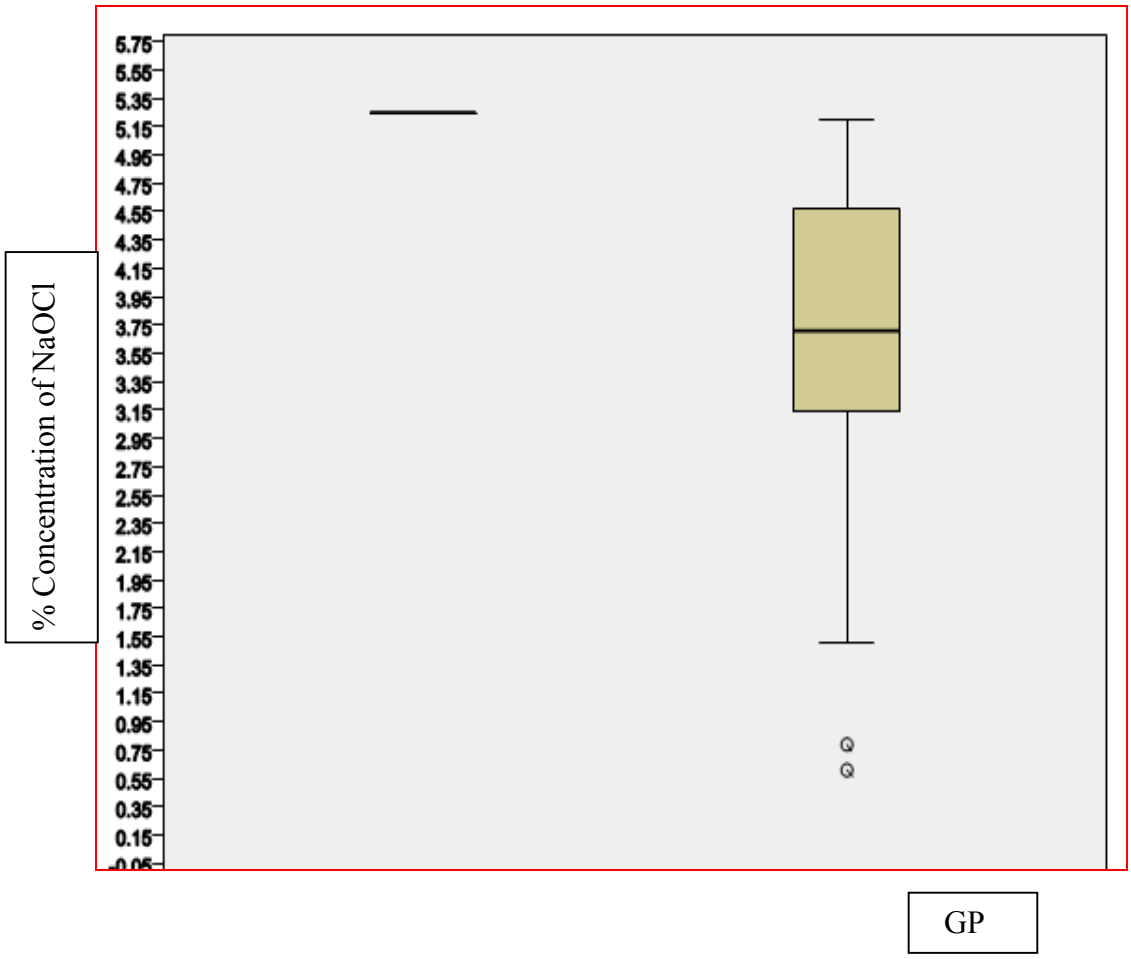

Figure 5-22. Concentration of sodium hypochlorite used by general practitioners, as calculated by titration.

5.5 Volume of irrigant used by endodontists and general practitioners

5.5.1 Volume of different irrigating solutions used in endodontic treatment of teeth with necrotic pulp

Volume of use of sodium hypochlorite

Sodium hypochlorite was commonly used by the two groups. Higher than 10mL concentration was the most common volume used by 42% of the ENDO and 49% of the GP. The second most common choice was 5-10mL by endodontists (39%). GP second most common choice was 1-5mL and 5-10mL. There was no statistically significant difference in volume of sodium hypochlorite used in treating teeth with necrotic pulp between the two groups of practitioners (Fisher's Exact test, p=0.444) (Fig. 5-23).

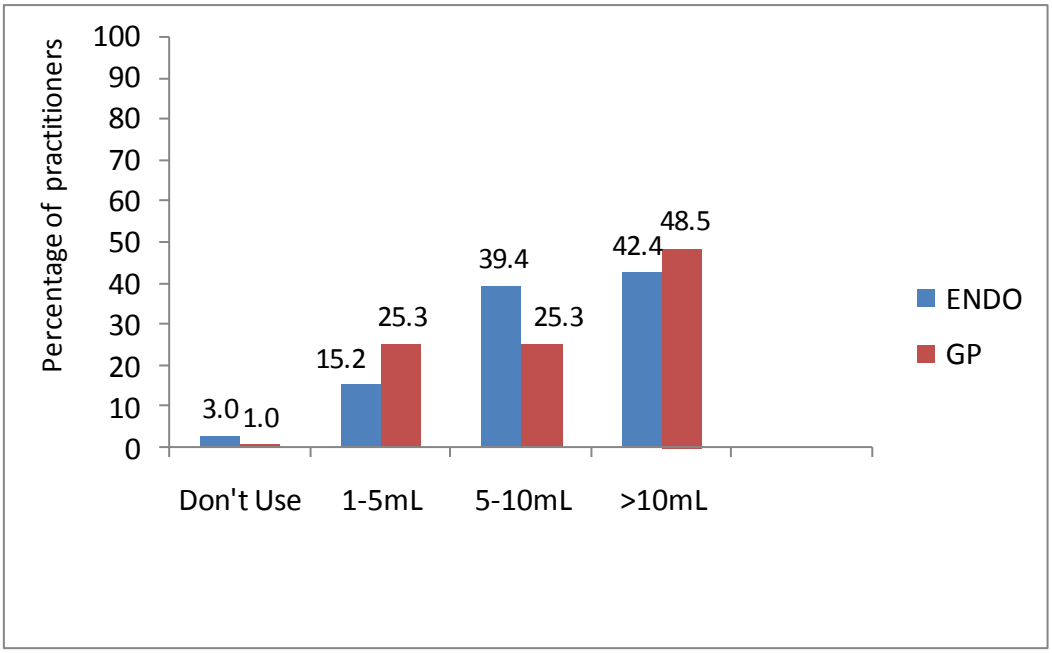

Figure 5-23. Volume of sodium hypochlorite irrigant used in treating teeth with necrotic pulp by ENDO and GP (Fisher's Exact test, p=0.444).

Volume of use of EDTA

EDTA was more commonly used by endodontists than GP. Volume of 1-5mL was used by 67% of the endododontists and 51% of the GP. Unlike NaOCl, a lower volume of EDTA was favored by the two groups. The second most common choice was 5-10mL volume for endodontists (20%) and Don't Use for GP (46%). Volume of >10mL was the least common choice for both groups. The endodontist group demonstrated a statistically significant difference with GP group in volume of EDTA used in treating teeth with necrotic pulp (Fisher's Exact test, p<0.001) (Fig. 5-24).

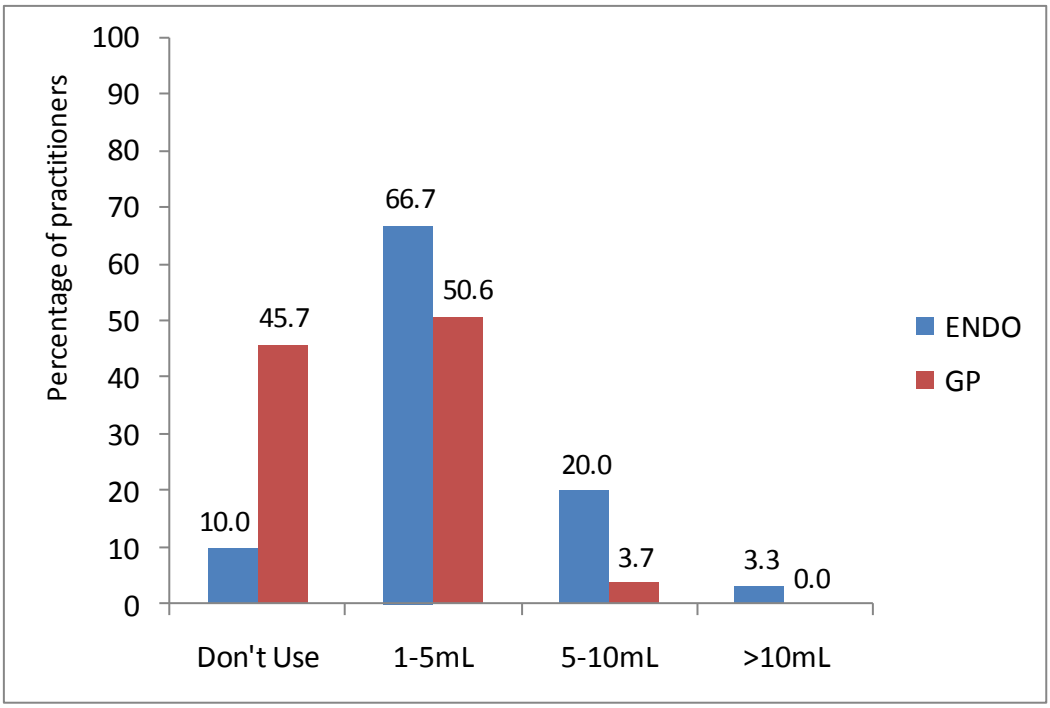

Figure 5-24. Volume of EDTA irrigant used in treating teeth with necrotic pulp by ENDO and GP (Fisher's Exact test, p<0.001).

Volume of use of RC-Prep™

RC-Prep™ was more commonly used by the GP. In the endodontist group first choice was "Do Not use" (52%) and the second choice was the 1-5mL (41%). In the GP group, the most common choice was the 1-5mL volume by 79% and the second most common choice was "Don't use" by 16%. Volume of >10mL was the least common choice for the two groups. Volume of RC-Prep™ used by GP was a statistically significant in comparison to endodontist group in treating teeth with necrotic pulp (Fisher's Exact test, p=0.002) (Fig. 5-25).

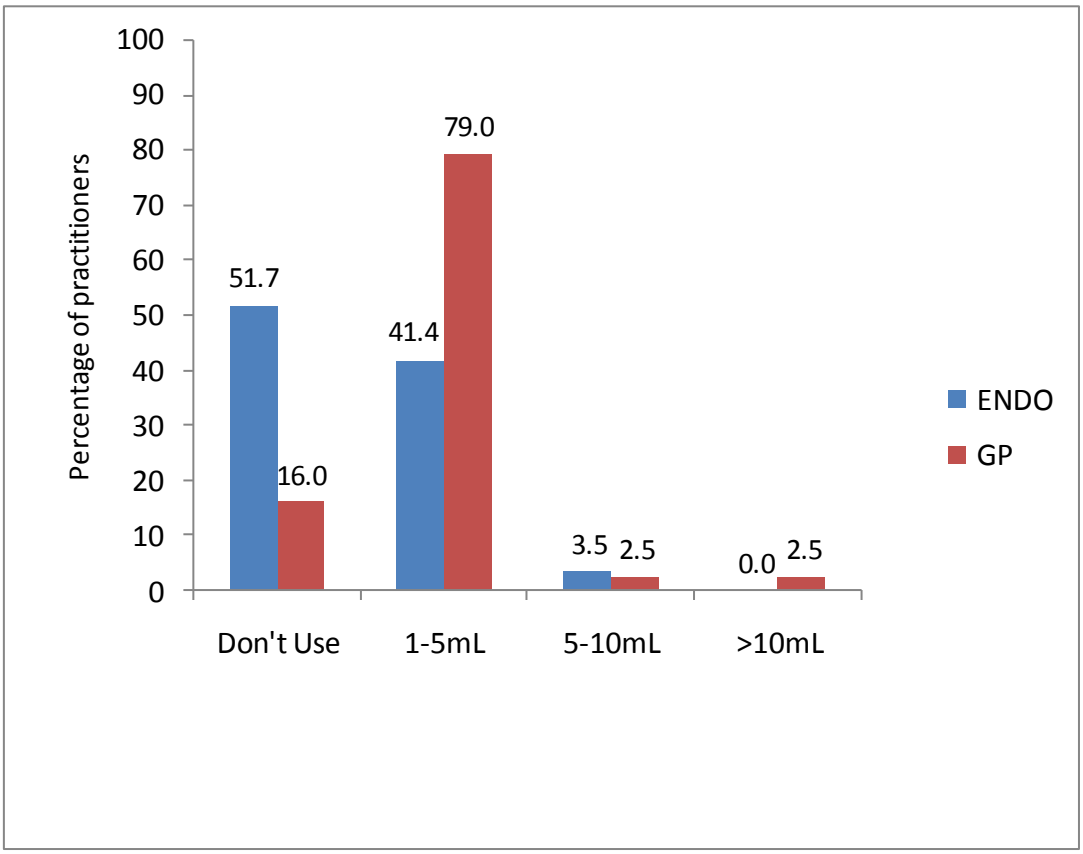

Figure 5-25. Volume of RC-Prep™ irrigant used in treating teeth with necrotic pulp by ENDO and GP (Fisher's Exact test, p=0.002).

Volume of use of chlorhexidine

Chlorhexidine was used more commonly by endodontists than by GP. The most common choice was "Do Not use" for the two groups, endodontists (50%) and GP (72%) accordingly. The second most common choice in volume of use by the two groups was to use 1-5mL of chlorhexidine. Volume of >10 mL was least commonly used by both groups. The endodontist group differed from the GP group marginally statistically insignificant regarding the volume of chlorhexidine used in treating teeth with necrotic pulp (Fisher's Exact test, p=0.059) (Fig. 5-26).

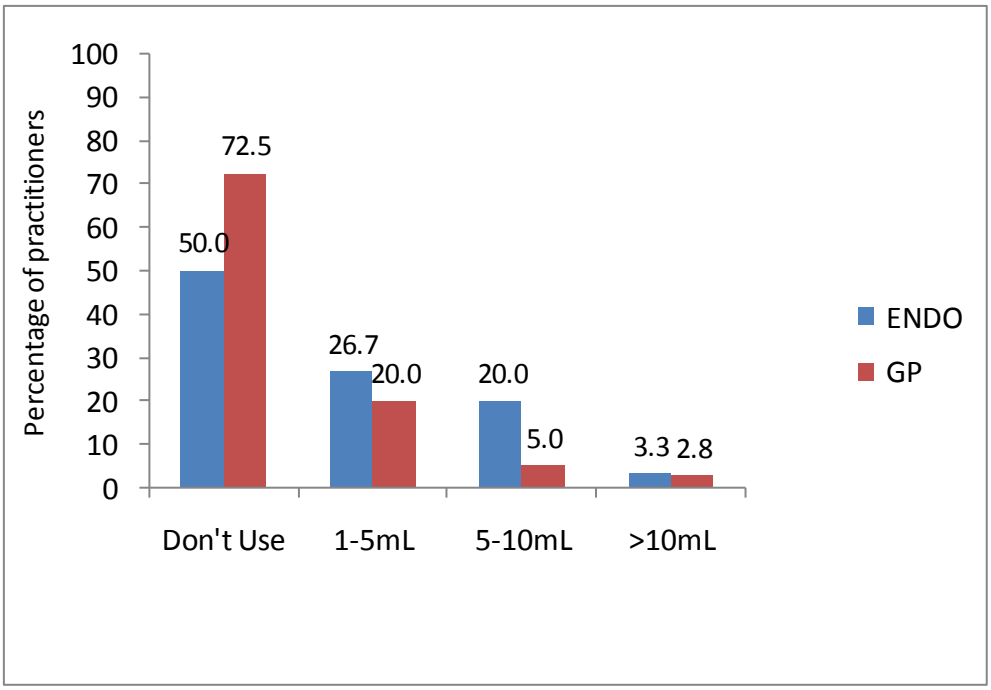

Figure 5-26. Volume of chlorhexidine irrigant used in treating teeth with necrotic pulp by ENDO and GP (Fisher's Exact test, p=0.059).

Volume of use of MTAD™

Most GP and endodontists did not use MTAD™ in this study. Only a few endodontists (3%) and GP (3%) used MTAD™ in volumes of 1-5mL and 5-10mL.

Volume of >10mL was least commonly used by both groups. There was no statistically significant difference in volume of MTAD™ used between the two groups of practitioners in treating teeth with necrotic pulp (Fisher's Exact test, p=0.860) (Fig. 5-27).

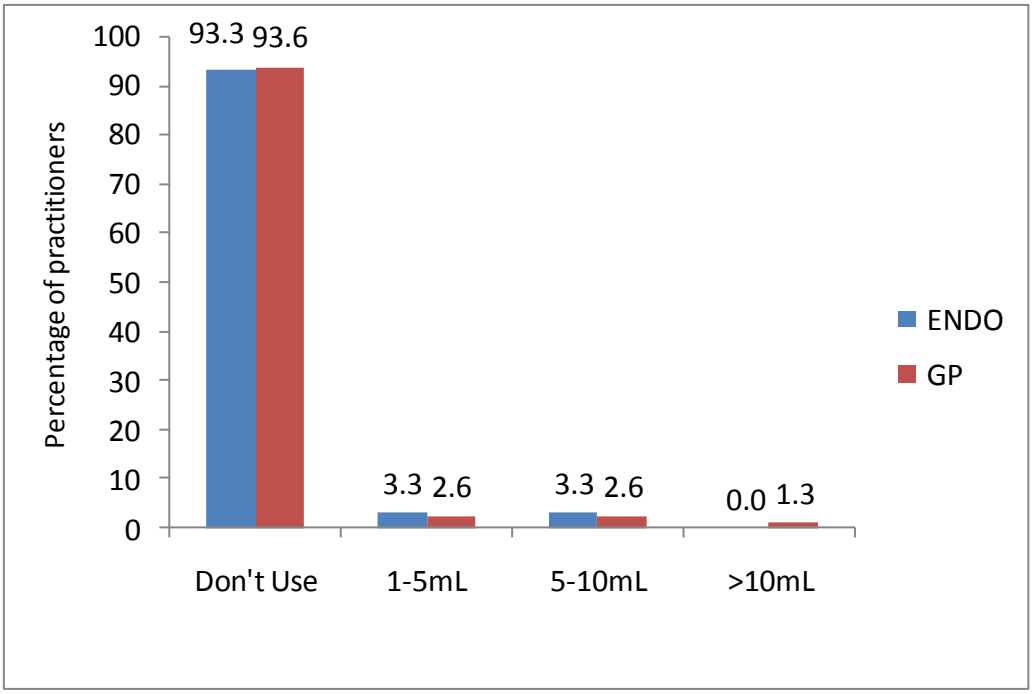

Figure 5-27. Volume of MTAD™ irrigant used in treating teeth with necrotic pulp by ENDO and GP (Fisher's Exact test, p=0.860).

Volume of use of Smear Clear™

Most GP and endodontists did not use Smear Clear™. The only used Smear Clear™ volume by endodontists (7%) and GP (6%) used was 1-5mL. There was no statistically significant difference in volume of Smear Clear™ used between the two groups of practitioners in treating teeth with necrotic pulp (Fisher's Exact test, p=0.341) (Fig. 5-28).

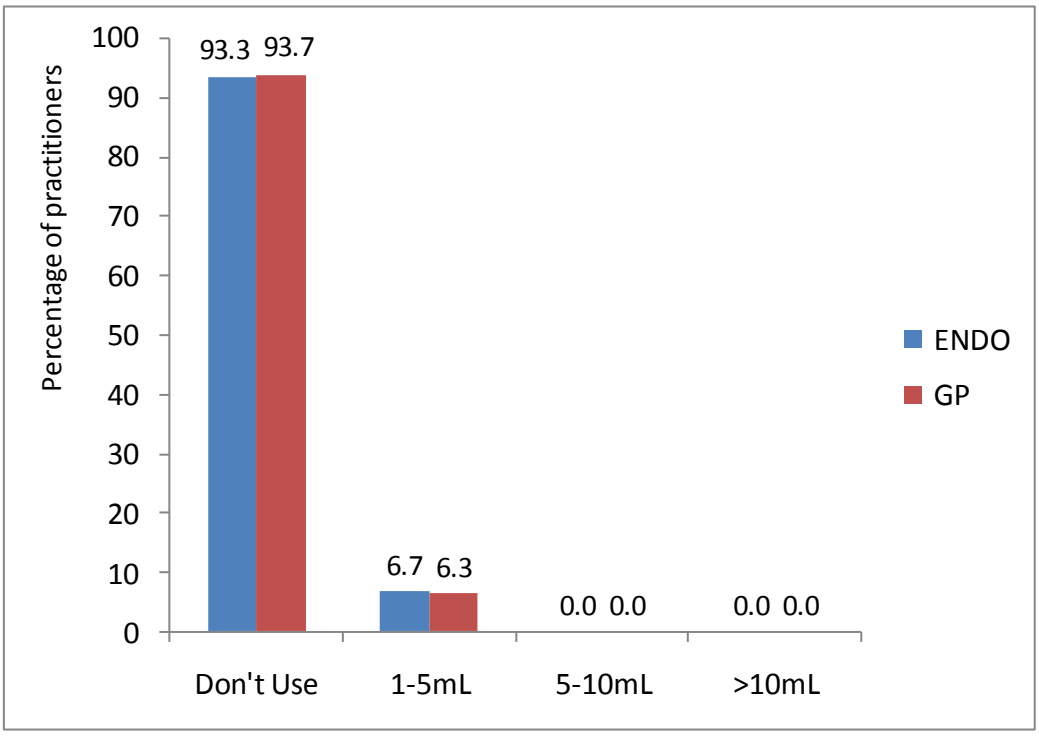

Figure 5-28. Volume of Smear Clear™ irrigant used in treating teeth with necrotic pulp by ENDO and GP (Fisher's Exact test, p=0.341).

Volume of use of citric acid

Endodontists and GP did not use citric acid in treating teeth with necrotic pulp. There was no variation in the volume of use, therefore statistical analysis was not performed (Fig. 5-29).

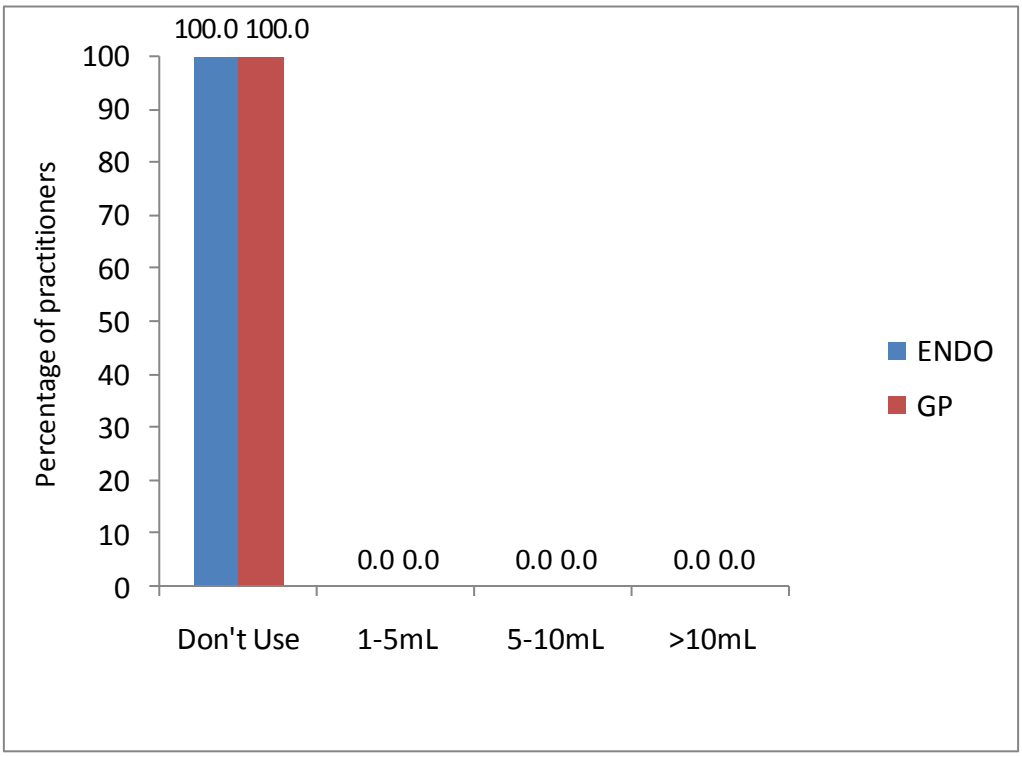

Figure 5-29. Volume of citric acid irrigant used in treating teeth with necrotic pulp by ENDO and GP

Volume of use of alcohol

The most commonly used alcohol volume in treating teeth with necrotic pulp in the two groups was 1-5mL, ENDO (27%) and GP (14%). Volume of >10 mL was never used by either group. In the GP group 86% and in the endodontist group 67% did not use alcohol in their endodontic treatment. The endodontist group demonstrated a statistically significant difference as compared to the GP group in volume of alcohol used in treating teeth with necrotic pulp (Fisher's Exact test, p=0.035) (Fig. 5-30).

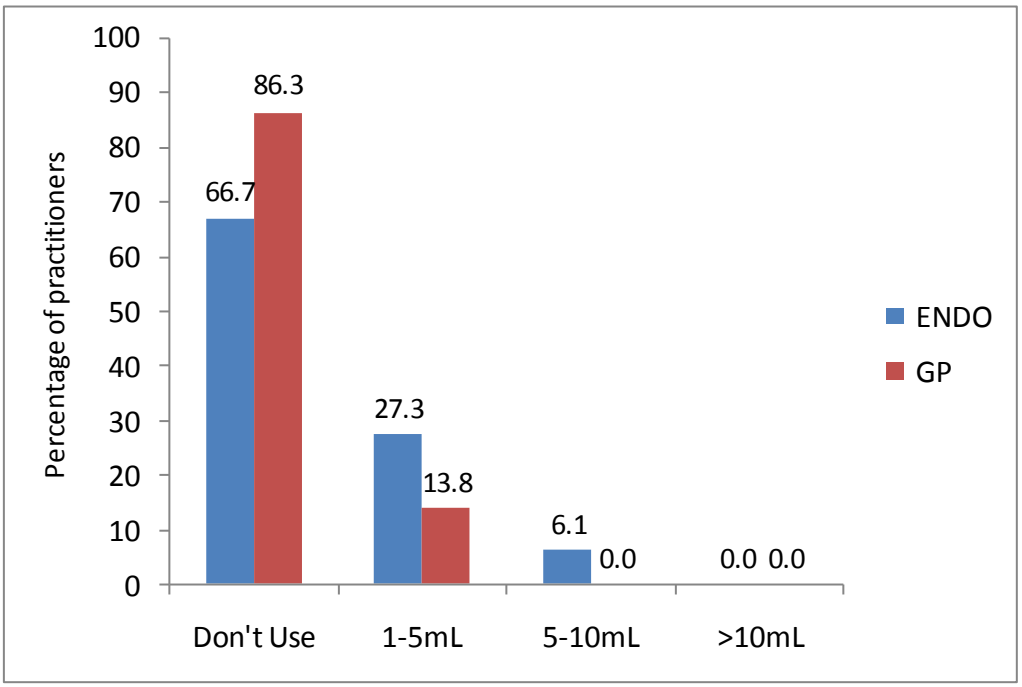

Figure 5-30. Volume of alcohol irrigant used in treating teeth with necrotic pulp by ENDO and GP (Fisher's Exact test, p=0.035).

Volume of use of saline

Saline was not commonly used by either group in treating teeth with necrotic pulp. The most commonly used volume of saline used was 1-5mL for both groups, endodontists (13%) and GP (7%). The second most common choice was to use 5-10mL and >10mL of saline for endodontists (3%) and GP >10mL (4%) correspondingly. There was no statistically significant difference between the two groups of practitioners in volume of saline used in treating teeth with necrotic pulp (Fisher's Exact test, p=0.773) (Fig. 5-31).

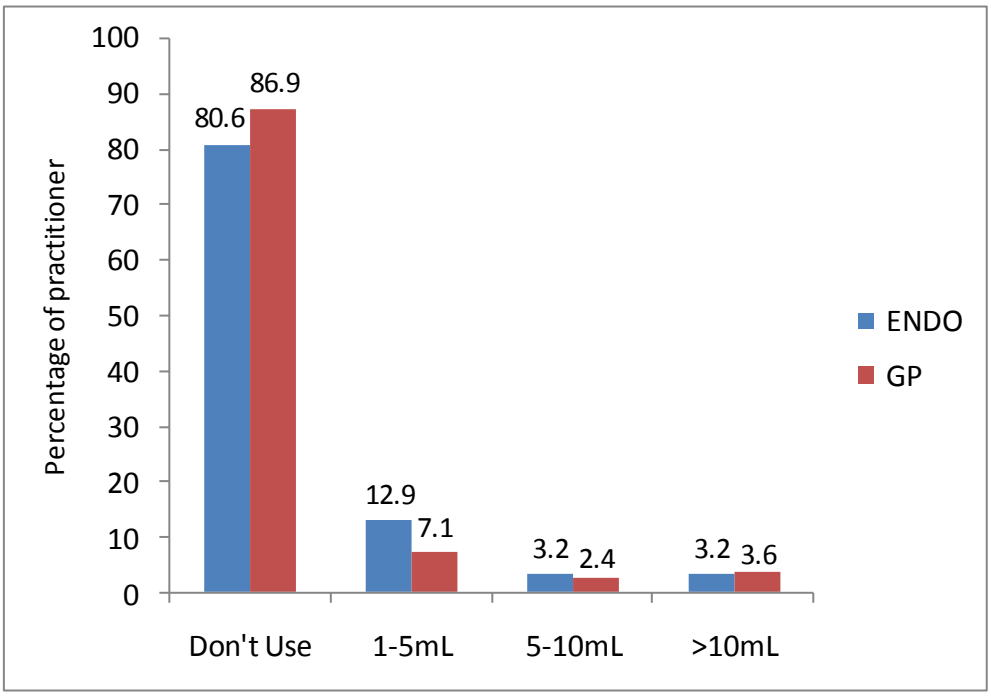

Figure 5-31. Volume of saline irrigant used in treating teeth with necrotic pulp by ENDO and GP (Fisher's Exact test, p=0.773).

Volume of use of water

Water was not commonly used by either type of practitioners in treating teeth with necrotic pulp. The most commonly used volume of water used by the two groups was 1-5mL, endodontists (19%) and GP (18%) correspondingly. The second most common volume was >10mL, endodontists (6%) and GP (12%). There was no statistically significant difference between the two groups of practitioners in volume of water used in treating teeth with necrotic pulp (Fisher's Exact test, p=0.536) (Fig. 5-32).

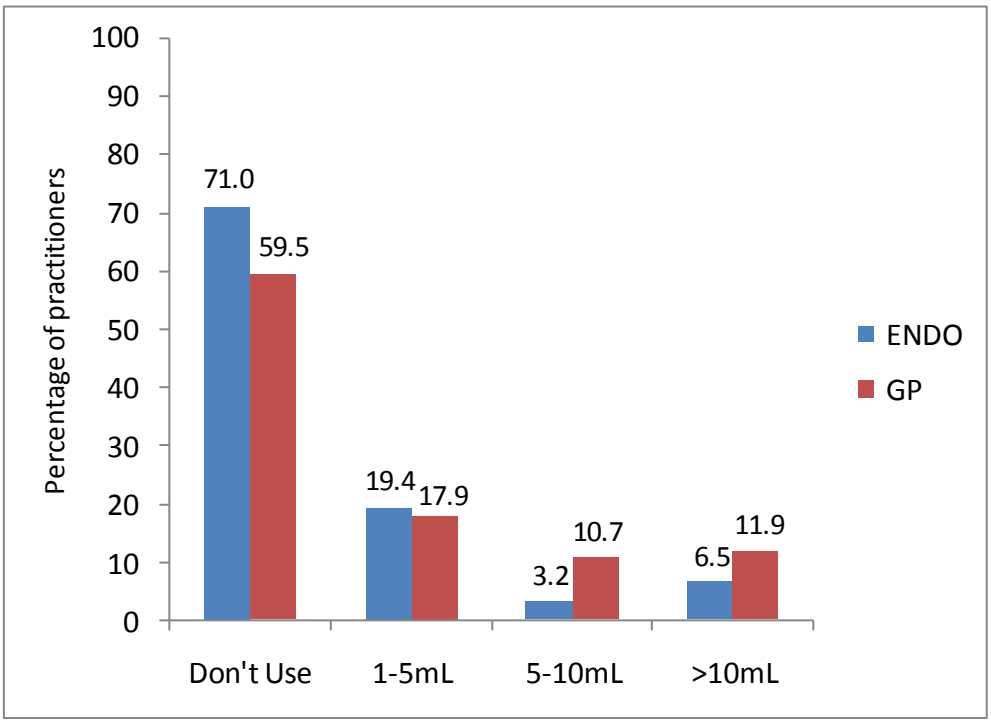

Figure 5-32. Volume of water irrigant used in treating teeth with necrotic pulp by ENDO and GP (Fisher's Exact test, p=0.536).

5.5.2 Difference in volume of use

Difference in volume of irrigants used by endodontists and general practitioners in treating teeth with vital pulp vs. non-vital pulp

There was a statistically significant difference between the two groups (Chi-Square test, p=0.036) when comparing volume of used in endodontic treatment of teeth with vital pulp vs. non-vital pulp. Most GP (87%) and endodontists (71%) used similar volumes of irrigants in treating teeth with vital pulp vs. non-vital pulp. Endodontists (29%) and GP (13%) used different volume in treating teeth with vital pulp in compare to non-vital pulp (Fig. 5-33).

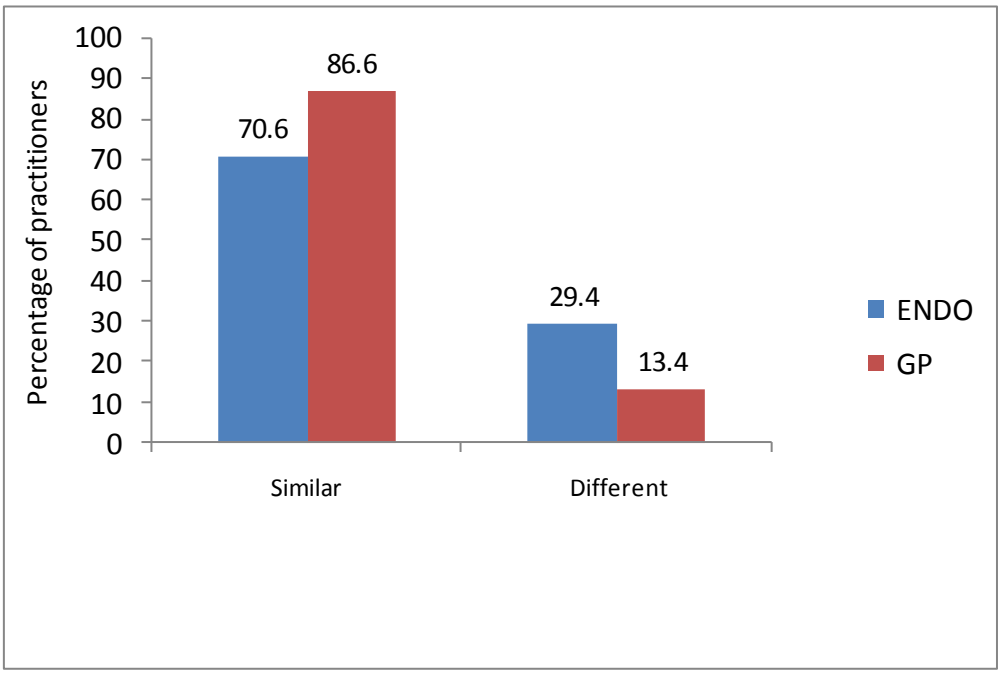

Figure 5-33. Percentage of ENDO and GP who used similar or different volumes in treating teeth with vital pulp in comparison to teeth with non-vital pulp (Chi-Square test, p=0.036).

5.6 Sizes of different irrigation needle tips used by endodontists and general practitioners

Use of different sizes of stainless steel needle tips during the irrigation in endodontic treatment

The most common stainless steel needle tip size used was 27G for the two groups, endodontists (29%) and GP (36%). The second most common choice for endodontists (20%) was to use tips sizes 30G and 25G, and for GP to use size 30G (23%). The least common size gauge needle used for the two groups was >30G, endodontists (9%) and GP (3%) (Fig. 5-34).

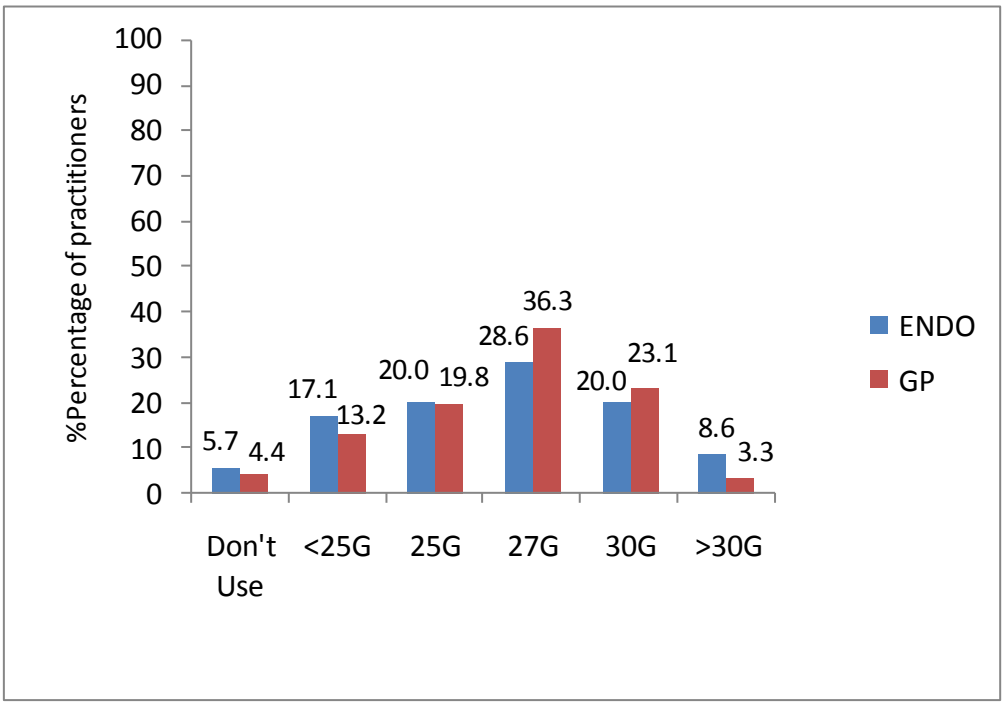

Figure 5-34. Percentage of ENDO and GP using different guage of stainless steel needle tips during irrigation

Use of different sizes of NiTi needle tips during the irrigation in endodontic treatment

NiTi needle tip was not commonly used by the two groups, endodontists (85%) and GP (80%). The most common needle gauge used was 30G needle by endodontists (12%) and 30G and 27G for GP (7%). Endodontists did not use sizes 25G, 27G and >30G needle tips for irrigation in endodontic treatment. There was no statistically significant difference between the two groups (Fisher's Exact test, p=0.673) (Fig. 5-35).

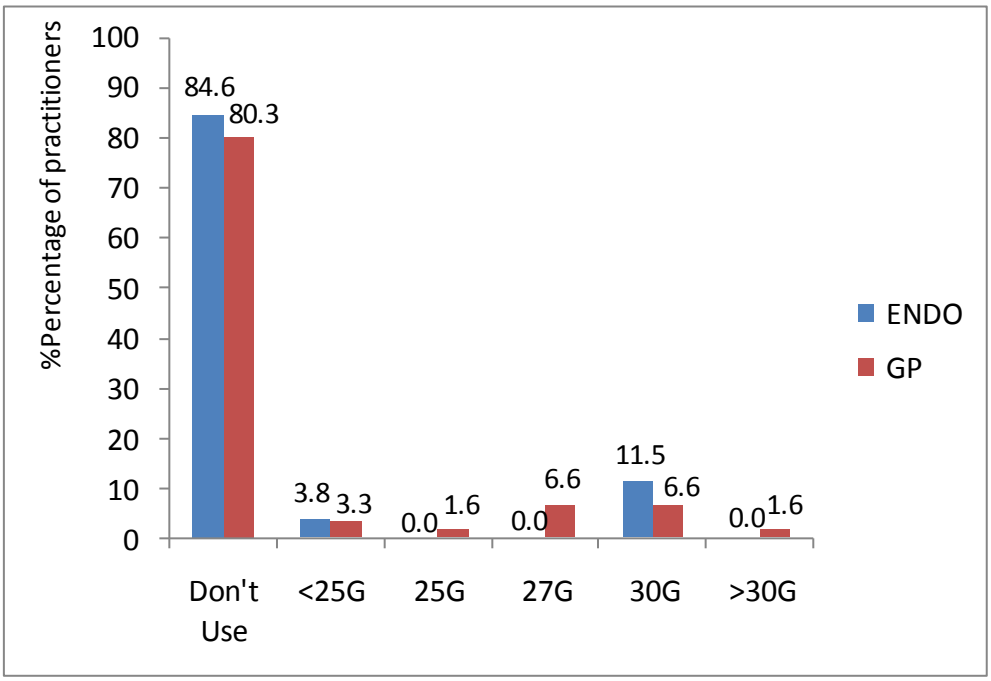

Figure 5-35. Percentage of ENDO and GP using different gauge of NiTi needle tips during irrigation (Fisher's Exact test, p=0.673).

5.7 Depth of irrigation needle tip insertion

Tip insertion in the root canal chamber area by endodontists and general practitioners

The median value for endodontists placing the irrigation needle tip in pulp chamber area was always (100% of the time),where 75% of them inserted the irrigation needle to pulp chamber area ranging from 90% of the time to always (100% of the time). Of all, 25% of endodontists reported inserting needle in pulp chamber area less than 90% of the time. There was more variation within the GP group. Seventy five percent of GP irrigate in pulp chamber area within the range of 54% of the time to always (100% of the time). The median value was 96%. There was no statistically significant difference

between the two groups of practitioners in dept of irrigation needle tip insertion in the pulp chamber area (independent sample t-test, p=0.565) (Fig. 5-36).

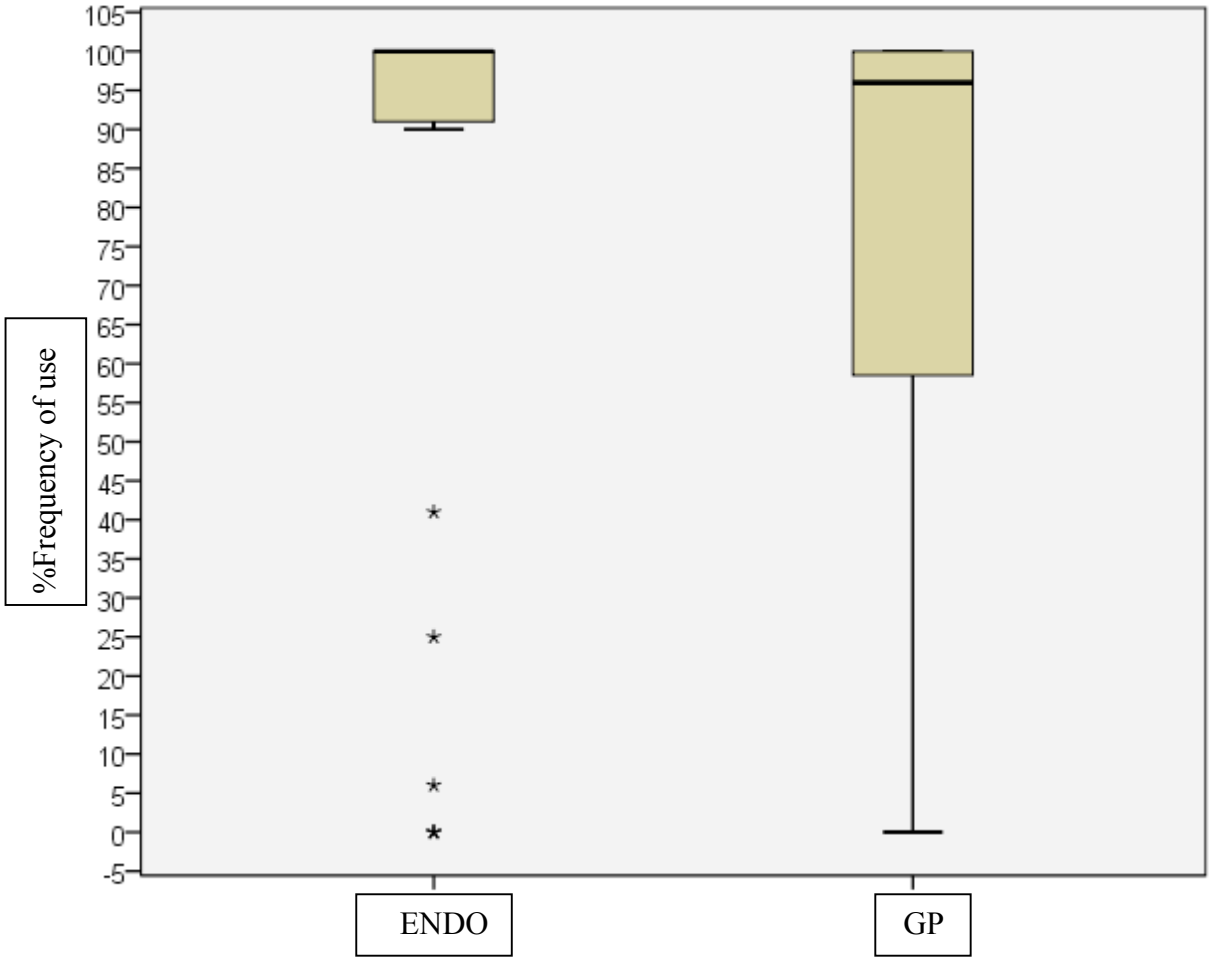

Figure 5-36. Frequency of needle tip insertion for irrigation within pulp chamber area by ENDO and GP (independent sample t-test, p=0.565).

Mid/Coronal canal area

In the endodontists' group 75% of them inserted irrigation needle tip in coronal/mid canal area within the range from 67% of the time to always (100% of the time). The median value was 94% (there were three outliers). In the GP group 75% of them inserted the irrigation needle tip in coronal/mid canal area with the range from 80% of the time to always (100% of the time). Twenty five percent of GP reported inserting

the irrigation needle less than 80% of the time in mid/coronal area (there were seven outliers). The median value was 96%. There was no statistically significant difference between the two groups of practitioners in depth of irrigation needle tip insertion in the coronal/mid canal area (independent sample t-test, p=0.285) (Fig. 5-37).

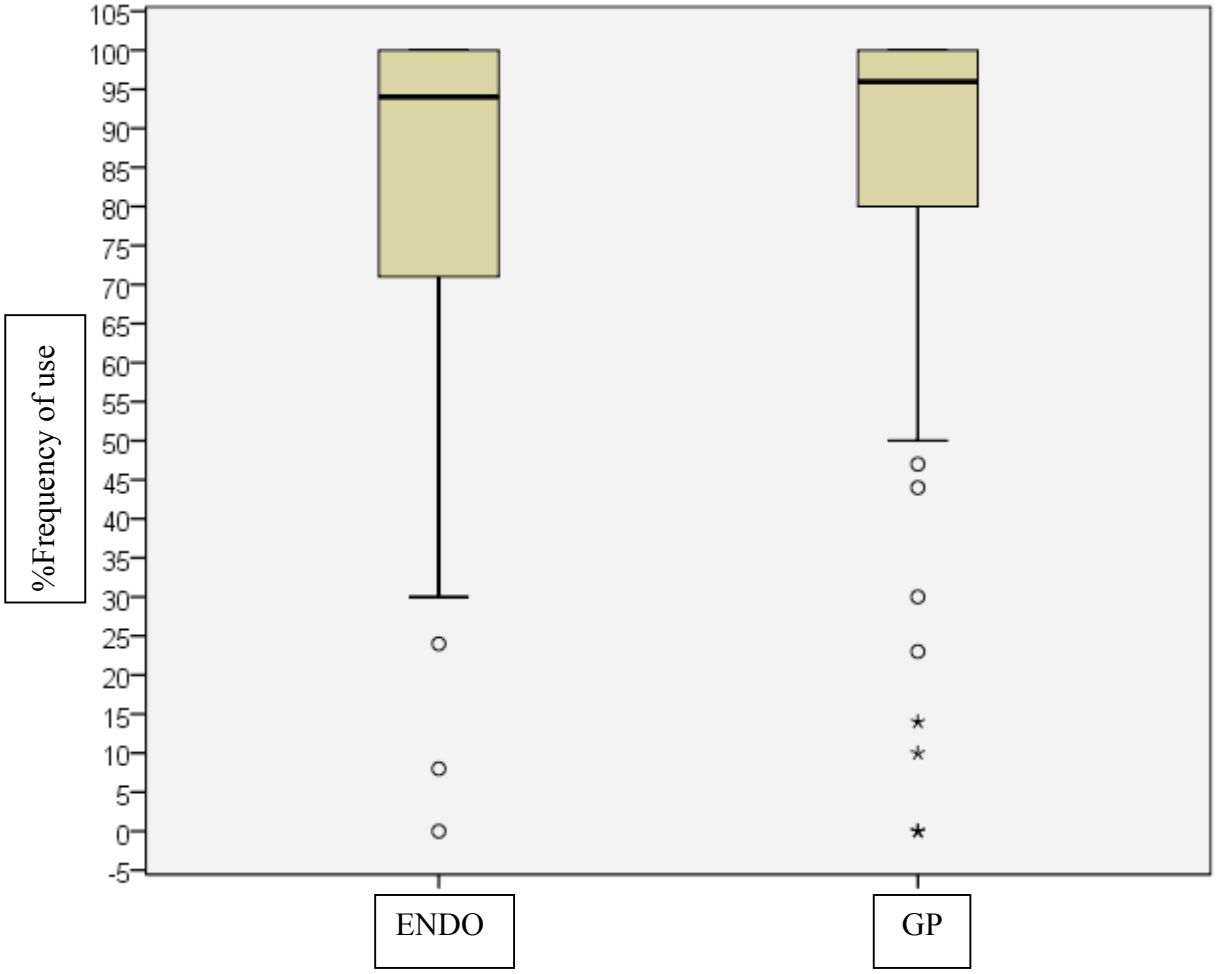

Figure 5-37. Frequency of needle tip insertion for irrigation within coronal/mid canal area by ENDO and GP (independent sample t-test, p=0.285).

Apical canal area

There was a substantial variation among endodontists in depth of irrigation needle tip insertion in apical area. Seventy five percent of endodontists irrigated apical area

within the range from 8% of the time to 92% of the time. The median value was 51%. Of all, 75% of GP varied from never (0% of the time) inserting the irrigation needle tip in apical area to 37% of the time with the median value of 9% (there were five outliers). There was a statistically significant difference between the two groups of practitioners in the frequency of irrigation needle tip insertion in the apical area (independent sample t-test, p=0.002) (Fig. 5-38).

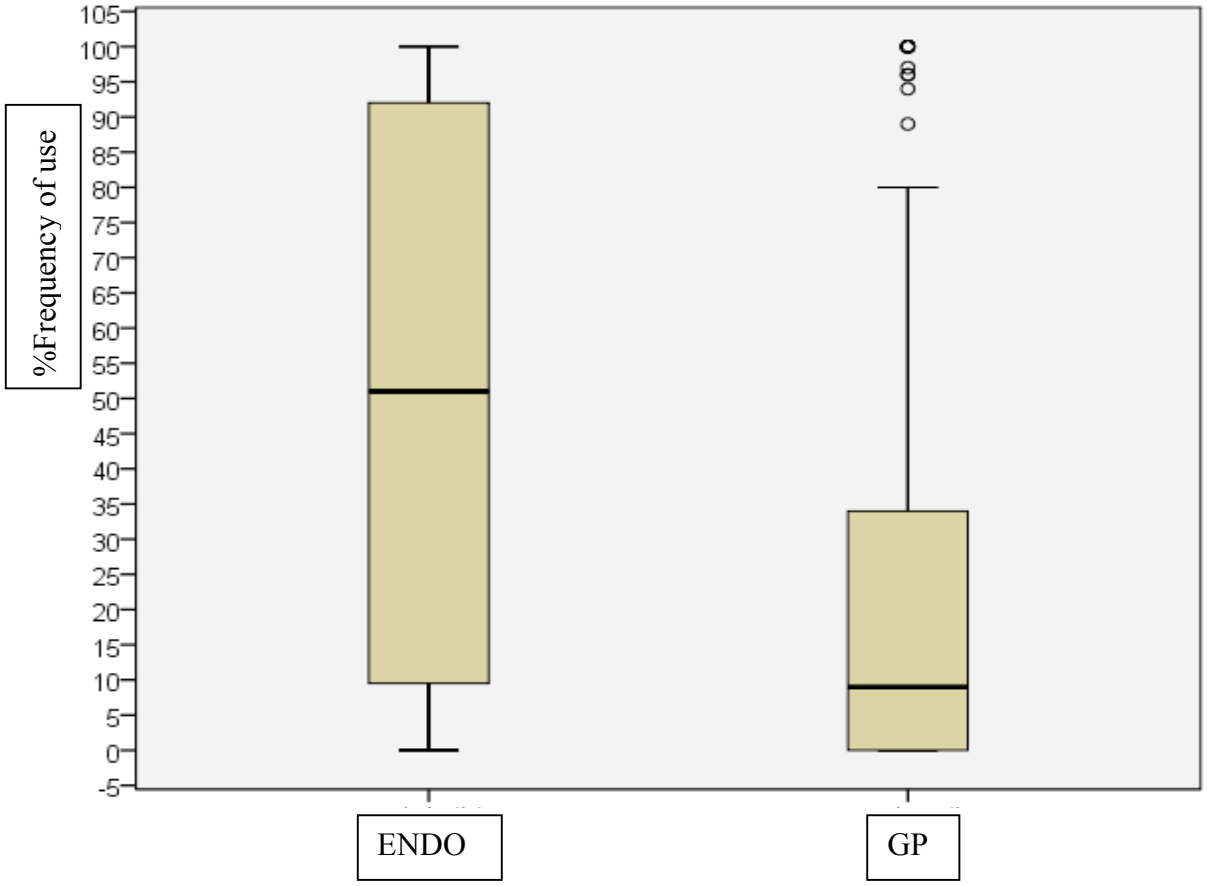

Figure 5-38. Frequency of needle tip insertion for irrigation within apical canal area by ENDO and GP (independent sample t-test, p=0.002).

5.8 Sequence of different irrigants used by endodontists and general practitioners

5.8.1 Sequence of different irrigants in treating teeth with non-vital pulp

Choice for the starting irrigants

The most common irrigant used as an initial irrigant in treating teeth with non-vital pulp by both endodontists (85%) and GP (78%) was sodium hypochlorite. The Second most common irrigants of choice in endodontist group (6%) were RC-Prep™, saline and water. The second most common initial irrigant of choice in the GP group was RC-Prep™ (17%) followed by water (14%). Chlorhexidine was never used as an initial irrigant in treating teeth with non-vital pulp by the endodontist group. MTAD™, Smear Clear™, citric acid and alcohol were never used as initial irrigants in treating teeth with non-vital pulp by the GP group. There were no statistically significant differences between the two groups of practitioners in choice of the initial irrigants used in treating teeth with non-vital pulp, NaOCl (Chi-Square test, p=0.462), EDTA (Fisher's Exact test, p=1.000), RC-Prep™ (Fisher's Exact test, p=0.156), chlorhexidine (Fisher's Exact test, p=1.000), MTAD™, Smear Clear™, citric acid and alcohol (Fisher's Exact test, p=0.259), saline (Fisher's Exact test, p=1.000),water (Fisher's Exact test, p=0.239) and other (Fisher's Exact test, p=1.000) (Fig. 5-39).

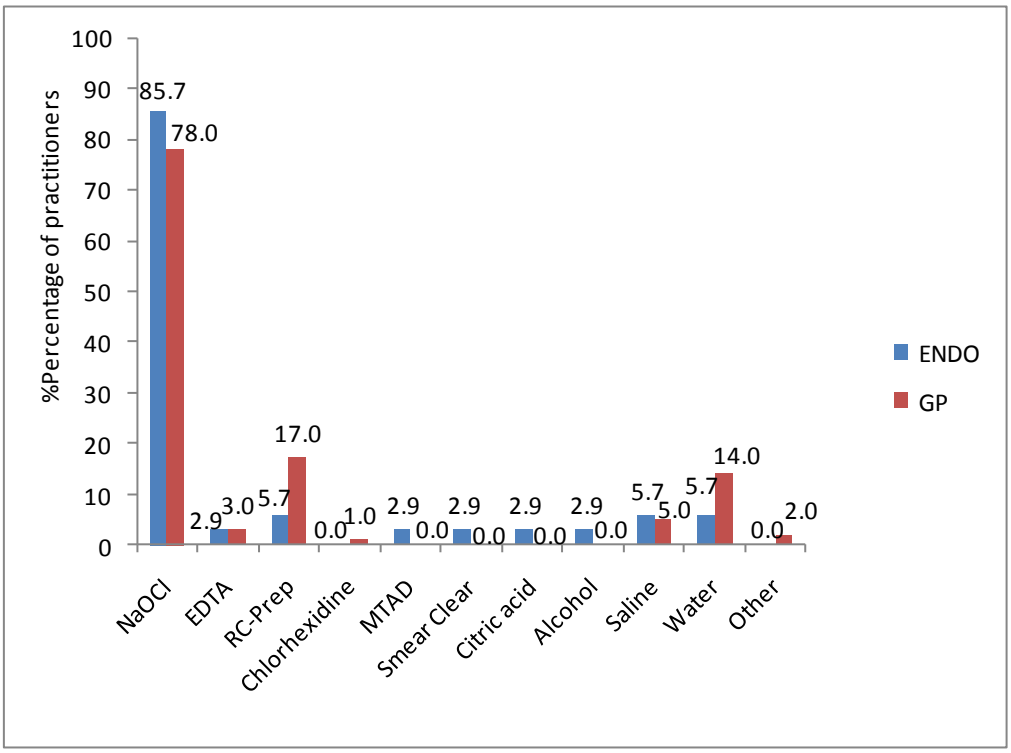

Figure 5-39. Initial irrigants used by ENDO and GP in treating teeth with non-vital pulp.

Choice for the in-between irrigants

The most common irrigant used as an in-between irrigant in treating teeth with non-vital pulp by both endodontists (77%) and GP (84%) was sodium hypochlorite. The Second most common irrigant of choice in the endodontist group was EDTA (63%) followed by RC-Prep™ (37%). The second most common used as the in-between irrigant of choice in the GP group was RC-Prep™ (51%) followed by EDTA (28%). Citric acid was never used as the in-between irrigant in treating teeth with non-vital pulp by endodontist group. MTAD™ was never used as the in-between irrigant in treating teeth with non-vital pulp by the GP group. Except for EDTA (Chi-Square test, $p<0.001$) and saline (Fisher's Exact test, $p=0.039$), there was no statistically significant difference between the two groups of practitioners in choice of the in-between irrigant used in

treating teeth with non-vital pulp, NaOCl (Chi-Square test, p=0.361), RC-Prep™ (Chi-Square test. p=0.158), Chlorhexidine (Fisher's Exact test, p=0.427), MTAD™ (Fisher's Exact test, p=0.259), Smear Clear™ (Fisher's Exact test, p=0.604), citric acid (Fisher's Exact test, p=1.000), alcohol (Fisher's Exact test, p=0.165), water (Fisher's Exact test, p=0.590) and other (Fisher's Exact test, p=1.000) (Fig. 5-40).

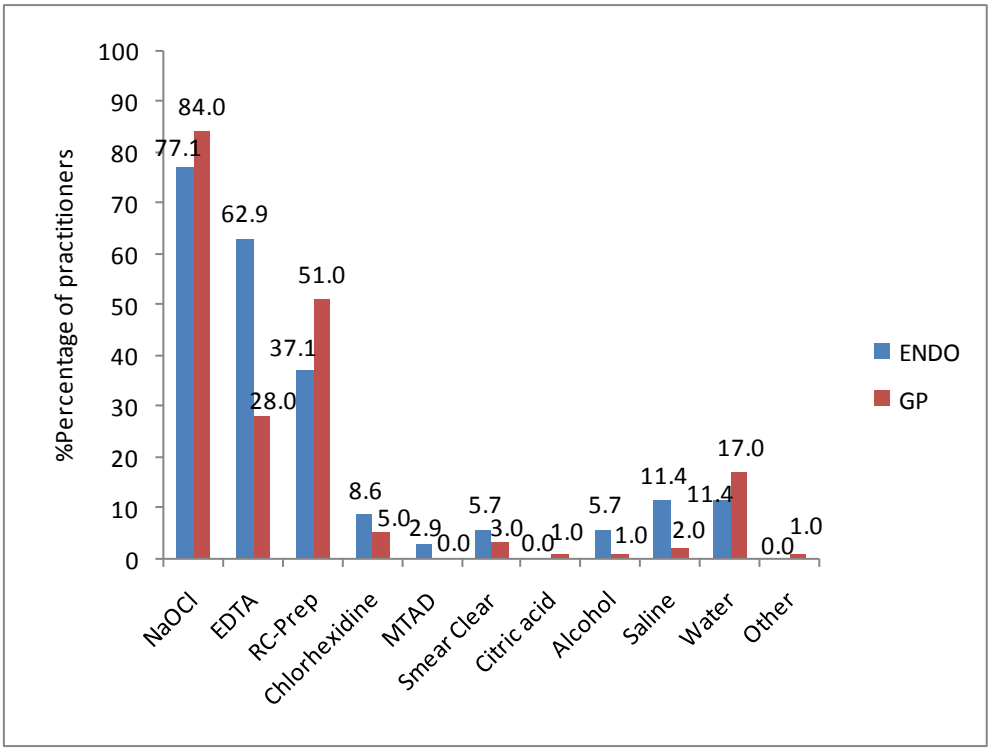

Figure 5-40. In-between irrigants used by ENDO and GP in treating teeth with non-vital pulp.

Choice for the final irrigants

The most common irrigant used as a final irrigant in treating teeth with non-vital pulp by both endodontists (46%) and GP (52%) was sodium hypochlorite. The second most common irrigant of choice in the endodontist group (26%) was chlorhexidine followed by alcohol (20%). The second most common final irrigant of choice in the GP

group was water (23%) followed by chlorhexidine (15%). MTAD™ and citric acid were never used as the final irrigants in treating teeth with non-vital pulp by the endodontist group. Citric acid was never used as the final irrigant in treating teeth with non-vital pulp by the GP group. There was no statistically significant difference between the two groups of practitioners in choice of final irrigant used in treating teeth with non-vital pulp, NaOCl (Chi-Square test, p=0.522), EDTA (Chi-Square test, p=0.535), RC-Prep™ (Fisher's Exact test, p=1.000), chlorhexidine (Chi-Square test, p=0.154), MTAD™ (Fisher's Exact test, p=0.568), Smear Clear™ (Fisher's Exact test, p=0.453), citric acid (no statistical testing performed), alcohol (Chi-Square test, p=0.241), saline (Fisher's Exact test, p=0.676),water (Chi-Square test, p=0.468) and other (no statistical testing performed) (Fig. 5-41).

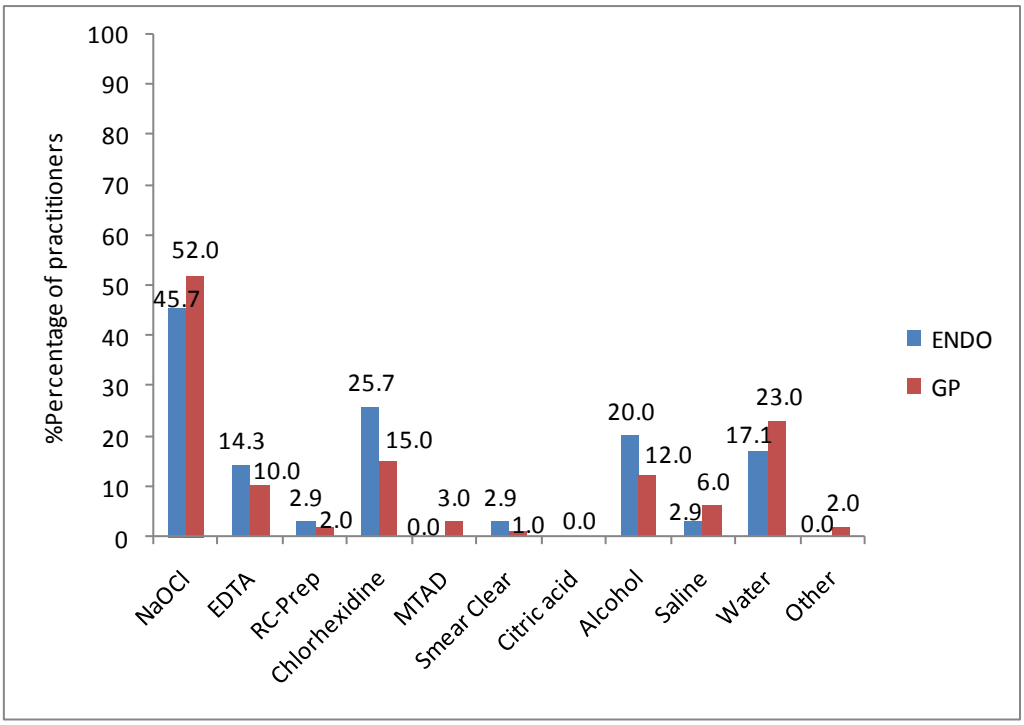

Figure 5-41. Final irrigants used by ENDO and GP in treating teeth with non-vital pulp.

5.8.2 Difference in order of use between treatments of vital and non-vital pulps

There was no statistically significant difference between the two groups (Chi-Square test, p=0.417) when comparing sequence of different irrigants used in endodontic treatment of teeth with vital pulp and non-vital pulp. Most GP (86%) and endodontists (79%) used similar order of irrigants in treating teeth with vital pulp and non-vital pulp. Endodontists (21%) and GP (14%) used different order of irrigants in treating teeth with vital pulp in comparison to treating non-vital pulp (Fig. 5-42).

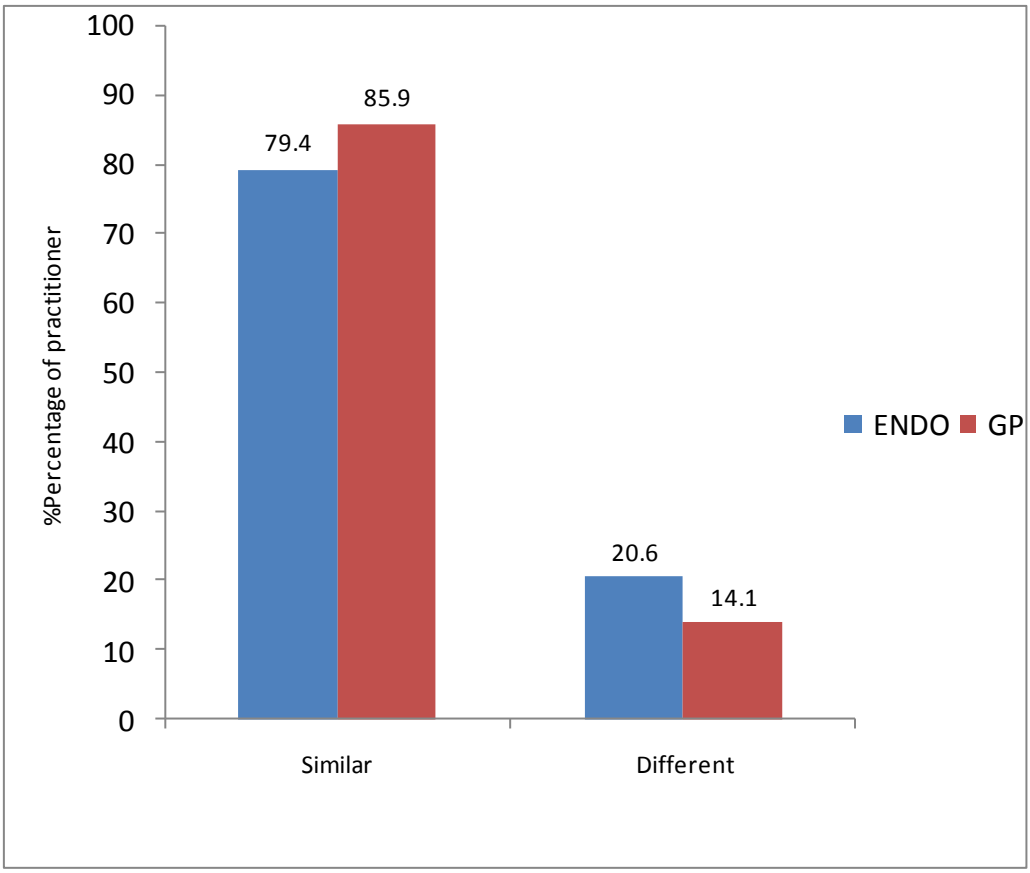

Figure 5-42. Percentage of practitioners who used similar or different sequence of various irrigants in treating teeth with vital pulp in comparison to teeth with non-vital pulp (Chi-Square test, p=0.417).

Chapter 6: DISCUSSION

6.1 Epidemiological studies on irrigation in BC

6.1.1 Survey studies

There have been no previous survey studies conducted in the province of British Columbia about the choice of irrigants and irrigation techniques used by endodontists and general practitioners. Several studies have shown better prognosis of root canal treatment when performed by endodontists as compared to general practitioners (Eriksen *et al*. 1991). Therefore, significant differences between the two groups in the methods used to irrigate the root canal might be one explanation for the poorer outcomes found in treatments provided by the GP group (Eriksen et al. 1991). Our hope is that if the collected data shows important differences, the results can be used to increase the awareness of proper irrigation techniques, improve communication between endodontists and general practitioners, and consequently improve the overall quality of endodontic treatment provided in British Columbia. As the present study was limited to BC, the results may not be a true representation of the whole of Canada or North America.

6.1.2 Response rate

The response rate of a questionnaire is defined as the number of completed and partially completed questionnaires divided by the number of eligible sample units (Groves 1989; Locker 2000). High response rates are needed to increase the internal validity of surveys and to maximize their generalizability from the study sample to the professional group at large (Evans 1991; Gough *et al*. 1977).

In our study we decided to survey 150 general practitioners as representatives of the 2564 general practitioners in BC. Evans (1991) stated that small samples with a high

response rate are more valuable than large samples with low response rates. The overall response to the survey was 70.3%. The ENDO group's response rate was 83.3%.The high response rates were achieved by surveying 10 offices at a time; hence we were able to encourage participation from non responders by making telephone call reminders to them within a week of initial contact. In total, we made only three telephone reminders within a period of one month. Anonymous surveys do not allow for follow up.

6.1.3 Questionnaire design

Questionnaire design can have an effect on the response rate as well as on the interpretation of the results. Asch *et al*. (1977) found that the length of a questionnaire did not seem to influence the response rate. Despite our questionnaire containing 49 questions and perhaps appearing complicated, the response rate of 70.3% indicates that other factors influenced the response. The response rate for similar studies have ranged from 25.1%-94.5% (Salus *et al.* 2002; Lee *et al.* 2009; Jenkins *et al.* 2001; Clarkson *et al.* 2003). A minimum response rate of 75 per cent is optimal for surveys of health professionals (Gough *et al*. 1977).

A combination of a visual analogue scale (VAS) and a categorized scale were used in our survey. Questions 1-20 and 37-39 related to frequency of use were marked in a VAS in which 'never' indicated '0%' and 'always' indicated '100%' of the time. The advantages of the VAS are its simplicity and ease of use by elimination of language barriers. A further advantage of the VAS is that in a VAS there is no loss of information and a participant is not forced into choosing a preset option.

6.2 Concentration of NaOCl

Laboratory results of NaOCl concentration

Within a week of collection, all the samples were titrated in the laboratory to determine their sodium hypochlorite concentration. Ten samples were collected at a time. In order to avoid delay and possible dilution of samples, two parallel measurements were conducted. Exposure of the NaOCl to oxygen, room temperature and light can inactivate it significantly (Piskin *et al.* 1995). Although more than two parallel measurements from each sample might have been better, it seemed acceptable to proceed with only two measurements since the results showed only minimal variation.

The results indicated that 50% percent of the GP group used hypochlorite in concentrations of 3.12%-4.55%. This result is quite similar to the result of a previous survey in which 48.4% of the GP group reported using concentrations of 3-5%. Lee *et al.* (2009) reported that in initial root canal treatment of teeth with closed apices 2.5% and 5.25% NaOCl were the most common irrigants used.

Survey results of NaOCl concentration

According to several studies, the reduction of intracanal microbial load does not seem to be different following the use of either 0.5% or 5.25%sodium hypochlorite (Cvek *et al.* 1976; Bystrom *et al.* 1985). In a different study Clegg *et al.* (2006) demonstrated that 6% NaOCl was more effective against biofilm bacteria than 3% and 1% NaOCl. While increased tissue dissolution capacity improves with increased concentration of NaOCl (Zehnder *et al.* 2002), so does the potential for tissue toxicity (Hulsmann *et al.* 2000). Fear of NaOCl extrusion into the periapical tissues may be the explanation for why a majority of the GP group (78.7%) chose ≤5% NaOCl in comparison to the

majority of the ENDO group (82.3%) who selected ≥5% NaOCl. Sim *et al*. (2001) reported that there was a significant decrease in the elastic modulus and flexural strength of dentin after long-term exposure of 2 hrs to 5.25% NaOCl, whereas 0.5% NaOCl caused no change in dentin properties. Considering that higher concentrations of NaOCl result in better tissue dissolution, it is beneficial in teeth with vital pulp to use higher concentrations of NaOCl to dissolve the pulpal tissue. Free chlorine in NaOCl dissolves vital and necrotic tissue by breaking down protein into amino acids (Johnson *et al.* 2009).

In our study we did not measure the pH of the sodium hypochlorite. The pH of commercially available hypochlorite is 11-12. Zehnder *et al.*(2002) reported that higher concentration of NaOCl was substantially more effective in tissue dissolving and that pH was not a factor.

6.3 Frequency of use of different irrigants

Irrigation of the root canal with antibacterial irrigants is considered a crucial part of chemo-mechanical preparation (Haapasalo *et al*. 2005). In our study, sodium hypochlorite was the most common irrigant used by the two groups. Clarkson *et al.* (2003) (Australia), Lee *et al*. (2009) (USA) and *Omari et al.* (2004) (Jordan) in their studies also reported sodium hypochlorite as the most common choice of irrigant. Contrary to these results, studies done in the UK by Whitworth *et al.* (2000) and *Jenkins et al*. (2001) showed that a local anaesthetic was the most common endodontic irrigant.

Based on our pilot study we did not see a reason to include local anaesthetic as part of the questionnaire. However, an option was given to participants to specify other irrigants used, but the only irrigants mentioned by ≥2% of the GP group was hydrogen peroxide. In our study MTAD™ was almost never used whereas in a different study

MTAD™ was the first choice in retreatment cases with closed apices (Lee *et al.* 2009). The reason for such great difference in the use of MTAD™ between the two studies is not known. However, one explanation may be differences in local university curriculum or targeted marketing strategies by the companies.

Endodontists used ethylenediamine tetraacetic acid (EDTA) in greater frequency than the GP group. This significant difference in use could be because endodontists have a deeper understanding of the properties of liquid and paste type EDTA formulations.The former being regarded as more effective chelator because of easy refreshing of the material in the canal. EDTA is used to remove the inorganic portion of the smear layer (Torabinejad *et al*. 2002). The smear layer is comprised of inorganic and organic material such as dentin debris, pulp tissue remnants, and may also contain bacteria (Gwinnett 1984). The smear layer blocks the entrance to dentinal tubules and may protect the bacteria in dentinal tubules by preventing antibacterial agents from coming in direct contact (Torabinejad *et al*. 2002). There was a statistically significant difference in use of RC-prep™ between the two groups with a higher frequency of use by the GP group. In the GP group there appears to be a perception that RC-Prep™ will act as a lubricating agent for rotary NiTi instruments whereas the opposite is true. RC-prep™ instead of lowering physical stress on rotary files as thought, carbowax-based lubricants, depending on instrument geometry, have either no effect or even a counter effect (Peters *et al.* 2005).

MTAD™, Smear Clear™, citric acid and saline were almost never used by either the ENDO or GP group.

6.4 Volume of use for different irrigants

The main component of NaOCl is chlorine. Chlorine is responsible for the dissolution of organic components of root canal contents and the antimicrobial effect of NaOCl. Depending on the volume and concentration of chlorine, it is consumed rapidly during the first phase of tissue dissolution (Moorer *et al*. 1982). Teeth with vital pulp may require higher volumes of NaOCl as there will be more organic tissue present in vital teeth. Sodium hypochlorite was used in the highest volume, >10mL, by both groups. The chemical properties of this irrigant, antimicrobial and tissue dissolving activity, are important for the practitioners. In addition, NaOCl is readily available at a low cost. Volumes of 6mL and 12mL NaOCl have shown to be as effective as 50mL in removing debris from the apical portion of the root canal (Sluis *et al*. 2006). Volumes of 5-10mL of chelator irrigant are recommended for canal rinsing after the shaping procedure is completed (Calt *et al.* 2002).

In our study there was no statistically significant difference in volume of irrigants used between the two practitioners groups except for EDTA, RC-Prep™ and chlorhexidine. Although EDTA, RC-Prep™ and chlorhexidine showed statistically significant differences in volume of use between the two groups, volumes of 1-5mL were the most common for both groups. Chlorhexidine 0.1-0.2% is used widely for plaque control in oral cavity and commonly after oral surgery, while 2% is the concentration of root canal irrigating solution because of its better antibacterial activity (Zamany *et al.* 2003).

6.5 What is the critical zone?

The apical canal may harbor a critical amount of micro-organisms that would maintain periradicular inflammation; thus the apical 3mm of the root canal system is considered to be a "critical zone" in the management of infected canals (Sjogren *et al*. 1990; Simon 1994).

6.6 Type and size of irrigation needles used

6.6.1 Stainless steel irrigation needles

The access of irrigants to the apical third of canals and removal of debris are dependent on the size of the instruments used in the canal and the external diameter of the needle (Baugh *et al*. 2005). Instrumentation to size #30 file is the minimal canal enlargement required in the apical part of the canals for the removal of debris and the smear layers (Khademi *et al*. 2006). In Ram's (1977) study, when the canal was enlarged to a No. 25 file, debris was left unflushed. In our study population, stainless steel needle tips, sizes 27G and 30G, were used most commonly by the two groups, ENDO (29% and 20%) and GP (36% and 23%) respectively. According to the ISO standards specifications for medical needles in general (and to which endodontic needles should also comply), the diameters of 27G and 30G stainless steel needles are 0.42mm and 0.31mm (ISO 9626 1991,2001). In order to have the needle tip placed in the apical third area, it is crucial to match the irrigation needle tip diameter to the canal diameter.

In a study by Wu *et al.* (2000), the range of canal diameters at 1mm from the apex varied from size #35-50, in premolars size #25-40, in upper molar buccal roots size #20-25, in upper palatal roots size#35, in lower mesial roots size #40 and in lower distal roots size #50. A needle size 30G can reach the critical zone when canals are prepared to the

minimum diameter size #25 at the apex (Chow 1983; Abou-Rass *et al.* 1982). For optimal penetration of irrigants to the apical third of the root canal, it is recommended that minimum canal instrumentation should be done to file size #30 (Khademi *et al.* 2006). Little fluid exchange or displacement of debris takes place 1mm below the orifice of the needle (Chow 1983), hence a reasonable distance away from the apex would be 2-3-mm where adequate irrigant exchange still would take place (Boutsioukis *et al*. 2010). In a different study Boutsioukis *et al.*(2007) examined the clinical relevance of the standardization of endodontic irrigation needle dimensions. They concluded that a needle size of 27G corresponded to file size #45, size 30G corresponds to file size #35 and needle size 25G to file size #55.

Keeping a correlation between canal diameter and needle size penetration, the practitioner should choose the right irrigation needle tip size to optimize the penetration in the apical third of the root canal in order to flush the dentinal debris and dissolve the smear layer. Smaller needles, besides having better depth of penetration, are more effective in creating a better current as a larger needle in a small canal creates more resistance to the fluid leaving the canal (Chow 1983).Use of needle size ≥27G by ENDO (57%) and GP (63%) groups fall within the standards recommended by dental researchers (Boutsioukis *et al.* 2010; Khademi *et al*. 2006; Abou-Rass *et al.* 1982).

6.6.2 NiTi irrigation needles

Both groups, ENDO (85%) and GP (80%), did not use NiTi needle tip for irrigations although they are more flexible than the stainless steel irrigation needles. Boutsioukis *et al*. (2007) concluded that the NiTi needle tip exceeded ISO specifications for external diameters. This discrepancy in size may affect the needle tip penetration

where canals are instrumented to size#25. However, it is likely that exceeding ISO external diameter limits in NiTi needles did not play a role in the preference of both groups for stainless steel needles over NiTi needles.

6.7 Depth of irrigation needle tip insertion

There was no statistical difference in the depth of irrigation needle tip penetration in the pulp chamber and mid/coronal canal areas. The ENDO group significantly more often (p=0.002) chose to insert the needle in the apical third of the canal. The ENDO group's specialist training may have helped them understand the importance of chemically cleaning the "critical zone" as well as know the limitations of the irrigant flow beyond the needle tip orifice. Such factors may have influenced their decision to insert the irrigation needle tip more frequently in the apical third area in order to clean the critical zone. In the GP group, fear of NaOCl extrusion into periapical tissues (which was the most common irrigant used) may have been another reason for their hesitation to insert the needle into the apical area. Considering that there was no significant difference (p=0.673) between the two groups in the selection of needle tip size, lack of instrumentation to large canal sizes may have been a factor why the GP group was unable to insert the needle into the apical canal.

6.8 Sequence of different irrigants used

Sodium hypochlorite was the most widely used irrigant by both GP and ENDO. Most commonly, it was used as an initial irrigant and less commonly as a final irrigant; in this regard there was no significant difference between the two groups. Sodium hypochlorite is the only irrigant with the capability to dissolve organic tissue. Sodium hypochlorite is thus an ideal irrigant to use as an initial irrigant.

EDTA, RC-Prep™, citric acid, saline and water all lack antibacterial activity and there was no significant difference in their use as an initial irrigant between the two groups. EDTA, RC-Prep™, MTAD™, Smear Clear™, citric acid have the ability to remove the smear layer (Haapasalo *et al*. 2010).

A 1-5µm thick smear layer is the result of direct action by the endodontic instrument on the root canal wall (Mader *et al*. 1984). During shaping of the canal and specifically after canal instrumentation has been completed, it is beneficial to use chelators as in-between or final irrigants to remove the smear layer. In our study EDTA, RC-Prep™ and Smear Clear™ were used as in-between irrigants. EDTA, RC-Prep™ and citric acid should not be mixed with sodium hypochlorite as they reduce the available chlorine in solution, making the sodium hypochlorite irrigant ineffective on bacteria and necrotic tissue (Zehnder *et al.* 2005).

Except for EDTA and saline, there was no statistically significant difference between the two groups in use of different irrigants used as an in-between irrigant for treating teeth with necrotic pulp.

Chorhexidine, MTAD™ and alcohol have antibacterial activity but they were used rarely as an initial irrigant by the two groups. EDTA and RC-Prep™ were used more often as an in-between irrigant and chlorhexidine as a final irrigant. Chlorhexidine should not be mixed with NaOCl as brownish-orange precipitate is with possibly carcinogenic reaction product (Basrani *et al*. 2009). Chlorhexidine is a good irrigant to use after EDTA when dentinal tubules are opened. Chlorhexidine has an antibacterial effect and substantivity (antibacterial effect remains in the tissue via binding of active

CHX molecules). In addition, chlorhexidine has an affinity for dental hard tissues (Rolla *et al.* 1970) and unlike NaOCl does not cause dentinal erosion (Haapasalo *et al.* 2010).

Alcohol was used as an initial irrigant ENDO (3%), GP (0%) and as a final irrigant ENDO (20%), GP (12%), respectively. Alcohol does not have tissue dissolution or smear layer removal properties and using this irrigant as an initial or in-between irrigant is unlikely to have any benefits. Alcohol is antibacterial and evaporates quickly, which may help in drying the canals in areas where paper points are inaccessible.

In our study both groups used antimicrobial irrigants (sodium hypochlorite and chlorhexidine) frequently in treating teeth with vital and non-vital pulp. We found that the use of antimicrobial irrigants in BC is within the generally accepted guidelines for endodontic treatment (ESE 1994). However, there appears to be a lack of attention by both groups regarding the use of chelators to remove the smear layer, but, more significantly by the GP group. Although even endodontists should be encouraged to use chelators more frequently, their overall level of knowledge and skill puts them in a key position to communicate their expertise to the GP group e.g. in study clubs. Both groups use a relatively similar irrigant delivery system. It should be emphasized that based on our study we cannot predict the overall success of endodontic treatment in the province of British Columbia as we focused only on one, albeit important, aspect. Success in endodontic treatment is multifactorial and is beyond the scope of our study.

6.9 Study limitations

It is important to discuss the limitations of the present study. These include: 1) no analysis of the non-response rate, 2) self-reported data, 3) no discussion of the use of iodine or hydrogen peroxide as irrigants, and 4) no discussion of non-manual irrigation

techniques 5) limited values obtained for volume and sequence of different irrigants used in treatment of teeth with vital pulp.

1) The present study had a relatively high response rate (70.3%). However, analysis of the non-response was not performed. Although such an analysis could test whether the non-response rate had or influenced the study findings, it was not done for practical and ethical reasons. The non-responders were approached several times and those who chose not to participate refused any further cooperation.
2) Another limitation of the present study is that most of the data had to be acquired through self-reporting. Some respondents may have forgotten or inaccurately remembered information, and thus a memory bias cannot be excluded. The questionnaire comprised two pages only, thus we could not test the reliability of the self-reporting by including repeated questions. Due to practical reasons (participants were already approached several times), it was also not possible to administer the questionnaire to a group of the same individuals twice, i.e. the reliability testing of individual answers was not possible.
3) Exclusion of iodine and hydrogen peroxide from the present study may be criticized, as other studies have reported on the use of these irrigants. However, we excluded them as our pilot study showed that very few practitioners in BC use these irrigants.
4) We included only manual irrigation techniques using needles in our study since this is the method commonly taught in North American dental schools.

5) Our questionnaire evaluated only the volume and sequence of the different irrigants used in the treatment of teeth with non-vital pulp. Teeth with necrotic pulp were studied in more detail as they have a higher failure rate in comparison to teeth with vital pulp.

6.10 Conclusions

- NaOCl was the most common irrigant used by both the ENDO and GP groups. In treating teeth with vital and non-vital pulp, EDTA was the second most common irrigant used by the endodontists and RC-Prep™ was the second most common irrigant used by GP. MTAD™, Smear Clear™, citric acid and saline were used infrequently by both ENDO and GP groups in treating teeth with vital and non-vital pulp.
- The majority of the ENDO group used higher concentrations of sodium hypochlorite (5-6%) than the GP group (3-5%).
- Laboratory results showed that fifty percent of the GP in the lower mainland used NaOCI in concentrations of 3.1%-4.6%.
- A higher volume of EDTA and chlorhexidine was used by the ENDO group while a higher volume of RC-Prep™ was used by the GP group. There was no significant difference between the two groups of practitioners in the volumes of the other irrigants used in treating teeth with vital and non-vital pulp.
- Stainless steel needles were used by the two groups and both groups most commonly used sizes 27G and 30G. NiTi irrigation needles were rarely used by either group.

- There was no difference between the two groups in the depth of irrigation needle penetration used in the chamber or in the mid/coronal root canal area. Compared to the GP, the ENDO tended to insert the irrigation needle more frequently into the apical area.
- The two groups of practitioners did not differ in the sequence of different irrigants used except for EDTA and saline, which were more commonly used as an in-between irrigant by the ENDO group than by the GP.

6.11 Future directions

Future studies could include a survey of practitioners from all over Canada as there may be substantial differences in endodontic treatment modalities according to location. A low response rate should be expected, and thus to survey such a large number of practitioners would require a team of examiners to follow up with non-respondents and encourage their participation.

Future studies could also explore use of other irrigation devices, for example, the use of electrical equipment that create sonic and ultrasonic vibrations, as well as the application of negative pressure or lasers during root canal treatment. A new irrigant, Qmix™, was recently introduced to the market, and the use of it amongst Canadian dental practitioners could also be examined.

Finally, as there were some important differences in endodontic treatments between general practitioners and endodontists, future studies should examine the reasons for these differences.

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APPENDIX: Questionnaire design

UBC DENTISTRY | THE UNIVERSITY OF BRITISH COLUMBIA

DEPARTMENT OF ORAL BIOLOGICAL AND MEDICAL SCIENCES

Dear Dr.

You are invited to participate in a research study conducted by the Department of Endodontics at U.B.C under the supervision of Professor Markus Haapasalo and Dr. Houman Abtin. Your response will be confidential. This study will help us learn more about the irrigation practices and the various irrigating solutions used by dentists. One of the objectives of the study is to help develop more comprehensive guidelines on chemical irrigation during root canal treatment for the benefit of our patients.
If you have questions about the study please contact Dr. Markus Haapasalo at 604 822 5996. If you have concerns about your rights as a research participant please contact the UBC research subject information line at 604 822 8598. Your participation in this study is voluntary. Completing and faxing this questionnaire to the investigators implies you have consented.
Please Completely Answer Each Question Even if Your Answer is "Maybe", "I Don't Know" or "I Don't Use"

Please place a line indicating which type of irrigants and how often you use in vital and non vital pulp tooth while performing endodontic treatment.

e.g. Never ↘ Always

	Tooth with vital pulp (Never – Always)	Tooth with non-vital pulp (Never – Always)
1-2) Sodium hypochlorite* irrigation in:		
3-4) EDTA irrigation in:		
5-6) RC-Prep lubricant in:		
7-8) Chlorhexidine irrigation in:		
9-10) MTAD irrigation in:		
11-12) Smear Clear irrigation in:		
13-14) Citric acid irrigation in:		
15-16) Alcohol irrigation in:		
17-18) Saline irrigation in:		
19-20) Water irrigation in:		

21) Please indicate the concentration of sodium hypochlorite (bleach) you use in irrigating the canals; you may circle more than one:

I don't not know ☐ 0.5% ☐ 1% ☐ 2% ☐ 3% ☐ 4% ☐ 5% ☐ 6% ☐

In questions 22-31, please indicate with ☑ the volume of irrigant you use in each canal during endodontic treatment of a necrotic tooth:

	I don't use	1-2ml	2-5ml	5-10ml	over 10ml
22) Sodium hypochlorite	☐	☐	☐	☐	☐
23) EDTA	☐	☐	☐	☐	☐
24) RC Prep lubricant	☐	☐	☐	☐	☐
25) Chlorhexidine	☐	☐	☐	☐	☐
26) MTAD	☐	☐	☐	☐	☐
27) Smear Clear	☐	☐	☐	☐	☐
28) Citric acid	☐	☐	☐	☐	☐
29) Alcohol	☐	☐	☐	☐	☐
30) Saline	☐	☐	☐	☐	☐
31) Water	☐	☐	☐	☐	☐

32) Do you use the same irrigant volumes in a vital tooth (pulpitis) ☐ YES ☐ NO

Please fax the filled questionnaire (both pages) to Dr. Houman Abtin, fax: 604-822-3562

Please fax the filled questionnaire (both pages) to Dr. Houman Abtin at UBC, fax: 604-822-3562

Please check ☑ the type and gauge of irrigation needle tips you use during the root canal treatment:

	I don't use	<25G	25G	27G	30G	>30G
33) Stainless steel needles	☐	☐	☐	☐	☐	☐
34) NiTi needles	☐	☐	☐	☐	☐	☐

Please place a line indicating how deep you place the irrigation needle tip in the canal:

Never Always
e.g. ○———|———○

	Never	Always
35) In pulp chamber area	○	○
36) In the coronal/mid canal area	○	○
37) In the apical canal area	○	○

Please indicate ☑ which is your first irrigant, additional irrigants in between and final irrigant during the endodontic treatment of a necrotic tooth.:

	Starting Irrigant	Irrigant/s used during the root canal treatment	Final Rinse
38) Sodium hypochlorite*	☐	☐	☐
39) EDTA	☐	☐	☐
40) RC Prep lubricant	☐	☐	☐
41) Chlorhexidine	☐	☐	☐
42) MTAD	☐	☐	☐
43) Smear Clear	☐	☐	☐
44) Citric acid	☐	☐	☐
45) Alcohol	☐	☐	☐
46) Saline	☐	☐	☐
47) Water	☐	☐	☐
48) Other	☐	☐	☐

	YES	NO
49) Do you use the same irrigant sequence in a vital tooth (pulpitis)	☐	☐

*Sodium hypochlorite = Bleach

Please complete the following if you would like to receive copy of our final report (**optional**).

Name: …….....

Address: …….....

E-mail:……....

Inquiries: please contact Dr. Markus Haapasalo, tel: 604-822 5996, email markush@interchange.ubc.ca

Thank you for your participation!