Disinfection Procedures: Effect on the Dimensional Accuracy of Gypsum Casts

MAYSON SALIH

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Supervisors

Prof. YI Osman

Prof. VJ Wilson

Disinfection Procedures: Effect on the Dimensional Accuracy of Gypsum Casts

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Abstract

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M. Salih

MSc(Dent) mini-thesis, Department of Restorative Dentistry, Faculty of Dentistry, University of the Western Cape.

Gypsum casts poured against contaminated impressions may put dental personal and laboratory technicians at risk and could result in cross contamination between dental prosthesis and patients. An ideal disinfection protocol for impressions or gypsum models should provide an adequate level of disinfection in a short period of time without affecting the physical properties of the materials (Hutching *et al*, 1996).

Since chemical disinfection of dental casts can alter their physical properties, the use of microwave disinfection is postulated. This method is thought to be effective in eliminating micro-organisms (Berg, Nielsen and Skaug, 2005), it is also practical and can be repeated many times without affecting the dental casts (Hersek *et al*, 2002).

The aim of this study was to assess the dimensional accuracy of gypsum models following chemical disinfection of the impressions and to compare it with the accuracy of gypsum models exposed to microwave irradiation disinfection.

Three impression materials were used in the study; irreversible hydrocolloid, zinc-oxide eugenol paste and polyether. All impressions were poured in type IV gypsum. In one group (control group) the impressions were rinsed under tap water before they poured in gypsum. The second group, impressions were immersed to 0.525% sodium hypochlorite for 10 minutes before pouring of mixed gypsum. The third group, the fully set gypsum models were irradiated in a microwave oven for 5 minutes. The overall dimensional accuracy of the resultant models was measured as mean percentage deviation from the master model. Analysis of variance (ANOVA) and Post-Hoc test for pair-wise comparison were used to analyse the data achieved with the different disinfection procedures as one factor and the type of impression material as the other.

Results indicated that the dimensional accuracy of the gypsum models disinfected in a microwave oven did not differ significantly from models in the control group. Except for models produced from SS White (SS White group, England) impressions where models irradiated in microwave exhibit significant improvement in the dimensional accuracy when compared with control group.

October 2007.

Declaration

I declare that the *Disinfection Procedures: Effect on the Dimensional Accuracy of Gypsum Casts* is my own work, that it has not been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

Mayson Salih October 2007.

Signed: …………………….

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CHAPTER ONE

INTRODUCTION

1.1 Introduction

The increase of awareness of the dangers of cross contamination with hepatitis B virus (HBV) and human immunodeficiency virus (HIV) during dental procedures is having a growing impact on attitudes towards infection control in the dental clinics and the dental laboratories. The potential route of transmission from patients to the dental technician is through contaminated impressions, models and prostheses.

Gypsum products are widely used as materials for the preparation of models in dentistry. Dental casts are transferred several times between the dental laboratory and the dental office. The potential contamination of these models by infectious human pathogens such as *Mycobacterium tuberculosis*, HIV and HBV has led to the development of more rigorous infection control procedures. It has been established that bacteria and viruses can be transmitted from patients to the gypsum models during the fabrication of the prosthesis, if the plaster is poured into contaminated impressions or through contamination of bite blocks and trial bases (Mitchell *et al*, 1997).

The usual solution to this problem has been to rinse the impressions under running water and to place them in an appropriate disinfection solution (ADA Council on Scientific Affairs and Council on Dental Practice, 1996). This should be done upon removal of the impression from the patient's mouth or in the dental laboratory prior to casting the model. However, two problems may arise. One is the risk that infectious organisms may still contaminate the gypsum models during the subsequent dental procedures such as jaw registration and the try-in procedures. The second is the dimensional changes that may arise due to the impressions being soaked in the disinfectants (Adobo *et al*, 1999, Tan *et al*, 1993, Hall, Munoza- Viveros and, Naylor, 2004 and Martin, Martin and Jedynakiewicz, 2007).

The use of microwave irradiation to disinfect items is widely available in dentistry. The procedure has shown satisfactory results when used to disinfect gypsum models (Berg, Nielsen and Skaug, 2005). If it could be shown that such a treatment will not harm the physical properties of gypsum models, it would be an appropriate method to use for disinfection especially as it could be repeated after each clinical procedure.

The purpose of this study was to assess the dimensional accuracy of gypsum models following chemical disinfection of the impressions and to compare it with the accuracy of gypsum models exposed to microwave irradiation disinfection.

1.2 Definition of terms

1.2.1 Disinfection:

This is the process by which virtually all recognized pathogenic micro-organisms are eliminated, but not essentially all microbial forms, on inanimate objects (Bergman, 1989). Disinfection is generally less lethal to pathogenic organisms compared to sterilization. The disinfection procedure leads to a reduction in the level of microbial contamination and covers, depending on the disinfectant used and the treatment time, a broad range of activity that may extend from sterility at one extreme to a minimal reduction in microbial contamination at the other extreme (ADA Council on Scientific Affairs and Council on Dental Practice, 1996).

1.2.2 Sterilization:

According to the Glossary of Prosthodontic terms sterilization is the process of completely eliminating microbial viability

1.2.3. Dental casts:

According to the Glossary of Prosthodontic terms a dental cast is a positive life size reproduction of a part of the oral cavity formed when a material is poured into a matrix or impression of the desired form.

1.2.4. Dimensional accuracy:

The dimensional accuracy is evaluated by measuring tooth to tooth distances within the same quadrant and in a cross-arch manner (Donavan and Chee, 2004).

1.2.5 Dimensional stability:

Dimensional stability is the ability of a material to retain its size and form over time. The dimensional stability of impression materials is affected by chemical reactions and their by-products (Donavan and Chee, 2004).

1.3 Statement of problem

Disinfection of stone casts is an important measure for the control of cross-contamination. Many approaches have been used to disinfect stone casts, but information regarding the accuracy of the resultant cast is limited. An easy to use, inexpensive and not damaging method is needed to routinely disinfect dental casts each time they could be potentially contaminated between the dentist and the dental laboratory.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Dental professionals are exposed to a wide variety of micro-organisms in the blood and saliva of their patients. These micro-organisms may cause infectious diseases such as the common cold, pneumonia, tuberculosis, herpes, hepatitis B and acquired immune deficiency syndrome (AIDS). The use of effective infection control procedures and universal precautions in the dental office and the dental laboratory will prevent cross-contamination that could extend to the dentist, dental office staff, dental technicians and patients (ADA Council on Scientific Affairs and Council on Dental Practice, 1996).

In the past, little thought has been given to the items that pass from the dental surgery to the dental laboratory. Dental laboratory personnel are now recognizing the importance of efficacious infection control measurements in the handling of contaminated dental materials. Such materials include impressions, occlusal rims, dentures or crown and bridge work that is taken from the patient's mouth and passed to the dental technician. It is inevitable that these items will be contaminated with the micro-flora of the mouth (Rowe and Forrest, 1978). Fabrication of stone casts from these impressions or later from contact with occlusal rims that may have been in the patients mouth may cause cross-contamination between patients and dental laboratory personnel.

Attempts to disinfect impressions and the resultant stone models have included the use of sodium hypochlorite, glutaraldehyde, iodophor, chlorhexidine, ethylene oxide gas, steam autoclave and ultraviolet rays. The antimicrobial effect of these treatments, as well as, their effects on the physical properties of the impressions and the resultant models were the scope of many investigations (Rowe and Forrest, 1978, Tan *et al*, 1993, Beyele *et al*, 1994, Adobo *et al* 1999, Taylor *et al* 2002, Twomey *et al* 2003, Martin, Martin and Jedynkiewicz, 2007)

2.2 Cross contamination and infection control

Health care professionals' risk of developing an infection after occupational exposure to a variety of microbial pathogens during provision of patient care has been well documented (Molinari, 2003). The occupational risk potential for disease transmission initially was ascertained with the observation that many human microbial pathogens could be isolated from oral tissue surfaces, oral secretions or both. The use of appropriate infection control precautions to protect against transmission of blood borne and other occupational microbial pathogens has become a routine component of health care provision (Molinari, 2003). The Centers for Disease Control (CDC) have recommended the routine use of gloves, surgical masks, and protective eyewear for dental personnel as appropriate infection control precautions.

Initial infection control guidelines (universal precautions) released in the 1970's focused on protecting health care workers from blood borne pathogens, such as HBV. Ongoing investigations and considerations of other non-blood borne methods of cross-infection subsequently resulted in the development of the body substance isolation system precautions which aimed to minimize potential transmission of bacterial, viral and mycotic organisms via respiratory, contact or other exposures with infectious body fluids (Molinari, 2003). The success of both the universal precautions and the body substance isolation system in providing effective infection control has led to the evolution of the current recommendations (the standard precautions) (ADA Council on Scientific Affairs and Council on Dental Practice, 1996) that used the best features of the universal precautions and the body substance isolation system.

2.2.1 Cross contamination and infection control in the dental office

In 1987 the Centers for Disease Control (CDC) recognized that blood and saliva from all dental patients was potentially infective and recommended universal precautions (Hutching *et al*, 1996). According to Runnells (1988) 23 serious infectious diseases, viral and bacterial, have the potential for transmission through the dental practice. Of all these diseases, the Acquired Immune Deficiency Syndrome (AIDS) as well as hepatitis and tuberculosis may have extremely serious complications (Bergman, 1989).

Since all patients with infectious diseases cannot be identified by their medical history, physical examination or readily available laboratory tests, the CDC introduced the concept of universal precautions. It refers to a method of infection control in which all human blood and certain human body fluids, such as saliva, are treated as if known to be infectious for HIV, HBV and other blood borne pathogens (ADA Council on Scientific Affairs and Council on Dental Practice, 1996). The British Dental Association (BDA) maintains that the only safe approach to routine treatment is to assume that every patient may be a carrier of an infectious agent (McNeill, Coulter and Hussey, 1992). The Federation Dentaire International (FDI) states that all patients' prostheses should be cleaned and disinfected before delivery to the laboratory (McNeill, Coulter and Hussey, 1992).

Items such as impressions, jaw relation records, casts, prosthetic restorations and devices that have been in the patient's mouth should be appropriately disinfected prior to shipment to the dental laboratory as these could be a source of cross-infection for the laboratory staff (ADA Council on Scientific Affairs and Council on Dental Practice, 1996).

2.2.2 Cross contamination and infection control in dental laboratories.

The possibility of the spread of infection or diseases through the dental laboratory has been reported. There are documented cases of infection of dental laboratory personnel traced to contaminated dental materials entering the dental laboratories (Hutching *et al*, 1996).

Dental laboratories should institute appropriate infection control programs. Such programs should be co-ordinated with the dental office. A receiving area should be designed separately from the production area. All received items should be disinfected before handling in the dental lab-oratory, unless the item has been disinfected in the dental office. Packing materials should be discarded to avoid cross contamination (ADA Council on Scientific Affairs and Council on Dental Practice, 1996).

Samples obtained from dentures, impressions, wax occlusal rims and crown and bridge work were cultured on their arrival at the dental laboratory to determine the extent of viable organisms present on these items (Powell *et al*, 1990). Results showed that 67% of all materials sent from dental offices to dental laboratories were contaminated with bacteria of varying degrees of pathogenicity.

In addition each item leaving the laboratory should be disinfected before it is returned to the dental office. Dentists should be informed about infection control procedures that are used in the dental laboratory (ADA Council on Scientific Affairs and Council on Dental Practice, 1996).

2.3 Contamination of impressions and gypsum models

Impression materials in contact with the oral tissues, saliva, and possibly blood may act as media for the potential transfer of organisms from the patients to dental office personnel and subsequently to dental lab personnel (Jennings and Samaranayake, 1991). Micro-organisms survive in and on impressions and thereby can be transmitted from the oral cavity to the laboratory personnel. The reverse path of contamination from the laboratory back to the dentist and the patient is also possible.

2.3.1 Contamination of Impressions

There is a wide belief that impressions may act as a vehicle for microbial transfer from the patient's mouth to dental gypsum models. A visual study of impressions immediately after removal from the mouth often reveals blood clinging to the impression material. Washing the impression sometimes does not clear away all the blood. However, there is no guarantee that all the organisms from the mouth which may possibly be attached to the impression surface have been removed by the washing procedure. Samaranayake, Hunjan and Jennings (1991) found that micro-organisms can be recovered from impression surfaces even after a 5-hour incubation period although in reduced amounts from that recovered immediately after impression making.

Studies (Samaranayake, Hunjan and Jennings, 1991, Jennings and Samaranayake, 1991, Sofou *et al*, 2002 b and Al- Jabrah, Al- Shumailan and Al- Rashdan, 2007) reported that the contamination level obtained for alginate impressions was higher than that found in rubber-based materials. This may partly be explained by the much more porous surface of the alginate impression compared to the polyvinylsiloxane and polyether impressions (Sofou *et al*, 2002 b). Jennings and Samaranayake (1991) suggested that an irreversible hydrocolloid material has an intrinsic retentive potential for microbes compared to elastomeric materials. They also reported that with non-disinfected polysulfide rubber-based impressions, the number of surface micro-organisms cultured diminished significantly after 30 minutes, while there was no reduction with non-disinfected irreversible hydrocolloid impressions.

Studies based on *in vivo* investigations have shown the presence of bacteria on all impressions (Rowe and Forrest, 1978, Bergman, 1989, and Sofou *et al*, 2002 a), although at a low level. Rowe and Forrest (1978) from their study indicated that all the samples cultured from impressions were cloudy after 24 hours of culturing indicating microbial growth. *Staphylococcus aureus*, *Escherichia coli*, and *Candida albicans* were found to survive on alginate and elastomeric impressions (Bergman, 1989). One study showed that 12% of impressions taken from known tuberculosis patients harbored *Mycobacterium tuberculosis* (Ray and Fuller, 1963 cited in Sofou *et al*, 2002a). Of the literature reviewed only one study examined the presence of viruses but found no positive samples on impressions (Powell *et al*, 1990).

One study (Sofou *et al*, 2002 a) aimed to assess qualitatively and quantitatively the bacterial contamination of alginate impressions entering a dental laboratory. Of the 107 impressions investigated, of which 62 impressions were disinfected and the other 45 impressions were rinsed under tap water only. Of all impressions 77 impression (72%) yielded growth of bacteria, while no growth was recorded in the remaining 30 samples. No growth was recorded in 24 (38.7%) of the 62 disinfected impressions and in six (13.3%) of the 45 rinsed only impressions.

Table 2.1 gives a summary of some of the available literature that investigated contamination of impressions with micro-organisms. The table covered the published literature from the year 1978 to 2007.

Study	**Year**	**Impression**	**Bacterial growth**	**Viral growth**	**Fungal growth**
Rowe and Forrest	1978	Alginate, and thiokol rubber	+	NA	NA
Powell *et al*	1990	Alginate and rubber impression materials	+	_	NA
Jennings and Samaranayake	1991	Alginate and polysulfide	+	NA	NA
Samaranayake, Hunjan and Jennings	1991	Irreversible hydrocolloid and elastomeric	+	NA	+
Sofou *et al*	2002 a	Alginate	+	NA	NA
Al- Jabrah, Al-Shumailan and Al-Rashdan,	2007	Alginate, polyether and polyvinyl siloxane	+	NA	NA

Table 2.1: Summary of the literature reviewed for impression contamination with micro-organisms. (+: positive growth, _: negative growth, NA: not available information)

2.3.2 Contamination of gypsum models

An item that is transferred numerous times between the dental laboratory and the dental office is the dental cast. During fabrication of the prosthesis, contamination of the cast can occur multiple times during each appointment. Casts can be contaminated in the first place because it is poured against a contaminated impression, from record bases that can become contaminated after been placed in the patient's mouth for maxillary and mandibular relationship records, and from contamiated trial denture (Mitchell *et al*, 1997). The micro-organisms are transferred from these contaminated items to the surface of the cast (Mansfield and White, 1991). In addition if not effectively disinfected each time they are removed from the patient's mouth, contaminated acrylic resin bases subsequently placed on the dental casts and then returned to the dental laboratory can be a source of cross-contamination.

Mitchell *et al* (1997) investigated the level of bacterial colonization of dental casts after artificial contamination with saliva. The results indicated that contamination of dental casts did not decrease when the cast was allowed to set for 4 hours before handling.

Sofou *et al* (2002 b) aimed to determine the effect of the casting and setting of dental stone on the level of bacterial contamination from impressions onto the dental stone models. Impressions in alginate, polyvinylsiloxane, and polyether were used, and models were cast in dental stone. Samples were taken from the impression surfaces before and after casting, and from the stone models after removal of the impressions. The microbial load on the surfaces of the three impression materials was slightly higher than the numbers of bacteria on the dental models. Thus, the heat produced during the setting of the plaster did reduce the bacterial contamination but not significantly contribute to a reduction of the bacterial contamination of the casts. Table 2.2 summarizes some of the published studies between 1989 and 2002, that investigated contamination of stone models.

Study	**Year**	**Models**	**Bacterial growth**	**Viral growth**	**Fungal growth**
Schutt	1989	Stone casts	+	NA	NA
Powell *et al*	1990	Stone cast	+	_	NA
Mansfield and White	1991	Stone cast	+	_	NA
Mitchell *et al*	1997	Microstone	+	NA	NA
Sofou *et al*	2002 b	Stone cast	+	NA	NA

Table 2.2: Summary of the literature reviewed for the contamination of gypsum models with micro-organisms. (+: positive growth, _: negative growth, NA: not available information)

2.4 Disinfection of impressions and gypsum models

An important distinction must be made between disinfection and sterilization. Disinfection is the inhibition or destruction of pathogens, while sterilization is the total destruction of all forms of life, particularly the destruction of bacteria and fungal spores. A basic guideline for infection control is to sterilize rather than disinfect whenever possible (ADA Council on Scientific Affairs and Council on Dental Practice, 1996). Most of the procedures currently used to control the transmission of infectious diseases from dental impressions have focused on disinfection not sterilization. This focus on disinfection is due in part to concern for the accuracy of the impression materials subjected to procedures necessary for sterilization, such as immersion in disinfectants for extended periods of time (ADA Council on Scientific Affairs and Council on Dental Practice, 1996).

In the past rinsing of the impression under running water was the recommended practice. This has been shown to reduce approximately 90% of the bacteria present on an impression surface (Taylor, Wriht and Maryan, 2002). However, a significant number of bacteria will remain vital. There is still no universally recognized and accepted impression disinfection protocol available (Sofou *et al*, 2002 a and Taylor *et al*, 2002).

When considering the method of disinfection for impressions and dental casts, two factors are important: the effect of the treatment on the dimensional stability of the impressions and subsequently the dimensional accuracy of the resultant models and the surface detail reproduction of both materials (impression and gypsum). Also, the deactivating effect of the impression material and/or gypsum material on the disinfecting solution, which could reduce the efficacy of the process, that must be considered (McNeill *et al*, 1992).

2.4.1 Chemical disinfection

When chemical solutions are used for disinfection, the manufacturers' instructions must be followed carefully. Particular attention should be given to dilution requirements, contact time, temperature requirements, and antimicrobial activity, spectrum and re-use life of the disinfectant (Owen and Goolam, 1993). A chemical disinfectant in the dental setting must be registered by the Environmental Protection Agency (EPA) as a hospital disinfectant, and must be tuberculocidal. Virucidal efficacy must include, as a minimum, both lipophilic and hydrophilic viruses (ADA Council on Scientific Affairs and Council on Dental Practice, 1996).

The efficacy of a disinfectant is not necessarily the same for an impression as, for example, a countertop. Organisms are incorporated into the impression material during the clinical impression making process, where they may be isolated from the disinfectant. In addition, the surface chemistry of some impression materials may inhibit certain disinfectants, and other disinfectants may be better absorbed into the impression material (Schwartz *et al*, 1994).

Impressions must be rinsed to remove the saliva, blood and debris and then disinfected. Since the compatibility of an impression material with a disinfectant varies, the manufacturers' recommendations for proper disinfection must be followed.

2.4.1.1 Spray disinfection

Rowe and Forrest (1978) suggested the use of chlorhexidine solutions in an aerosol spray in two different concentrations to disinfect dental impressions. The microbiological study showed that impressions treated with a 0.02% chlorhexidine spray showed positive bacterial growth, while those treated with a 0.5% spray showed negative growth after 24 hours and remained clear after 1 week (Rowe and Forrest 1978). In 1988 the ADA recommended that all impressions or the resultant dental casts be rinsed with water, sprayed with an ADA- accepted disinfectant, and to follow the manufacturers' recommended contact time for disinfection of impressions (Beyerle *et al*, 1994).

The problem with spray disinfection is the inability of the solution to completely cover and maintain contact with all of the surfaces of the cast for the required amount of time (Twomey *et al*, 2003). Depending on the angle of the spray dispenser, the undercut areas and interproximal surfaces may be missed in the application of the solution.

2.4.1.2 Immersion disinfection

The ADA and the CDC have suggested that to eliminate cross-contamination the dental cast should be poured against a disinfected impression or to disinfect the resultant cast itself (ADA Council on Scientific Affairs and Council on Dental Practice, 1996 and Kohn *et al*, 2003). In 1996 the ADA revised their guidelines to incorporate immersion disinfection.

ADA infection control guidelines (2003) recommend the use of disinfectants that require contact time of less than 30 minutes. The ideal disinfectant must be an effective antimicrobial agent and one that causes no adverse response in the dimensional accuracy and surface texture features of the impression material and the resultant gypsum cast (Twomey *et al*, 2003).

Disinfectants that are most commonly used include: sodium hypochlorite, glutaraldehyde, iodophor and phenol (Taylor *et al*, 2002). The ability of certain disinfectants to destroy pathogens depends on the duration of exposure to the disinfecting agent, and the nature of the infectious pathogens (Owen and Goolam, 1993).

The literature varies markedly in the concentration, type and the immersion time of disinfection for impressions. Rowe and Forrest (1978) suggested that immersion of impressions in a mixture of 0.5% solution of chlorhexidine and 70% alcohol for 1 minute will inhibit bacterial growth.

An *in vitro* study by Jennings and Samaranayake (1991) aimed to compare the disinfection efficiency of chlorhexidine gluconate, sodium hypochlorite and glutaraldehyde on polysulfide rubber-based impressions, irreversible hydrochlorides and polyvinyl siloxane impressions. The results showed that the use of 0.2%

chlorhexidine gluconate was found to be less effective than both 2% glutaraldehyde and 0.0125% sodium hypochlorite. They also suggested that immersion in 2% glutaraldehyde or 0.0125% sodium hypochlorite for 30 minutes may be effective in the elimination of cross-infection from the dental impressions (Jennings and Samaranayake, 1991).

Microbiological studies showed that immersion in 0.525% sodium hypochlorite (Beyerle *et al*, 1994 and Schwartz *et al*, 1994) and in 2% acidulated or alkaline glutaraldehyde (Owen and Goolam, 1993) for 10 minutes achieved effective disinfection.

A study by Johansen and Stackhouse (1987) suggested a full range of sterilization for impressions. They suggested that impressions be cleaned of blood and debris, and placed in a 2% glutaraldehyde sterilization solution for an overnight soak for effective sterilization.

It is critical to assess the stability of the disinfectant solution and the antimicrobial effectiveness of the solution over time. It is reported that sodium hypochlorite loses chlorine with use (Gerhardt and Williams, 1991), also that aluminum trays inactivate the solution (Owen and Goolam, 1993). On the other hand, glutaraldehyde loses its concentration with use, its vapor is known to be toxic when released into the air, and it can damage nickel coated impression trays (Owen and Goolam, 1993).

Table 2.3 summarizes a range of published literature that reviewed the effect of chemical disinfection of impressions and gypsum models in cross-contamination control.

Study	**Year**	**Impression material**	**Disinfectant**	**Contact time**	**Antimicro-bial effect**
Rowe and Forrest	1978	12 alginate, and 2 thiokol rubber	0.5% chlorhexidine	Immersion for 1 min	+
Rowe and Forrest	1978	2 alginate and 2 elastomeric	0.02% chlorhexidine	Spray	–
			0.5% chlorhexidine	Spray	+
Jennings and Samaranayake,	1991	irreversible hydrochloride	0.2% chlorhexidine gluconate	Immersion for 30 minutes	–
			2% glutaraldehyde	Immersion for 30 minutes	+
			0.0125% sodium hypochlorite	Immersion for 30 minutes	+
Schwartz *et al*	1994	Irreversible hydrocolloid	Idofive (idophor)	NA	–
			0.52% Sodium hypochlorite	NA	+
			Alcide LD	NA	+
			OMC II (phenol)	NA	–
Beyerle *et al*,	1994	Irreversible hydrocolloid	0.52% Sodium hypochlorite	Immersion for 1 to 5 minutes	+

			0.052% Sodium hypochlorite	Immersion for 1 to 5 minutes	+
Mitchell *et al*,	1997	dental casts	2% glutaraldehyde	immersion for 20 seconds	+
Al- Jabrah, Al- Shumailan and Al- Rashdan,	2007	Irreversible hydrocolloid, polyether and polyvinyl siloxane	Dimenol	Spray	+
			2% Perform ID	Immersion for 5 minutes	+
			MD 520	Immersion for 5 minutes	+
			Haz-tabs	Immersion for 5 minutes	+

Table 2.3: Summary of the literature reviewed for antimicrobial effect of chemical disinfection on impressions and gypsum models. (+: positive antimicrobial effect, _: negative antimicrobial effect)

2.4.1.3Additive disinfectant

One solution to the problem of cast/ impression cross- contamination may be the incorporation of disinfectants into the gypsum at the time of mixing the material, thereby disinfecting the cast and the impression. In order to make the procedure more accessible some manufacturers' have attempted to add disinfectants to the dental stone powder. These disinfectants include sodium hypochlorite, glutaraldehyde, calcium hypochlorite, phenol and iodophor (Abdelaziz, Combe and Hodges, 2005).

Schutt (1989) evaluated the bactericidal effect of a dental gypsum material containing 0.25% chloramine- T on irreversible hydrocolloid impressions and dental casts. The disinfectant stone inhibited bacterial growth in 39 of 40 impressions and casts, while all casts and impressions poured with the non-disinfectant stone were contaminated.

Another study by Mansfield and White (1991) evaluated the antimicrobial effect of 4 disinfectant solutions mixed with type IV dental stone. One hour after the initial set of the stone, only sodium hypochlorite and glutaraldehyde effectively reduced the number of bacteria compared to the negative control. While iodophor was only effective after 24 hours and phenol showed no antimicrobial effect at all. In contrast, Ivanoski *et al* (1995) found that 2% glutaraldehyde and povidone-iodine were the most effective disinfectants after one hour and sodium hypochlorite was only effective after 24 hours. Glutaraldehyde showed the least adverse effects on the physical properties of the set cast, while povidone-iodine caused a decrease in the compressive strength of the set cast (Ivanoski *et al*, 1995).

Incorporation of a disinfectant in the dental stone powder or the use of disinfectant solution as a substitute for water during mixing of the gypsum seems to be effective in reducing the level of organisms in the resultant cast. The main disadvantage of adding disinfectants to dental stone is that the disinfectant may reduce both the tensile and compressive strength of the resultant cast, and in addition it may adversely affect the surface detail reproduction of the cast (Twomey *et al*, 2003).

2.4.2 Steam autoclave and ethylene oxide sterilization

Conventional steam autoclaves and ethylene oxide gas are capable of sterilizing rather than disinfecting materials in a reasonably short period of time. Sterilization of impressions with a conventional steam autoclave was suggested by Holtan, Olin and

Rudney (1991). However, irreversible hydrochlorides deteriorate rapidly at elevated temperatures and in the presence of moisture, so they cannot be sterilized by autoclaving or other high temperature methods of serialization (Firtell, Moore and Pelleu, 1972).

When subjecting polyvinylsiloxane impressions to steam sterilization a minimum of one hour is needed before pouring the impression in order to allow the impressio to reach room temperature. On the other hand, impressions treated in ethylene oxide gas autoclaves need to be degassed for 24 hours before being poured. Failure to degas the impressions produces casts with clinically unacceptable surfaces due to gas inclusion (Holtan, Olin and Rudney, 1991). Shorter periods of time for degassing were evaluated, but 24 hours was found to be the shortest time at which a cast could be poured with an acceptable stone surface.

Autoclave sterilization of dental casts has been suggested (Whyte and Brockhurst, 1996 and O’Brien, 2002). Loss of strength and surface hardness and an expansion greater than 0.2% occurs after autoclaving for 5 minutes at 132°C. With these changes the resultant models were considered unacceptable for normal dental use (Whyte and Brockhurst, 1996). However, it is claimed that under carefully controlled conditions by soaking the casts in 1% sodium succinate solution for 20 minutes, then dried for 2 hours, autoclaved, soaked in water for 10 minutes and dried again the cast retains adequate properties for ordinary laboratory use(Whyte and Brockhurst, 1996). The main considerations are that this treatment is time consuming, needs extra laboratory steps and is technique sensitive.

The use of ultraviolet rays has been suggested to disinfect impressions (Drum, 1970). Ultraviolet radiation in the range between 200-300 nm for 5 minutes is suggested to achieve complete disinfection without altering the physical properties of the impression (Drum, 1970).

2.4.3 Microwave disinfection

It has been shown that microwave irradiation may be used for decontamination of food, certain microbiologic laboratory materials, contact lenses, fabric and medical waste (Tonuci, Paschoalatto and Pisani, 2007). Since microwave irradiation quickly heats the internal aspects of objects, it is possible that the organisms growing within these objects may be efficiently killed by the use of this method of sterilization.

The use of microwave irradiation to disinfect dentures has been suggested to overcome some of the problems associated with chemical disinfection (Dixon, Breeding and Faler, 1999, Banting and Hill, 2001 and Silva *et al*, 2006). Irradiation at 60 Hz in a microwave oven for 5 minutes was found to kill all *Candida albicans* in contaminated denture bases and soft lining materials while the specimens (contaminated dentures) were immersed in water (Dixon, Breeding and Faler, 1999). Silva *et al* (2006) found that microwave irradiation for 6 minutes at 650 W produced sterilization of complete dentures contaminated with *Staphylococcus aureus* and *Candida albicans*.

The effect of microwave irradiation on the hardness of the denture base materials with or without soft liners has been investigated (Dixon, Breeding and Faler, 1999 and Machado, Breeding and Puckett, 2005). They found that microwave irradiation did not compromise the hardness of either denture base or the resilient liners or the adhesion of the lining material to the denture base.

Microwave irradiation of dental casts for 5 minutes at 900 W gives a high level of disinfection that complies with European Standard EN 1,040 (Berg, Nielsen and Skaug, 2005). An investigation of the activity of a microwave oven set at 2,450 MHz, 325W, 650W, and 1,400 W on suspensions of various non-sporogenic bacteria showed that all bacteria were killed in 5 minutes or less. However, bacterial spores were only killed when a 1,400 W setting was used for 10 to 20 minutes (Berg, Nielsen and Skaug, 2005).

2.5 The effect of disinfection procedures on impressions and gypsum models

A major obstacle in chemical disinfection of impressions and gypsum models is that the disinfectant may affect the physical properties of the impression and the resultant cast, in particular as regards dimensional accuracy and surface characteristics. Many studies have evaluated the physical properties of impressions and dental models after different disinfection treatments. The results were varied and controversial (Storer and McCabe, 1981, Johansen and Stackhouse, 1987, Lepe and Johanson 1997, Taylor *et al*, 2002).

2.5.1 Dimensional accuracy

A number of techniques and measuring devices have been used to evaluate distortion of dental impression materials subjected to disinfection procedures. Among these have been micrometers, measuring microscopes, still photographs made with a stereomicroscope, tactile examination of margins, and electronic digital calipers.

2.5.1.1 Irreversible hydrocolloids

Some studies indicate that spray or immersion disinfection of impressions has no effect on the dimensional accuracy of the impression material or the physical properties of the resultant cast (Adobo *et al*, 1999, Tan *et al*, 1993, Hall, Munoza-Viveros and Naylor, 2004 and Martin, Martin and Jedynakiewicz, 2007). Other studies reported that immersion disinfection resulted in unacceptable dimensional changes in irreversible hydrocolloids, polyether, and polyvinylsiloxane impressions

(Bergman *et al*, 1985 cited in Hutching *et al*, 1996, Lepe and Johanson, 1997 and Lepe *et al*, 2002).

Herrera and Merchant (1986) showed that immersion of irreversible hydrocolloids in disinfectant solutions resulted in a significant difference in the anterior-posterior dimension of the resultant casts. However, Taylor *et al* (2002) found that irreversible hydrocolloids immersed in sodium hypochlorite for 10 minutes showed a significant improvement in the dimensional accuracy of the casts compared to the control group. This illustrates the diversity of reports on accuracy of gypsum casts following immersion in disinfecting solutions.

2.5.1.2 Zinc-oxide eugenol impression paste

Only a few studies reported on the effect of disinfection treatment on the dimensional stability of zinc-oxide eugenol impressions. Storer and McCabe (1981) tested the effect of 16 hours immersion disinfection in sodium hypochlorite, in 2% alkaline glutaraldehyde and in 4% formaldehyde on zinc-oxide eugenol impressions. They observed significant dimensional changes with sodium hypochlorite. Osslon, Bergman and Bergman in 1982 (cited in Owen and Goolam, 1993) investigated the dimensional accuracy of zinc-oxide impressions after immersion for one hour in 2% alkaline glutaraldehyde, in 0.5% chlorhexidine and in chlorinated sodium phosphate. None of the zinc-oxide eugenol impressions were found to be adversely affected by the disinfectant investigated.

2.5.1.3 Rubber-based impression materials

The American Dental Association’s Specification No. 19 for elastomeric impression materials allows a maximum dimensional change of 0.50% at 24 hours. The effect of immersion disinfection on the dimensional stability of rubber based impression materials has been studied. Johansen and Stackhouse (1987) compared the linear dimensional changes in five rubber-based elastomers after their immersion in 2% glutaraldehyde solution for 16 hours. Polyvinyl siloxane, polysulfide and condensation reaction silicones showed no significant dimensional changes between wet and dry specimens. While polyethers showed a remarkable expansion after immersion for 16 hours (Johansen and Stackhouse, 1987).

The three primary families of rubber-based impression materials (addition reaction silicones, condensation reaction silicones, and polyethers) were studied (Thouati *et al*, 1996) when immersed in three groups of disinfectants   In comparison with non-immersed specimens, immersion for 30 minutes in a freshly prepared 5.25% sodium hypochlorite disinfectant solution led to statistically significant dimensional variations for all impression materials tested.

Analysis of dimensional changes following treatment of light and heavy bodied polyvinylsiloxane impressions with conventional steam autoclave and ethylene oxide gas showed that casts following steam autoclave can be used for fabrication of diagnostic casts and some transitional prosthesis, but not for routine construction of crowns and bridges and partial dentures. While casts made from impressions treated with ethylene oxide gas are acceptable for the use in the fabrication of fixed and removable prosthesis (Holtan, Olin and Rudney, 1991).

2.5.1.3 Gypsum

When attempts had been made to disinfect dental models by mixing disinfectants with dental stone it was assumed that the process would affect the dimensional accuracy of the resultant models. Abdelaziz, Attia and Combe (2004) evaluated the dimensional accuracy of gypsum mixed with 0.525% sodium hypochlorite or 0.1% povidone iodine as a water substitute. They showed that there was no significant effect on the dimensional accuracy of the resultant casts.

Table 2.4 is a summary of the literature reviewed on the effect of disinfection procedures on the dimensional accuracy of impressions and gypsum models. The review covered a range of the literature between 1981 and 2007.

Study	Year	material	Disinfectant	Effect
Storer and McCabe	1981	Zinc-oxide eugenol impressions	immersion for16 hours in sodium hypochlorite	Significant dimensional change of the resultant models.
			2% alkaline glutaraldehyde	No effect
			4% formaldehyde	No effect
Osslon, Bergman and Bergman (cited in Owen and Goolam, 1993)	1982	Zinc-oxide eugenol impressions	immersion for one hour in 2% alkaline glutaraldehyde, 0.5% chlorhexidine and chlorinated sodium phosphate	No effect
Herrera and Merchant	1986	Irreversible hydrocolloid impressions	Immersion for 30 minutes in sodium hypochlorite, povidone iodine, glutaraldehyde, or phenol	Difference in the anterior-posterior dimensions of the resultant models.
		Rubber-based impressions		No effect

Johansen and Stackhouse	1987	Polyvinyl siloxane impressions	Immersion in 2% glutaraldehyde for 16 hours	No effect
		Polysulfide impressions		Minimal shrinkage (not significant) of the resultant models.
		condensation reaction silicone impressions		Minimal shrinkage (not significant) of the resultant models.
		Polyether impressions		Expansion of the resultant models.
Holtan, Olin and Rudney	1991	light and heavy bodied polyvinylsiloxane impressions	conventional steam autoclave and ethylene oxide gas	Dimensional changes of the resultant models.
Thouati *et al*	1996	Rubber-based impressions	immersion for 30 minutes in 5.25% sodium hypochlorite	Expansion of the resultant models.
Lepe and Johanson	1997	Addition silicon and polyether impressions	Immersion for 18 hours in 2% acidulated glutaraldehyde	Increase in the occluso-gingival height of the resultant models.
Adabo *et al*	1999	Rubber-based impressions	Immersion for 10 minutes in 5.25% sodium hypochlorite or 30	No effect on the resultant models.

			minutes in 2% glutaraldehyde	
Taylor *et al*	2002	Irreversible hydrocolloid impressions	immersion for 10 minutes in sodium hypochlorite	Improve the dimensional stability of the resultant models.
Abdelaziz, Attia and Combe	2004	Gypsum models	0.525% sodium hypochlorite or 0.1% povidone iodine	No effect on gypsum models
Hall *et al*	2004	Irreversible hydrocholoide and additional silicon impressions	Spray with Asepto-Sol	No effect on the resultant models.
		Gypsum models	Mix with Asepto-Sol	No effect
Abdullah	2006	Gypsum models	Repeated immersion in sodium hypochlorite for 30 minutes	Significant expansion of the resultant models.
Yilmaz *et al*	2007	Polyether impressions	Immersion for 10 minutes in 2% glutaraldehyde or 0.525% sodium hypochlorite	Insignificant expansion of the resultant models.
Martin, Martin and Jedynakiewicz	2007	alginates, addition-cured	5.25% sodium hypochlorite,	Acceptable dimensional

		silicones, condensation-cured silicones and polyether impressions	Perform ID and Sterilox.	changes of the resultant models.

Table 2.4: Summary of the literature reviewed on the effect of disinfection procedures on dimensional stability of impressions and of dimensional accuracy of gypsum models.

2.5.2 Surface detail reproduction

Rowe and Forrest (1978) treated 4 impression materials (alginate, Thiokol elastomer, silicone elastomer and polyether) with 0.5% chlorhexidine for 30 seconds, 1 minute, 5 minutes and 24 hours. The surfaces of the stone models poured against these impressions showed no significant differences from the control group that was incubated in tap water for similar periods. However, a study by Hutching *et al* (1996) showed that there was an increase in the surface roughness and reduction in the detail reproduction of dental casts after immersing the impressions in sodium hypochlorite solution for 10 minutes. The surface roughness appeared to increase as the pH of the solution was lowered.

Taylor *et al* (2002) found that after the immersion of irreversible hydrocolloid impressions in sodium hypochlorite for 10 minutes, the resultant stone models showed partial deterioration that led to poor surface quality. Ahmad *et al* (2007) found that immersion disinfection with Perform-ID led to a reduction of the surface detail reproduction and a lowered abrasion resistance of the resultant gypsum casts.

However, the use of sodium hypochlorite or povidone iodine as a mixing substitute for water to disinfect the gypsum models resulted in no significant effect on the producibility of the resultant casts (Abdelaziz, Attia and Combe, 2004).

2.5.3 Surface hardness

In general the effect of adding disinfectants when mixing the dental stone resulted in a decrease in strength, except for type V dental stone where there was a significant increase in the dry compressive strength of the casts(Twomey *et al*, 2003). When 0.5% calcium hypochlorite was added to type V gypsum the resultant models had acceptable mechanical properties (Twomey *et al*, 2003).

The use of sodium hypochlorite or povidone iodine as a mixing substitute for water to disinfect gypsum models did increase the incidence of abutment fracture during the release of the casts from the impressions, but the increase in fracture was not statistically significant (Abdelaziz, Attia and Combe, 2004). Abutment fracture indicates the lack of ability to withstand binding stresses applied during the release of the cast.

2.6 Dentists and dental lab-oratory personnel attitudes to disinfection

Dental office personnel may not follow the recommended protocols for disinfecting impressions and other items that come in contact with patients (Mullar-Bolla *et al*, 2004, Kugel *et al*, 2000 and Sofou *et al*, 2002 a). In most situations there is a significant and problematic lack of communication between dentists and dental laboratory personnel. A survey (Jagger, Hugget and Harrison, 1995) that involved 800 commercial dental laboratories in the UK showed that only 49% of the responding laboratories (22% response rate) had a cross-infection policy. 35% of the laboratories did not disinfect the work on arrival at the laboratory from the dental office.

Kugel *et al* (2000) surveyed 400 dental laboratories in the United States and found that 44% of those responding laboratories stated that they had no knowledge that the impressions they received had been disinfected in the dental office, or if disinfected they did not know the method of disinfection used or the length of time involved and the material used in the disinfectant procedure.

In 2004 a survey aimed to determine the disinfection procedures of irreversible hydrocolloid and silicone impressions taught and used in the European Union dental schools was conducted by Mullar-Bolla *et al* (2004). A questionnaire was sent to prosthodontic, pedodontic and orthodontic departments in the 131 European Union dental schools. Of the responding departments 15%, mostly orthodontic departments, never disinfected irreversible hydrocolloid impressions, and 11% never disinfected silicon impressions. The immersion method was used by 65% of the respondents for irreversible hydrocolloid impressions and for 73% of the respondents for silicon impressions, with a disinfection time of 10.3 ± 6.3 minutes (Mullar-Bolla *et al*, 2004).

2.7 Factors affecting the dimensional stability of impressions and dimensional accuracy of gypsum models

2.7.1 Chemical composition of the material

There are five major factors related to the chemical composition of the impression materials that may result in dimensional changes in the impressions. These include polymerization shrinkage, loss of by-products (water or alcohol), thermal contraction from oral temperature to room temperature, imbibition when the material is exposed to water, disinfectant or a high humidity environment over a period of time and incomplete recovery of deformation following removal of the impression from the oral cavity (Anusavice, 2003).

2.7.1.1 Irreversible hydrocolloid impressions

Irreversible hydrocolloid impressions may lose water by evaporation from its surface or by exuding fluids onto the surface by the process of syneresis. As a result the material shrinks due to the evaporation and syneresis. If the impression is placed in water, it absorbs water by the process of imbibition. The impression swells during imbibition, thereby altering the original dimensions. The effects of syneresis, evaporation and imbibition on the dimensional stability of the impression after removal from the mouth will lead to inaccurate casts and models (Anusavice, 2003).

Distortion of alginate impressions begins almost immediately after removal from the mouth. A progressive shrinkage will continue until the impression is no longer clinically acceptable (Christensen, 1984).

2.7.1.2 Zinc-oxide eugenol paste impressions

Shrinkage of less than 0.1% may occur with zinc-oxide eugenol impressions during hardening. No significant dimensional change subsequent to hardening should occur (Anusavice, 2003).

2.7.1.3 Polyether impressions

A polyether impression has the ability to absorb water from the atmosphere which leads to simultaneous leaching of the water-soluble plasticizer (Anusavice, 2003). Whereas most impression materials shrink over time due to continual polymerization and loss of volatile by-products, polyether materials swell over time due to water sorption (Donovan and Chee, 2004).

2.7.1.4 Type IV dental stone

Normally, the setting of gypsum products is accompanied by expansion, and the expansion is generally considered a result of thrusting action of the dehydrate crystals during the setting reaction. During the process of converting the solution of hemihydrate in water to dehydrate, numerous crystals are produced. As individual crystals grow to their final size, the primary branches develop pressure against the surrounding crystals resulting in volumetric expansion. Such minimal setting expansion of gypsum casts is thought to be beneficial in terms of aiding compensation for metal shrinkage, wax pattern dimensional changes, and other inaccuracies in the casting process. At the same time excessive model inaccuracy may result in unacceptable deviation from the natural structures and in clinically unacceptable prosthesis. Although the setting expansion of conventional dental stone is 0.25% or less, that of the high expansion stone can be as high as 0.5%. (Teraoka and Takahashi, 2000)

2.7.2 Tray selection

The impression tray influences the setting expansion of the stone. The use of a custom tray may have a significant effect as it provides a uniform thickness of impression material to improve the accuracy of the working cast. Any material used to make custom trays must be dimensionally stable over time and must not permanently deform during the impression making procedure or as the impression is retrieved from the oral cavity. Although custom trays have been recommended, the main objective in stock tray selection is to provide a rigid tray which provides retention for the impression material. It has been suggested that metal and rigid plastic stock trays provide greater accuracy than flexible plastic trays.

Thongthammachat *et al* (2002) evaluated the effect of tray selection on the accuracy of the resultant models. In the study two types of stock trays (plastic stock trays, perforated metal stock trays) and 4 types of custom tray materials (autopolymerizing acrylic resin, thermoplastic resin, and 2 types of light-polymerized acrylic resins) were used with 2 types of impression materials (addition polymerizing silicone and polyether), to make impressions of a metal master model. The results indicated that accurate casts can be made with either stock trays or custom trays.

However, Teraoka and Takahashi (2000) emphasized that stone models do not uniformly expand in the open tray, and the dimensional changes in the stone casts in three-dimensions increases when used with a high expansion stone.

2.7.3 Environmental factors

Once the impression is removed from the mouth and exposed to air at room temperature, some shrinkage associated with syneresis and evaporation is bound to occur. Thermal changes between the mouth temperature (37°C) and room temperature (23°C) may lead to the impression shrinking slightly. Controversially, if the impression is immersed in water or exposed to a humid environment, swelling as a result of imbibition will occur (Anusavice, 2003).

If pouring of irreversible hydrocolloid impressions must be delayed, it should be rinsed under tap water, disinfected, wrapped in surgical paper towel saturated in water, and placed in a sealed plastic bag or humidor (Anusavice, 2003). If it is not placed in a tightly closed storage box, the impression material will constrict considerably and lose its elasticity (Chen, Liang and Chen, 2004). This not only causes large discrepancies but also makes it difficult to separate the model from the impression. Therefore, it is recommended for alginate impressions to be stored under conditions of 100% relative humidity (Chen, Liang and Chen, 2004).

Storage of set gypsum models at room temperature produces an insignificant dimensional change. However, if the storage temperature is raised to between 90° to 110° C, shrinkage occurs as the water of crystallization is removed and the dehydrate reverts to hemihydrate (Anusavice, 2003). The gypsum cast is then slightly soluble in water. When a dry cast is immersed in water, negligible expansion may occur (Anusavice, 2003).

2.7.4 Storage time

It has been documented that zinc-oxide eugenol impressions can be stored and preserved indefinitely without any dimensional change (Anusavice, 2003). Chen, Liang and Chen (2004) investigated the effect of storage time on the accuracy of different impression materials. After an impression was taken, dental stone was immediately poured into the alginate impressions, while the silicone impressions were poured 30 minutes later with a waiting period of 1 hour for complete setting. The second and third stone dies were made 1 and 24 hours later, respectively. The results showed that, in the first and second rounds, the models produced from alginate impressions had accuracies close to those of the models produced from the elastomeric impressions. However, after 24 hours, the models produced from the alginate impressions were relatively unstable compared to those produced from elastomeric impressions.

It is recommended that for maximum accuracy, alginate impressions must be poured within 10 minutes of removal from the mouth. While polyether impressions should be poured within 1 hour of their removal from the mouth (Donovan and Chee, 2004).

2.8 Discussion

There are a number of problems associated with the use of chemical disinfection of impressions and dental casts. Chemical disinfection takes time and is expensive to perform in a busy dental practice. Moreover, all chemical disinfectants are potentially harmful to the health of the user and to the environment (Owen and Goolam, 1993). Furthermore, chemical disinfectants are not compatible with irreversible hydrocolloids (Berg, Nielsen and Skaug, 2005). Consequently, to a large extent, disinfection procedures of impressions are not followed in dental practices (Mullar-Bolla *et al*, 2004, Kugel *et al*, 2000 and Sofou *et al*, 2002 a). The lack of communication between dentists, staff members and dental laboratory personnel along with poor training of laboratory personnel in disinfection techniques may have a direct effect in the lack cross- infection control and on the perceived inaccurate fit of the prosthetic appliances achieved in dental practices due to the disinfection procedures.

The prosthesis will become contaminated by the patient after the try-in stage and following adjustments in the mouth and will re-contaminate the cast after being repositioned (Mitchell *et al,* 1997). In practice, contaminated gypsum casts should be disinfected after each clinical procedure. However, studies have focused on disinfecting the contaminated impressions without reference to the cast.

A major obstacle in chemical disinfection is that the disinfectant may affect the physical properties of the impression and the resultant cast, in particular dimensional accuracy and surface characteristics of the cast. Study results are varied and controversial. These variations are dependent on the method adopted and depending on the type of test block used (with full arch casts, cavities for inlays, or conforming to American Dental Association standard No. 196' 8), on the use of retentive or nonretentive impression trays, and on the use of adhesives.

Since the instability of irreversible hydrocolloids and polyether impression materials in aqueous solutions and under humid conditions has been reported, reduced dimensional stability of these impressions after immersion in disinfectants can be expected. Manufacturers' have attempted to overcome the problems associated with impression disinfection by adding disinfectants to dental stone (Schutt, 1989). The method seems to be effective in eliminating cross- contamination between impressions and dental models (Mansfield and White, 1991, Ivanoski *et al*, 1995), but there is no published evidence that shows for how long these disinfectants will persist or prevent recontamination from the repeated intra-oral placement of the acrylic resin base.

On the other hand, microwave irradiation is effective and practical. It would eliminate cross-contamination via the cast because it can be repeated at every stage as required (Berg *et al*, 2005). Disinfection can be performed quickly and without the use of toxic, pungent, or allergic chemicals. The effect of microwave irradiation on the strength and hardness of gypsum casts has been tested (Hersek *et al*, 2002). The results indicate an improvement in these qualities, although there was some concern that cracks or porosities in the surface might occur when type IV gypsum casts were exposed to irradiation with a very high wattage (1,450 W).

2.9 Conclusion

Impressions, dental casts and prostheses are a potential route of cross-infection from patients to the dental technician. ADA and CDC recommend disinfection of all impressions and dental prostheses before shipment to dental laboratories. There is no universally accepted protocol for impression disinfection.

Studies on the effect of chemical disinfection on the physical properties of impressions and dental casts are varied and their results are controversial. Microwave irradiation disinfection is thought to be effective, repeatable and may improve the quality of the dental casts, and may serve the purpose of controlling cross-infection between the patients and the personnel in the dental laboratory.

CHAPTER THREE

AIMS AND OBJECTIVES

3.1 Aims

The aims of the present study were:

1. To assess the dimensional accuracy of gypsum models following chemical disinfection of the impressions.
2. To assess the dimensional accuracy of gypsum models exposed to microwave irradiation for disinfection purposes.

3.2 Objectives

The objectives of the study were:

1. To determine the effect of immersion disinfection of impressions with sodium hypochlorite disinfection on the resultant cast.
2. To determine the effect of microwave irradiation disinfection on the gypsum casts.
3. To compare dimensional accuracy of stone models poured after chemical disinfection of impressions and stone models exposed to microwave disinfection procedures.
4. To evaluate the behaviour of different impression materials with different disinfection treatments.

CHAPTER FOUR

MATERIALS AND METHODS

4.1 Materials

4.1.1 Impression materials

Three impression materials (figure 4.1) that are currently used in the Prosthetic Dentistry Department at the University of the Western Cape were tested in this study. These include an irreversible hydrocolloid (Blueprint Cremix/De Trey, Dentsply, Germany), a zinc-oxide eugenol impression paste (SS White, SS White Group, England), and a medium consistency polyether impression paste (Impregum™ F, 3M ESPE, Germany).

All impressions were poured in type IV gypsum (figure 4.1), die stone (GC Fujirock® EP, GC Europe N.V).

All the impression materials and gypsum products were mixed and manipulated according to the manufacturer’s instructions. Normal tap water at room temperature was used for all mixing procedures of the irreversible hydrocolloid impressions and the gypsum materials.

Figure 4.1: impression materials and gypsum product used in the study, a: Blueprint Cremix/De Trey, Dentsply, Germany, b: SS White, SS White Group, England, c: Impregum ™ F, 3M ESPE, Germany and d: GC Fujirock® EP, GC Europe N.V.

4.1.2 Sample size

A total of 90 impressions were recorded, 30 impressions in each material. The batch of impressions for each material were divided into 3 groups (n= 10) (figure 4.2).

Group I: impressions rinsed under running tap water for 10 seconds and poured immediately in gypsum (control).

Group II: impressions rinsed for 10 seconds then immersed in 0.525% sodium hypochlorite solution for 10 minutes (Beyerle *et al*, 1994 and Schwartz *et al*, 1994), rinsed again and poured in gypsum.

Group III: impressions rinsed for 10 seconds and poured immediately in gypsum. After setting of the gypsum casts was completed the casts were separated from the impression and irradiated in a microwave oven for 5 minutes at 2,450 MHz and 900W (Berg, Nielsen and Skaug, 2005).

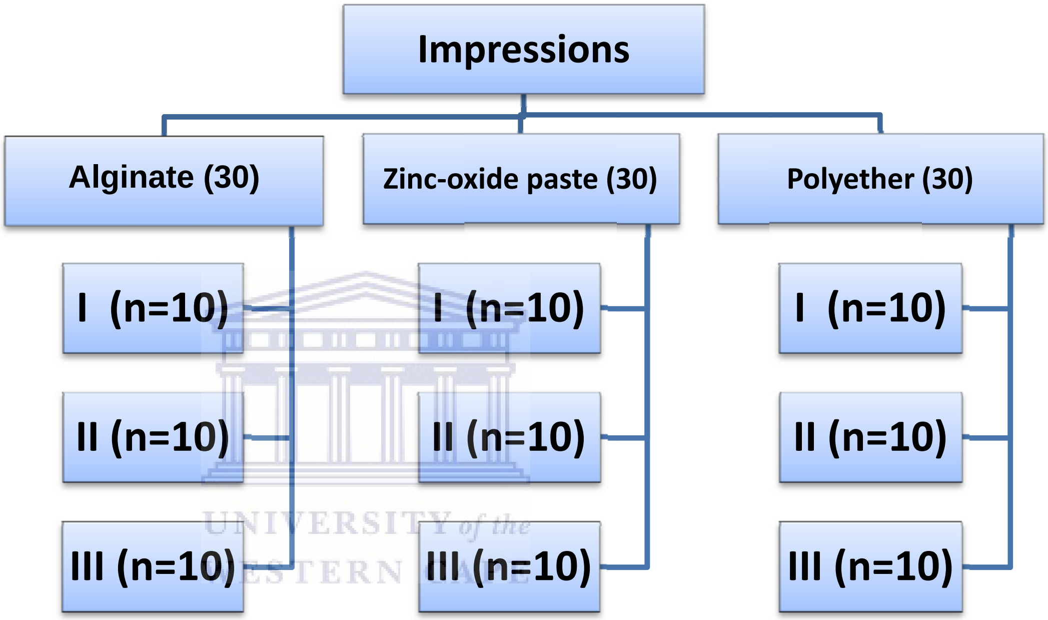

Figure 4.2: Diagrammatic illustration of the materials used in the study and the different disinfection protocols.

4.2 Methods

4.2.1 Master model

An acrylic master model was constructed to represent an edentulous maxillary arch. An alginate impression was made in a stock tray of the original model. Auto-polymerized acrylic resin was then poured into the impression with vibration. After polymerization was complete, the acrylic resin cast was separated from the impression, finished and stored in a water bath at room temperature for 24 hours before being used as the master model (Abdelaziz, Attia and Combe, 2004).

Reference points (A, B, C and D) for measurements on the cast were made using stainless steel dowel pins (Brass dowel system, J.M.Ney Crop, Bloomfield) placed in the approximate position of the incisal papilla (A), the left and right second molars (B and C)and in the centre of the hard palate(D) (figure 4.3). A hole was drilled in the position of each reference point with an acrylic bur, and a dowel pin was then seated and secured in place with an auto-polymerized acrylic resin. The undercuts and irregularities around the pins were blocked out with a chemically cured acrylic resin. After complete setting of the resin, the pins were cut to the level of the alveolar ridge and grooves were scored onto the occlusal surface of each pin in the shape of an ‘x’(figure 4.4 and 4.5)

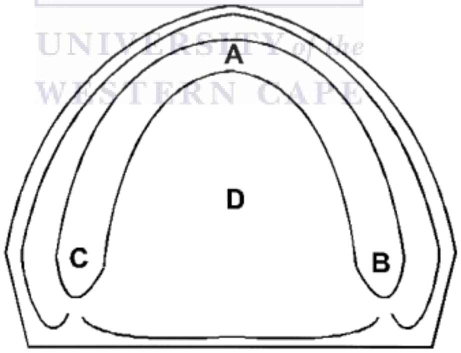

Figure 4.3: Diagrammatic representation of the master model, A, B, C, and D are the reference points.

Figure 4.4: Master model with the 4 reference points.

Figure 4.5: Occlusal view of the groove on the occlusal surface of the reference point.

4.2.2 Special tray construction

Custom made light- cured acrylic resin special trays (Megatray, Megadent, Germany) were constructed on the acrylic master model. In order to ensure a uniform thickness and distribution of impression material, the special trays were constructed after a spacer of appropriate thickness was applied to the master model. Special trays for alginate impressions were constructed with a 3 mm spacer, and the special trays for polyether impressions were constructed with a 2 mm spacer. The special trays for zinc-oxide eugenol paste were close fitting spaced trays (Basker and Davenport, 2002).

To stabilize the tray during impression making and for even distribution of the impression material, stops were made in the approximate position of the palatine fovea and the right and left first premolar region. The trays were then perforated and coated with an appropriate adhesive recommended by the manufacturer for each impression material.

4.2.3 Specimen preparation

Each impression material was proportioned, mixed and manipulated according to the manufacturers' instructions. Impressions were then recorded of the master model and allowed to set according to the recommended time of the manufacturer. After setting the impression was separated from the master model and rinsed under running tap water for 10 seconds, the excess water was shaken off. The integrity of the reference points reproduction was visually checked. Impressions were then randomly subjected to one of the proposed disinfection protocols.

4.2.3.1 Alginate impressions

Tap water and alginate powder (Blueprint Cremix/De Trey, Dentsply, Germany) were proportioned according to the measuring cups provided by the manufacturer. The material was hand mixed for 30 seconds.

A spray-on tray adhesive (Adhesive Fix, Dentsply DeTrey, Germany) was used for all alginate impressions. The adhesive was sprayed onto the special trays and allowed to dry before loading of the impression material. The mixed impression paste was applied to the custom impression tray, and impressions were recorded of the master model. The excess material was wiped away. The impressions were separated from the master model 5 minutes after the start of mixing (figure 4.6). After each impression the master model was cleaned prior to the next impression.

4.2.3.2 Zink-oxide eugenol impressions

Equal lengths of base and catalyst of the zinc-oxide eugenol paste (SS White, SS White Group, England) were squeezed from the tubes onto a mixing pad. The pastes were mixed with a stainless steel spatula for 30 seconds in broad sweeping strokes. The master model was coated with a thin layer of separating medium (Vaseline, Unilever, South Africa) to prevent adhesion of the impression material to the master model.

The mixed impression paste was applied to the custom impression tray, and the impression was recorded of the master model. The excess material was wiped away and the tray left *in situ* for 5 minutes as the manufacturer' recommended. After setting of the material the impression was separated from the master model (figure 4.6). After each zinc oxide eugenol impression the master model was cleaned with a solvent (Orange solvent, Chemist Sultan, USA) and coated with another layer of separating medium prior to the next impression.

4.2.3.3 Polyether impressions

Equal lengths of the base and catalyst paste of medium consistency polyether impression material (Impregum ^{TM} F, 3M ESPE, Germany) were squeezed onto a mixing pad. The pastes were mixed with a stainless steel spatula for 30 seconds in broad sweeping strokes. The master model was coated with a thin layer of separating medium (Vaseline, Unilever, South Africa) to prevent adhesion of the impression material to the master model.

A tray adhesive (Adhesive, Coltene ®, Switzerland) was brushed onto the custom tray and dried according to the manufacturers' instructions before loading of the impression paste into the custom tray. The mixed impression paste was applied to the custom impression tray, and the impression was recorded of the master model. The excess material was wiped away and the tray left *in situ* for 7 minutes as the manufacturer recommended. After setting of the material the impression was separated from the master model (figure 4.6). Following each impression, the master model was cleaned and coated with another layer of separating medium prior to the next impression.

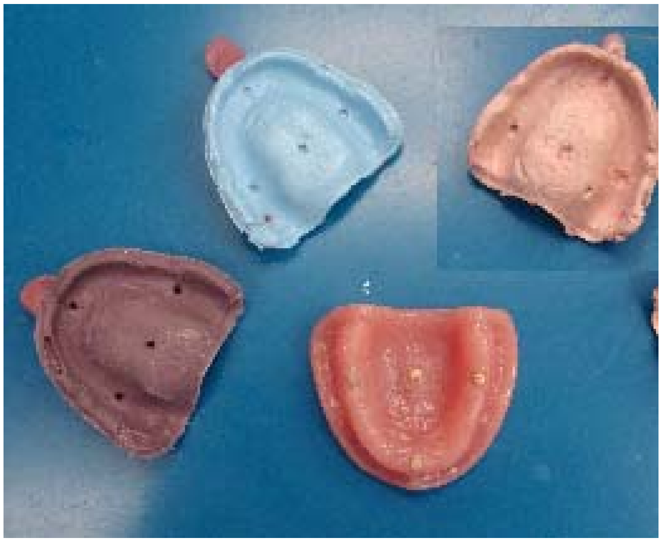

Figure 4.6: Three impressions of the master model with Impregum (Impregum ™ F, 3M ESPE, Germany), Blueprint (Blueprint Cremix/De Trey, Dentsply, Germany) and SS White (SS White Group, England).

4.2.3.4 Gypsum models

Type IV gypsum (die stone) (GC Fujirock® EP, GC Europe N.V) was dispensed according to the manufacturer's recommendations regarding the correct water: powder ratio. The gypsum was added to the water over 10 seconds and allowed to soak for a further 20 seconds and then hand mixed for 40 seconds.

The impressions were poured using a vibrator. Initially the mixed gypsum was vibrated along one side of the impression, then the impression was turned 90 degrees to allow the material to flow to the other end of the impression without entrapment of air. After that, additional stone was poured over the remainder of the exposed impression surface. Excess stone was vibrated off the impression surface.

The casts were allowed to set for one hour at room temperature and were then separated from the impressions (figure 4.7). A number was marked on the side of the cast for identification.

Figure 4.7: Gypsum model after separated from an alginate impression.

4.2.4 Disinfection procedures

4.2.4.1 Chemical disinfection

Specimens that were assigned to the chemical disinfection group were immersed in a disinfectant solution (freshly prepared) for the recommended time. The disinfectant solution was prepared by diluting 1% sodium hypochlorite (Milton sterilization fluid, Permark International, South Africa) in a 1:1 ratio with tap water to making a 0.5% sodium hypochlorite solution.

4.2.4.2 Microwave irradiation disinfection

Specimens that were assigned to the microwave disinfection group were poured in gypsum immediately after rinsing under running water for 10 seconds. After separation of the models from the impressions the models were irradiated in a microwave oven for 5 minutes. The microwave irradiation was performed in a household (Goldstar), the microwave oven set at 900W and 2,450MHz frequency. To ensure that the casts were adequately irradiated on all surfaces, the casts were first exposed for 2.5 minutes and subsequently turned upside down and again irradiated for the same amount of time (Berg, Nielsen and Skaug, 2005).

4.2.5 Measurements

To ensure that the die stone was perfectly stabilized, measurements were only carried out after 24 hours. Measurements were taken with a set of absolute digital callipers that are accurate to 0.01mm (figure 4.8)

Figure 4.8: Digital calliper: 1. internal measuring faces, 2. external measuring faces, 3. Inch/mm interchange, 4. LCD display screen, 5. zero setting button, 6. locking screw.

Three readings for each linear measurement (A-B, A-C, A-D, B-C, B-D and C-D) between the intersect of the 'x' on the occlusal surface of each post was made for each model (18 measurements for each model) (fig 4.9). All measurements were made by the same investigator, and a random 10% of the measurements were repeated to verify accuracy.

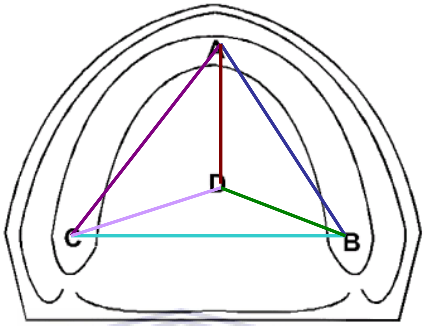

Figure 4.9: Diagrammatic illustration of the linear measurements.

4.3 Data collection:

The data was captured in an excel spreadsheet. The spreadsheet was designed to reflect the date, model number, type of impression material, disinfection procedure, and the mean value of the 3 measurements for each linear measurement (appendix 1).

4.4 Data analysis:

The mean of the three linear measurements obtained from the gypsum casts were compared to the actual linear measurement recorded from the master model. The mean of the linear measurements were then converted to a mean percentage deviation using the formula (M – E) /M × 100. Where M is the actual measurement on the master model, and E is the measurement on the experimental cast (control or post disinfection) (Lepe and Johanson, 1997 and Taylor, Wright and Maryan, 2002).

Data were analyzed with an analysis of variance (ANOVA) and Post Hoc test for pair-wise comparison. All data analysis was carried on SPSS 14 for windows.

4.5 Results

The overall dimensional accuracy of each model was expressed as a mean percentage deviation of the 6 linear measurements recorded and was compared to the master model. The results were graphically illustrated.

CHAPTER FIVE

RESULTS

The mean of the three linear measurements recorded from the gypsum casts were compared to the actual measurements recorded from the master model. The overall dimensional accuracy of each model was expressed as a mean percentage deviation of the 6 linear measurements recorded and was compared to the master model. The measurements, the mean and the percentage standard deviations of the 90 stone models and the master model are presented in appendix 1. The initial data indicated that there was no outlier in each of the different groups. An average dimensional change of each model was then calculated by taking the mean of the percentage deviation of each linear measurement.

Data were analyzed with an analysis of variance (ANOVA) and Post Hoc test for pair-wise comparison. All data analysis was computed on SPSS 14 for windows at a 95% confidence level.

5.1 Irreversible hydrocolloids (Blueprint, Cremix/De Trey, Dentsply, Germany)

Measurements of the stone casts obtained from Blueprint (Cremix/De Trey, Dentsply, Germany) impressions were larger than the master model with a 1.06% change in the control group, a 1.31% change in the chemical disinfection group and a 1.16% change in the group with microwave irradiation. The mean of the overall percentage deviation of each group is presented in table 5.1. Gypsum models in the control group (group 1) showed the greatest dimensional accuracy with a 1.065% overall deviation from the master model. These were followed by models exposed to microwave irradiation and then models from impressions in the chemical disinfection group.

procedure	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	10	1.0650	.22018	.06963	.9075	1.2225	.62	1.36
2	10	1.3110	.15803	.04997	1.1980	1.4241	1.05	1.57
3	10	1.1628	.17517	.05539	1.0375	1.2881	.96	1.46
Total	30	1.1796	.20713	.03782	1.1023	1.2570	.62	1.57

Table 5.1: Mean values of the overall percentage deviation of gypsum models poured from Blueprint impressions. (1- control, 2- immersion of impressions in 0.5% sodium hypochlorite and 3- microwave irradiation of casts).

The overall percentage deviation of the 3 treatment groups was used to express the accracy of the models following disinfection procedures. The overall accuracy of the models was analysed with the analysis of variance (ANOVA) at a 95% confidence level to determine if there is a significant difference between the combination of impression material (Blueprint, Cremix/De Trey, Dentsply, Germany) and/ or gypsum and disinfection method (table 5.2). The test showed a statistically significant difference (P value 0.022 which is less than 0.05) between the 3 disinfection procedures for impressions recorded with blueprint and poured in type IV gypsum (figure 5.1).

	Sum of Squares	df	Mean Square	F	P value
Between Groups	.307	2	.153	4.420	.022
Within Groups	.937	27	.035		
Total	1.244	29			

Table 5.2: Differences in dimensional accuracy of models poured in type IV gypsum from Blueprint impressions managed with different disinfection modalities.

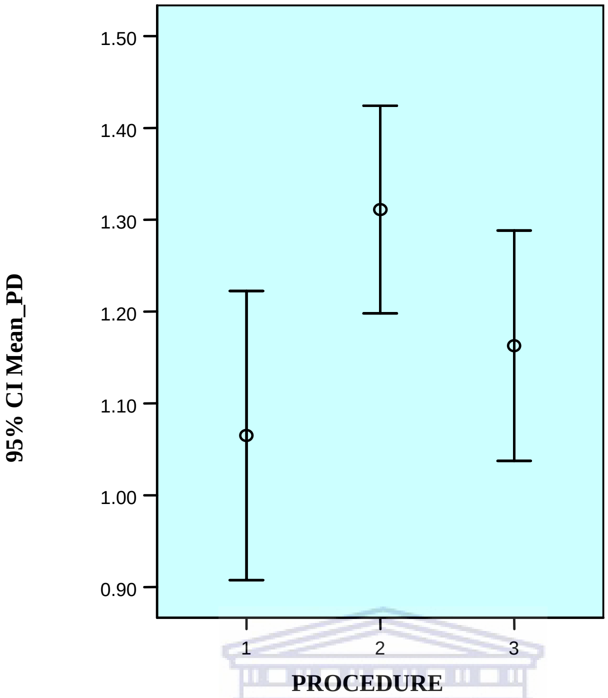

Figure 5.1: Dimensional accuracy of gypsum models cast from Blueprint impressions (1- control, 2- immersion of impressions in 0.5% sodium hypochlorite and 3- microwave irradiation of the cast).

Analysis with Post Hoc test for pair-wise comparison showed a statistically significant difference in the dimensional accuracy of casts poured from Blueprint impressions only rinsed under running water (control) and those immersed in a 0.5% sodium hypochlorite solutions for 10 minutes (P value 0.019). There was however no statistically significant difference in the dimensional accuracy of the models in the control group and the models in the microwave irradiated group (P value > 0.05) (table 5.3).

(I) Procedure	(J) Procedure	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-.24603	.08332	.019(*)	-.4587	-.0334
	3	-.09781	.08332	.752	-.3105	.1149
2	1	.24603	.08332	.019(*)	.0334	.4587
	3	.14822	.08332	.260	-.0645	.3609
3	1	.09781	.08332	.752	-.1149	.3105
	2	-.14822	.08332	.260	-.3609	.0645

Table 5.3: Differences in dimensional accuracy of gypsum models exposed to different disinfection procedures. (1- control, 2- immersion of impressions in 0.5% sodium hypochlorite and 3- microwave irradiation of casts). * The mean difference is statistically significant at the .05 level.

5.2 Zinc-oxide eugenol impression paste (SS White, SS White Group, England)

The overall percentage deviation of the 3 experimntal groups was used to express the accuracy of models following the disinfection procedures. The mean of the overall percentage deviation of each group is presented in table 5.4. Gypsum models in the microwave irradiation group (group 3) showed the greatest dimensional accuracy with a 0.07557% overall deviation from the master model. Followed by models in the control group, and those poured in the impressions exposed to the chemical disinfection (group 2). The control and chemical disinfection groups were similar in deviation from the master model.

Procedure	**N**	**Mean**	**Std. Deviation**	**Std. Error**	**95% Confidence Interval for Mean**		**Minimum**	**Maximum**
					Lower Bound	Upper Bound		
1	10	1.1765	.13547	.04516	1.0723	1.2806	.91	1.36
2	10	1.2786	.27571	.08719	1.0814	1.4758	.93	1.94
3	10	.7557	.18619	.05888	.6225	.8889	.49	1.07
Total	29	1.0666	.30866	.05732	.9492	1.1840	.49	1.94

Table 5.4: Mean values of the overall percentage deviation of gypsum models poured from SS White impressions (SS White Group, England). (1- control, 2- immersion of impressions in 0.5% sodium hypochlorite and 3- microwave irradiation of the cast).

Analysis of variance (ANOVA) at the 95% confidence level showed a significant difference ($P < 0.05$) in the dimensional accuracy of the gypsum models poured in zinc- oxide eugenol impressions and exposed to the different disinfection procedures (table 5.5 and figure 5.2).

Pair-wise comparison between the different disinfection procedures with Post Hoc test is summarized in table 5.6. There is a statistically significant difference between the dimensional accuracy of the models cast from SS White impressions and irradiated in a microwave oven and the models in control group ($P = 0.001$), and in the models cast from impressions in the chemical disinfection group ($P = 0.000$).

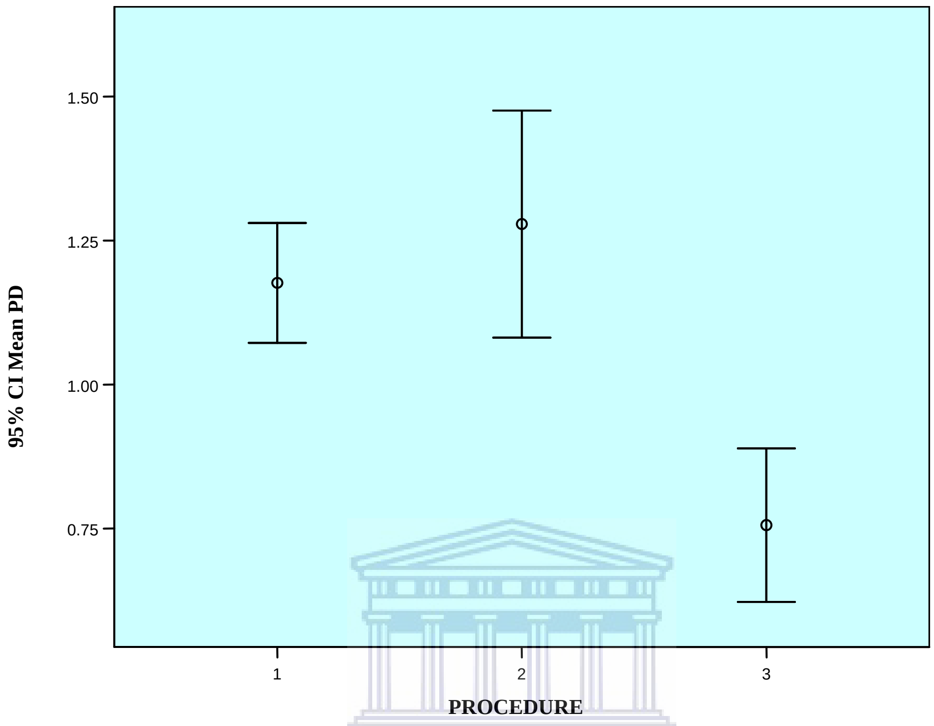

Figure 5.2: Dimensional accuracy of gypsum models poured in SS White impressions (1- control, 2- immersion of impressions in 0.5% sodium hypochlorite and 3- microwave irradiation of the cast).

	Sum of Squares	**df**	**Mean Square**	**F**	**P value**
Between Groups	1.525	2	.762	17.341	.000
Within Groups	1.143	26	.044		
Total	2.668	28			

Table 5.5: Differences in dimensional accuracy of models exposed to different disinfection treatments.

(I) Procedure	(J) Procedure	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-.10211	.09633	.897	-.3486	.1444
	3	.42077	.09633	.001(*)	.1743	.6673
2	1	.10211	.09633	.897	-.1444	.3486
	3	.52288	.09376	.000(*)	.2829	.7628
3	1	-.42077	.09633	.001(*)	-.6673	-.1743
	2	-.52288	.09376	.000(*)	-.7628	-.2829

Table 5.6: Differences in dimensional accuracy of gypsum models exposed to different disinfection procedures. (1- control, 2- immersion of impressions in 0.5% sodium hypochlorite and 3- microwave irradiation of casts). * The mean difference is significant at the .05 level.

5.3 Polyether impression materials (Impregum $^{\text{TM}}$ F, 3M ESPE, Germany)

The overall percentage deviation of the 3 treatment groups was used to express the accuracy of models following the different disinfection procedures. The mean of the overall percentage deviation of each group is presented in table 5.7.

Gypsum models in the control group and models exposed to microwave irradiation (group 3) showed a close similarity as regards dimensional accuracy. The models poured from impressions exposed to chemical disinfection (group 2) showed a higher deviation from the master model compared to the other 2 groups (figure 5.3).

Analysis of variance and post-hoc test for pair-wise comparisons showed that the deviation from the master model of models cast from impressions treated with chemical disinfection is statistically significant when compared to the models in the control group and the models exposed to microwave irradiation (group 3) ($P < 0.05$) (table 5.8 and 5.9).

Procedure	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	10	.6367	.10920	.03453	.5586	.7148	.49	.82
2	9	1.2773	.31530	.10510	1.0350	1.5197	.81	1.80
3	9	.7413	.19038	.06346	.5950	.8876	.52	1.10
Total	28	.8762	.35373	.06685	.7391	1.0134	.49	1.80

Table 5.7: Mean values of the overall percentage deviation of gypsum models cast from Impregum impressions. (1- control, 2- immersion of impressions in 0.5% sodium hypochlorite and 3- microwave irradiation of casts).

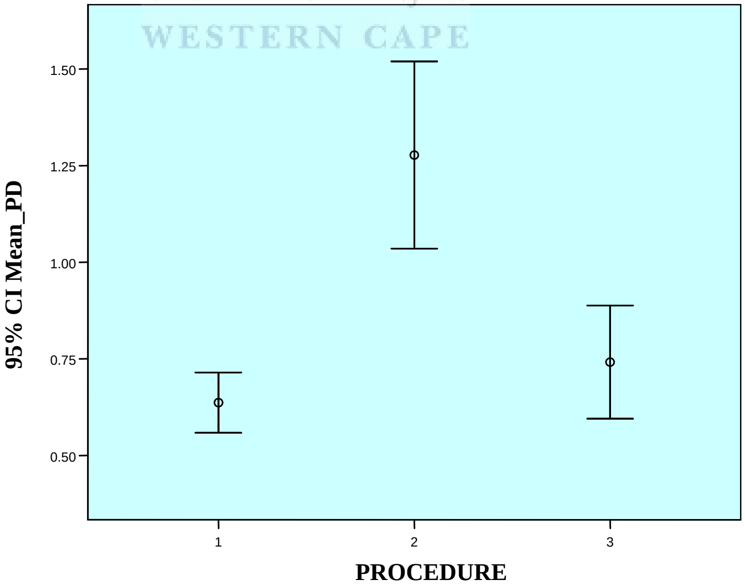

Figure 5.3: Dimensional accuracy of gypsum models poured in Impregum impressions, (1- control, 2- immersion of impressions in 0.5% sodium hypochlorite and 3- microwave irradiation of casts).

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	2.186	2	1.093	22.909	.000
Within Groups	1.193	25	.048		
Total	3.378	27			

Table 5.8: Differences in dimensional accuracy of models exposed to different disinfection procedures,

(I) Procedure	**(J) Procedure**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval**	
					Lower Bound	**Upper Bound**
1	2	-.64066	.10035	.000(*)	-.8982	-.3832
	3	-.10462	.10035	.921	-.3621	.1529
2	1	.64066	.10035	.000(*)	.3832	.8982
	3	.53603	.10296	.000(*)	.2718	.8002
3	1	.10462	.10035	.921	-.1529	.3621
	2	-.53603	.10296	.000(*)	-.8002	-.2718

Table 5.9: Differences in dimensional accuracy of gypsum models cast from Impregum impressions and treated with different disinfection procedures. (1- control, 2- immersion of impressions in 0.5% sodium hypochlorite and 3- microwave irradiation of casts). * The mean difference is significant at the .05 level.

Figure 5.4 is a summary of the percentage deviation of the gypsum models produced from the different impression materials and the different disinfection treatment regimens investigated in this study. The graph shows that all the models exhibit a degree of expansion when compared with the master model despite the impression material used. The degree of expansion and the accuracy of the models are related to the type of impression material used. Impregum impressions produced the most accurate models with all disinfection procedures.

All models expanded to the same level when poured in impressions immersed in chemical disinfectant solution, and expressed only a close deviation from the master model of that of the control group when irradiated in a microwave oven, with the exception of the SS White group where the models showed greater dimensional accuracy when irradiated in the microwave oven than models of the control group.

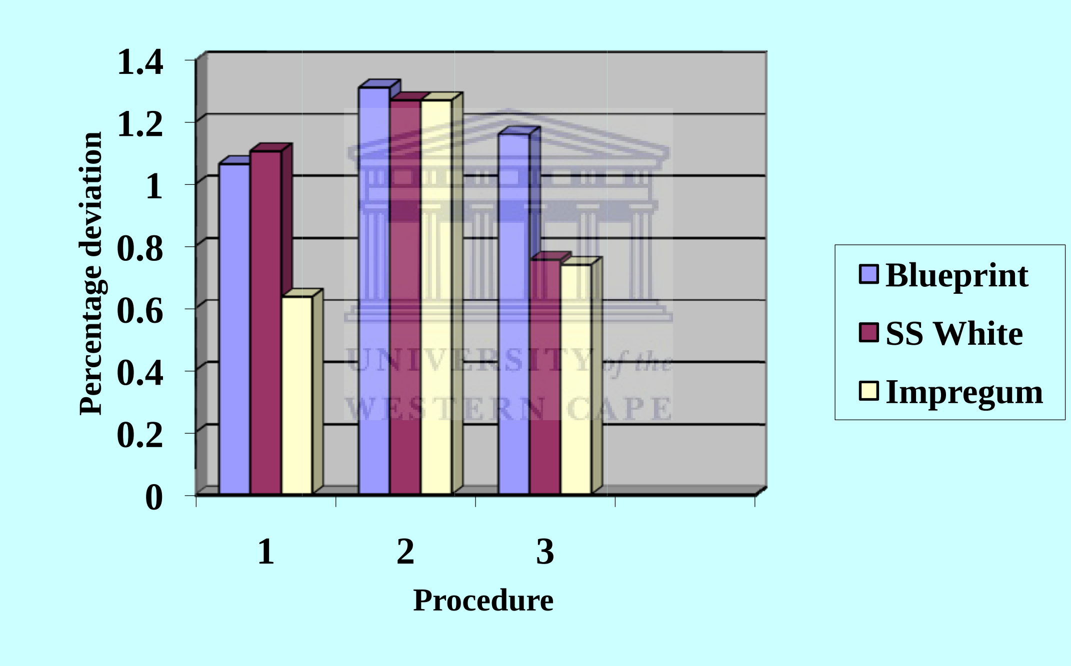

Fig 5.4 Summary of the percentage deviation of the gypsum models produced from the different impression materials and exposed to different disinfection regimens. (1- control, 2- immersion of impressions in 0.5% sodium hypochlorite and 3- microwave irradiation of casts).

CHAPTER SIX

DISCUSSION

Direct physical interaction between the dental clinic and the dental laboratory is intrinsic in the practice of general dentistry. It is also one of the areas most difficult to deal with from a cross-infection control point of view. Transmission of infected materials from the clinic to the laboratory not only exposed laboratory staff to risk but results in a high level of avoidable cross-contamination (Rowe and Forrest, 1978).

Several studies (Mansfield and White, 1991 Mitchell *et al*, 1997 and Sofou *et al*, 2002 b) have shown that micro-organisms can be recovered readily from stone casts separated from contaminated impressions. As a result of this, a number of systems have been proposed which aim to disinfect impressions satisfactorily and efficiently. Most of these systems rely on either spraying or immersing the contaminated impressions in disinfectants (ADA Council on Scientific Affairs and Council on Dental Practice, 1996). An alternative or additional approach to cast/impression disinfection is to decontaminate the cast produced from the impression by incorporating a disinfecting chemical into the gypsum at the time of mixing the gypsum (Abdelaziz, Combe and Hodges, 2005).

The disinfection process aims to eliminate micro-organisms from the surface of the impression. However, an undesirable side-effect of the disinfection process is the potential for a change in the dimensions of the impression that may be associated with a chemical or physico-chemical interaction between the set material and the disinfecting solution. The change of dimension of impression and gypsum models following immersion in disinfection solution has been the subject of a number of studies (Storer and McCabe, 1981, Herrera and Merchant, 1986, Thouati *et al*, 1996, Taylor *et al*, 2002 and Martin, Martin and Jedynakiwicz, 2007).

In 1991, the ADA Council on Dental Materials, Instruments, and Equipment recommended immersion disinfection of irreversible hydrocolloid and polyether impressions either in hypochlorite, iodophor, or glutaraldehyde with a phenolic buffer. There has been no change in the recommended concentration and contact time of the sodium hypochlorite since then. Thus, in this study, 0.525% sodium hypochlorite was used for chemical disinfection, the impressions were immersed in the disinfectant solution for 10 minutes. Polyether and irreversible hydrocolloid were chosen as the impression materials because of their hydrophilic nature and sensitivity to disinfection procedures. Zinc- oxide eugenol paste was selected because it is difficult to disinfect in sodium hypochlorite solutions as the two materials are incompatible (Storer and McCabe, 1981).

The most recognized specifications for the behavior of alginate and non-aqueous elastomeric impression materials are those set by ANSI/ADA. These specifications detail a range of testing procedures, which include amongst others, techniques for the measurement of dimensional change after setting. The technique as specified by ANSI/ADA and relies on direct measurements of an impression of a machined ruled block using the impression material under investigation. Measurements are taken with a travelling microscope, having a micrometer stage with an accuracy of 0.005mm. Some studies have used this method (Johansen and Stackhouse, 1987), while others have introduced modifications (Martin, Martin and Jedynakiwicz, 2007). Other acceptable methods of measuring the dimensional changes of a cast include measuring microscopes, micrometers, dial gauges and calipers (Taylor *et al*, 2002). The latter was used in this study with good reproducibility between readings of each linear measurement.

All the studies (Storer and McCabe, 1981, Taylor *et al*, 2002, Martin, Martin and Jedynakiwicz, 2007) evaluated the effect of disinfection regimen on the impressions or the subsequent models used the terms dimensional stability and dimensional accuracy interchangeably with no distinct line between the two. In this study, the term dimensional accuracy was used to refer to degree of changes from the master model in the gypsum models following the different disinfection procedures. All the measurements in the present study were carried out in the resultant models whether the impressions were immersed in disinfection solutions or the models were irradiated in a microwave oven.

6.1 Disinfection procedures

The mean percentage deviation of measurements recorded for the three different disinfection procedures produced comparable results. There was a statistically significant difference ($P < 0.05$) of the overall dimensional accuracy of models between the control group, sodium hypochlorite disinfection group and microwave irradiation group. The results of this study show that models treated with microwave irradiation present similar (Blueprint and Impregum) or improved (SS White) dimensional accuracy when compared to the models in the control group.

Immersion of impressions in sodium hypochlorite for 10 minutes appeared to significantly reduce the dimensional accuracy of the models produced from Blueprint (Cremix/De Trey, Dentsply, Germany) and Impregum (Impregum ™ F, 3M ESPE, Germany) impressions. The resultant models showed a greater degree of expansion when compared to the control group. Models produced from SS White (SS White Group, England) impressions immersed in sodium hypochlorite showed an insignificant linear expansion when compared to the models in the control group ($P = 0.897$).

Comparison of the percentage deviations obtained from models poured from impressions in the chemical disinfection group and the models in the microwave irradiation group showed greater dimensional accuracy in the latter group. The differences in the percentage deviation from the master model between the two groups were significant with models produced from SS White and Impregum impressions (P = 0.00).

None of the disinfection routines produced wildly unacceptable results, but clearly some results are better than others. It was interesting to observe how well the models produced from irreversible hydrocolloid, polyether and zinc- oxide eugenol impressions reacted to the alternative disinfection procedure with microwave irradiation, as the impressions were reported to be difficult to treat with sodium hypochlorite solutions as recommended by the ADA and CDC. It is difficult to relate the results of the present study to the literature since there are no available studies that investigate of the effect of microwave irradiation disinfection on the physical properties, and the dimensional accuracy in particular, of gypsum models or to compare the procedure with other methods of disinfecting impressions and models. However, the results of the present investigation do not furnish sufficient information as to all possible effects of microwave irradiation on gypsum casts. A separate study to investigate the effect of single and multiple irradiations on the physical properties of the casts should be designed to further explore this option of disinfection.

6.2 Materials

The results reported from this study compared favorably with other publications, although some studies have shown no dimensional changes following immersion disinfection of impressions and gypsum models. However, these groups of researchers used different brands of impression and gypsum materials and major differences in their methodology hampers the comparison.

6.2.1 Alginate (Blueprint, Cremix/De Trey, Dentsply, Germany)

Alginate impression material is inherently unstable (water based materials composed of 80% water), being susceptible to dimensional changes brought about by imbibition and syneresis (Donovan and Chee, 2004). Classically, it should be consigned to a 100% humid environment in its transport phase prior to casting in the laboratory.

The control group exhibited dimensional differences between 0.62% and 1.36% compared with the master model. The data indicated that the disinfecting treatment of impressions with sodium hypochlorite did cause changes in the subsequent models compared to the control group. The material/ disinfection interaction indicated a statistically significant difference, demonstrating that there was an interference of one factor with the other. These findings meet the expectation that immersion of irreversible hydrocolloid impressions in disinfectant solutions will adversely affect the dimensional accuracy of the subsequent models due to water imbibition by hydrocolloid impressions.

The dimensional changes observed with microwave irradiation of the casts took an intermediate position between the control and the sodium hypochlorite groups. Although there were no statistically significant differences between the models in the microwave irradiation group and the other groups, data indicated that models in the microwave irradiated group expressed a better dimensional accuracy than the models poured from impressions in the immersion disinfection group.

6.2.2 SS White (SS White Group, England)

Under the conditions of this experiment, the zinc-oxide eugenol paste impressions in the control group demonstrated poor dimensional accuracy. Models in the control group exhibited dimensional differences between 0.91% and 1.36% compared with the master model. The material exhibited a greater deviation from the master model than models produced from alginate impressions in the control group did. The finding was totally unexpected. It is widely believed that zinc-oxide eugenol impressions are accurate and dimensionally stable over time (Anusavice, 2007). One explanation for this dimensional inaccuracy is that impression making of the acrylic master model with SS White impression paste was extremely difficult. Impressions appeared to adhere to the master model and separated from the special tray. Although the use of a separating medium was beneficial, minor damages may have occurred during the separation process. However, this does not explain the greater dimensional accuracy observed with models in the microwave irradiation group.

The microwave irradiation group showed better behavior and greater accuracy with only 0.75% deviation from the master model compared with 1.17% and 1.27% deviation observed with the control group and immersion disinfection group respectively.

Beyond the expected, immersion in sodium hypochlorite did not affect the dimensional accuracy of models produced from SS White impressions. There was a slight expansion but it was statistically insignificant when compared to the control group.

6.2.3 **Impregum ^{TM} F (3M ESPE, Germany)**

According to the literature, polyether is one of the most difficult materials to disinfect (Anusavice, 2007). Polyether impressions are particularly sensitive to immersion in solutions. Polyether impression materials can absorb water from the atmosphere, and they swell over time due to water sorption (Donavan and Chee, 2004). As expected, the results indicated that the specimen models from impressions immersed in sodium hypochlorite showed a statistically significant expansion from the untreated control specimens. While casts irradiated in a microwave oven showed a dimensional accuracy similar to that exhibited by the control specimens.

The dimensional changes observed in this investigation for all the 3 impression materials were slightly higher than that observed in other studies (Taylor *et al*, 2002 and Martin, Martin and Jedynakiwicz, 2007). This can be partially due to the use of FujiRock (GC Fujirock® EP, GC Europe N.V) as the cast material. The chemical composition of the material seems to play an important part in the dimensional variations obtained. Heshmati and co-workers (2002) investigated the delayed setting expansion of different brands of type IV and V dental stone. They found that all the tested materials showed significant amounts of expansion after 2 hours in contrast to ADA specifications number 25 that indicates the final setting expansion of gypsum materials is completed 2 hours after mixing. Fuji Rock showed the highest setting expansion amongst type IV tested materials. The specimens expanded by 0.21% after 96 hours which was way higher than reported by the manufacturer (< 0.09%), with 71% of the expansion occurring after the first 2 hours, and continuing up to 96 hours (Heshmati *et al*, 2002).

In general, the results of this study compared favorably with the evidence in the literature. Although some studies indicated that immersion of impressions in sodium hypochlorite solutions resulted in dimensionally stable impressions and models, some degree of dimensional changes were observed even if they were not statistically significant. Comparison is difficult because each study has a unique compensation of different brands of impression materials, gypsum products, concentration of the disinfection solution and the exposure time. In the literature impressions immersed in sodium hypochlorite solutions ranged between 5.25%, 1% and 0.525% for a period of 18 hours, 16 hours, 30 and 10 minutes, which may have led to the great variability of the results obtained.

Yilmaz and co-workers (2007) indicated that immersion of polyether impressions in sodium hypochlorite solutions did not affect the stability of the impressions when compared with control group. The measurements of the polyether impression specimens were taken after 24 hours after the polyether impressions were left to dry at room temperature. It is possible that during storage of impressions at room temperature a degree of water evaporation may have occurred which counteracted the expansion following immersion. The same concept is applicable to the Adabo *et al* (1999) study where the impressions were left on the work bench for 20 minutes before pouring the models.

Thouati *et al* (1996) observed an expansion of elastomeric impressions after 30 minutes immersion in sodium hypochlorite. Martin, Martin and Jedynakiewicz (2007) indicated the same effect after 10 minutes immersion in sodium hypochlorite for alginate and polyether impressions supporting the findings by Thouati *et al* (1996). In both studies a high concentration (5.25%) of sodium hypochlorite solution was used. Chlorine is a highly reactive element, and at such high concentrations, could react and fix the impression material, which would lead to additional expansion of the die stone.

Storer and MaCabe (1981) showed that sodium hypochlorite is incompatible with zinc- oxide eugenol paste impressions. They indicated that impressions showed unacceptable dimensional changes and surface deterioration of the resultant models. Their results are not applicable here because of the long immersion time of 16 hours.

6.3 Clinical implications

Measurements of the stone casts obtained from the different impression materials investigated in this study were relatively larger than the measurements of the master model. Although, these percentage alterations are small, they demonstrate that impression materials cannot fully reproduce the model area and suggest that these differences should be considered when preparing indirect restorations and partial denture metal frameworks. When disinfection procedures increase this alteration even more, this level of deviation may be unacceptable. Under the conditions of this study disinfection of the models with microwave irradiation showed a great degree of dimensional accuracy, which suggests that the procedure is safe to perform. The other advantage of microwave irradiation disinfection is the reproducibility of the procedure every time the model becomes contaminated between the dental office and the laboratory during the different processes in prosthesis construction.

When microwave irradiation disinfection of models is applied adequate packing and systemic use of standard barrier techniques for all who come into contact with the impressions during pouring of the models is recommended. Another practical matter is that the casts ought to be trimmed after disinfection to reduce the risk of cross-contamination for the laboratory personnel.

CHAPTER SEVEN

LIMITATIONS OF THE STUDY

7.1 Limitations of the current study include:

- The relatively small sample size may affect the accuracy of the results.
- The measuring device is only accurate to 0.01mm. A more precise measurement device would be beneficial. Since minor differences would affect the degree of model accuracy.
- The technique used is intra-operator variable dependent.
- Materials under investigation were limited to a small range of commercially available brands of impression materials and gypsum products.
- A weakness of the study might be that two independent experimental series were compared, chemical disinfection of impressions and microwave irradiation of models.
- The ability of the disinfection treatment evaluated in this study to destroy potential infectious micro-organisms was not evaluated in this study. Earlier studies established the effectiveness of the procedure.

CHAPTER EIGHT

CONCLUSION

8.1 Conclusion

Under the conditions of this study microwave irradiation disinfection of gypsum models seems to not have an adverse effect on their dimensional accuracy. The models irradiated in the microwave oven showed a similar deviation from the master model to that of models produced from impressions that were not disinfected (the control group).

Unexpectedly, models produced from SS White (SS White group, England) impressions and then exposed to microwave irradiation disinfection showed a significantly greater dimensional accuracy compared with models in the control group.

Within the limitations of this study it could be concluded that microwave irradiation is an appropriate method to disinfect gypsum models in terms of dimensional accuracy. Hence, the procedure seems to produce models at the same level of accuracy with the models produced from impressions that had not been disinfected. As such, the disinfection procedure will not adversely affect the fit of the final prosthesis.

8.2 Recommendations

- A similar study should be designed with a larger sample size and a larger variety of impression and gypsum materials (different products and different commercial brands).
- A more precise measuring device should be used.
- A separate study should be designed to evaluate the effect of microwave irradiation on the physical properties of gypsum models

(compressive and tensile strength, surface quality and detail reproduction).

- The effect of repeatable microwave irradiation on the physical properties of gypsum models should be evaluated.
- Another study should be designed to determine the maximum number of models that can be irradiated in a microwave oven to ensure acceptable disinfection.

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APPENDIX I

DATA COLLECTION SHEET

Sheet one: Actual measurements.

SAMPLE	PROCEDURE	A_B Mean	A_C Mean	A_D Mean	B_C Mean	B_D Mean	C_D Mean
Master model	-	33.41	34.13	29.95	40.23	22.69	22.83
A 01	1	33.82	34.51	29.97	40.59	23.19	23.44
A 02	1	33.48	34.61	30.27	40.86	22.99	23.06
A 03	1	33.39	34.66	30.22	41.05	23.38	22.79
A 04	1	33.49	34.44	30.3	40.62	23.27	23.22
A 05	1	33.55	34.48	30.3	40.84	23.23	22.95
A 06	1	33.58	34.29	30.42	40.77	22.91	23.07
A 07	1	33.27	34.39	30.02	40.87	23.07	23.05
A 08	1	33.42	34.35	30.29	40.77	23	23.04
A 09	1	33.46	34.3	30.26	40.44	22.89	22.98
A 10	1	33.59	34.48	30.27	40.67	22.89	23.16
A 11	2	33.78	34.46	30.47	40.59	23.24	23.11
A 12	2	33.66	34.65	30.11	40.76	23.31	23.16
A 13	2	33.62	34.65	30.15	40.97	22.73	23.16
A 14	2	33.59	34.54	30.41	40.97	23.32	23.18
A 15	2	33.78	34.66	30.25	40.67	22.97	23.21
A 16	2	33.7	34.5	30.29	40.97	23.03	23.16
A 17	2	33.74	34.27	30.37	40.8	23.16	23.43
A 18	2	33.5	34.52	30.34	40.8	23.17	23.03
A 19	2	33.7	34.33	30.12	40.69	23.15	23.21
A 20	2	33.9	34.48	30.42	40.81	23.03	23.03
A 21	3	33.75	34.82	30.46	40.61	22.81	22.98
A 22	3	33.58	34.48	30.55	40.74	23.03	23.39
A 23	3	33.54	34.64	30.34	40.79	22.98	23.35
A 24	3	33.55	34.47	30.24	40.85	23.04	23.37
A 25	3	33.71	34.46	30.07	40.86	22.99	23.12
A 26	3	33.57	34.6	30.02	40.85	22.83	23.24
A 27	3	33.8	34.48	30.13	40.7	22.84	23.1
A 28	3	33.75	34.53	30.14	40.7	22.97	23.12
A 29	3	33.82	34.43	30.27	40.83	22.75	23.02
A 30	3	33.75	34.61	30.3	40.87	22.85	23.23
B 01	1	33.71	34.69	30.21	40.97	22.86	23.16
B 02	1	34.09	34.54	30.16	40.88	22.96	23.16
B 03	1	33.5	34.5	30.16	40.88	22.81	23.12
B 04	1	33.64	34.7	30.18	40.94	23	23.06
B 05	1	33.83	34.3	30.38	40.66	23.17	22.9
B 06	1	33.62	34.59	30.35	40.95	23.02	23
B 07	1	33.78	34.56	30.23	40.67	22.95	23.1
B 08	1	33.66	34.59	30.14	40.86	22.8	33.07
B 09	1	33.83	34.49	30.24	40.91	22.78	23.1
	1						23.08
B 10		33.69	34.47	30.36	40.92	23.12	

B 11	2	33.72	34.38	30.11	40.75	23	22.99
B 12	2	33.78	34.53	30.34	40.81	23.58	23.44
B 13	2	33.72	34.66	30.25	40.94	22.83	23.37
B 14	2	33.6	34.34	30.28	40.87	22.55	23.46
B 15	2	33.7	34.36	30.06	40.97	23.1	23.26
B 16	2	33.68	34.43	30.1	40.84	23.14	23.05
B 17	2	33.78	34.56	30.34	40.8	23.14	23.21
B 18	2	33.95	34.58	30.35	40.57	22.82	22.98
B 19	2	33.7	34.57	30.11	40.9	23.06	23.17
B 20	2	33.85	34.6	30.41	40.68	22.94	23.05
B 21	3	33.8	34.48	30.04	40.52	23.03	23.01
B 22	3	33.54	34.46	30	40.65	22.99	22.93
B 23	3	33.68	34.44	30.25	40.68	22.85	23.26
B 24	3	33.8	34.55	30.14	40.52	22.76	23.1
B 25	3	33.51	34.68	29.53	40.75	22.92	22.83
B 26	3	33.6	34.35	29.98	40.58	22.84	22.72
B 27	3	33.58	34.31	30.06	40.42	22.89	22.79
B 28	3	33.66	34.38	29.64	40.61	22.79	22.87
B 29	3	33.55	34.26	29.88	40.55	22.89	22.59
B 30	3	33.37	34.5	30.27	40.57	22.81	22.94
C 01	1	33.56	34.32	30.07	40.7	22.57	22.97
C 02	1	33.45	34.35	29.74	40.49	22.78	22.99
C 03	1	33.32	34.25	29.83	40.6	22.94	22.75
C 04	1	33.39	34.34	29.81	40.59	22.96	22.78
C 05	1	33.51	34.37	29.74	40.63	22.74	22.83
C 06	1	33.53	34.43	29.67	40.75	22.84	22.73
C 07	1	33.47	34.47	29.89	40.76	22.88	22.96
C 08	1	33.5	34.5	30.01	40.74	22.96	22.92
C 09	1	33.42	34.43	29.92	40.63	22.97	22.77
C 10	1	33.82	34.49	30.02	40.73	22.85	22.94
C 11	2	33.54	34.62	29.89	40.74	22.93	22.95
C 12	2	33.7	34.49	30.06	40.64	22.99	23.25
C 14	2	33.76	34.42	29.97	40.83	23.06	22.86
C 15	2	33.69	35.2	31.21	40.78	22.81	23
C 16	2	34.05	34.35	30.43	40.81	22.87	23.1
C 17	2	34.03	34.56	30.17	40.83	23.26	23.05
C 18	2	33.77	34.56	30.12	40.95	23.12	23.13
C 19	2	33.76	34.71	30.23	40.82	22.97	23.28
C 20	2	33.81	34.66	30.39	40.94	23.3	22.77
C 21	3	33.67	34.46	30.11	40.68	22.96	22.92
C 22	3	33.65	34.15	29.72	40.73	22.87	22.99
C 23	3	33.73	34.24	30.03	40.83		
C 24	3	33.63	34.38	29.95	40.7	22.91	23.07
C 25	3	33.48	34.33	29.89	40.67	22.85	22.91
C 26	3	33.42	34.24	29.87	40.68	22.88	23.02
C 27	3	33.56	34.44	29.89	40.66	22.72	23.01
C 28	3	33.5	34.75	29.81	40.88	22.84	23.02

C 29	3	33.53	34.3	30.01	40.74	22.9	22.96
C 30	3	33.91	34.36	29.79	40.95	22.95	23.05

Sheet two: Percentage deviation from the master model

SAMPLE	PROCEDURE	PD_A_B	PD_A_C	PD_A_D	PD_B_C	PD_B_D	PD_C_D	Mean_PD
A 01	1	1.227177	1.11339	0.066778	0.894855	2.203614	2.671923	1.362956
A 02	1	0.209518	1.406387	1.068447	1.565996	1.322168	1.007446	1.096661
A 03	1	0.059862	1.552886	0.901503	2.03828	3.040987	0.175208	1.294788
A 04	1	0.239449	0.908292	1.168614	0.969426	2.556192	1.708279	1.258375
A 05	1	0.419036	1.025491	1.168614	1.516281	2.379903	0.525624	1.172492
A 06	1	0.50883	0.468796	1.569282	1.342282	0.96959	1.051248	0.985005
A 07	1	0.419036	0.761793	0.233723	1.590853	1.674747	0.963644	0.940633
A 08	1	0.029931	0.644594	1.135225	1.342282	1.366241	0.919842	0.906353
A 09	1	0.149656	0.498096	1.035058	0.521999	0.881446	0.65703	0.623881
A 10	1	0.538761	1.025491	1.068447	1.093711	0.881446	1.445466	1.008887
A 11	2	1.107453	0.966891	1.736227	0.894855	2.423975	1.226456	1.392643
A 12	2	0.748279	1.523586	0.534224	1.317425	2.732481	1.445466	1.383577
A 13	2	0.628554	1.523586	0.66778	1.839423	0.176289	1.445466	1.04685
A 14	2	0.538761	1.201289	1.535893	1.839423	2.776554	1.533071	1.570832
A 15	2	1.107453	1.552886	1.001669	1.093711	1.234024	1.664477	1.275703
A 16	2	0.868004	1.08409	1.135225	1.839423	1.498457	1.445466	1.311778
A 17	2	0.987728	0.410196	1.402337	1.416853	2.071397	2.628121	1.486105
A 18	2	0.26938	1.14269	1.30217	1.416853	2.115469	0.87604	1.187101
A 19	2	0.868004	0.585995	0.567613	1.143425	2.027325	1.664477	1.142806
A 20	2	1.466627	1.025491	1.569282	1.44171	1.498457	0.87604	1.312935
A 21	3	1.017659	2.021682	1.702838	0.944569	0.528867	0.65703	1.145441
A 22	3	0.50883	1.025491	2.003339	1.267711	1.498457	2.452913	1.459457
A 23	3	0.389105	1.494287	1.30217	1.391996	1.278096	2.277705	1.35556
A 24	3	0.419036	0.996191	0.96828	1.541138	1.54253	2.365309	1.305414
A 25	3	0.897935	0.966891	0.400668	1.565996	1.322168	1.270258	1.070653
A 26	3	0.478899	1.377088	0.233723	1.541138	0.617012	1.795883	1.00729
A 27	3	1.167315	1.025491	0.601002	1.168282	0.661084	1.182654	0.967638
A 28	3	1.017659	1.171989	0.634391	1.168282	1.234024	1.270258	1.082767
A 29	3	1.227177	0.878992	1.068447	1.491424	0.264434	0.832238	0.960452
A 30	3	1.017659	1.406387	1.168614	1.590853	0.705156	1.752081	1.273458
B 01	1	0.897935	1.640785	0.868114	1.839423	0.749229	1.445466	1.240159
B 02	1	2.035319	1.201289	0.701169	1.61571	1.189952	1.445466	1.364817
B 03	1	0.26938	1.08409	0.701169	1.61571	0.528867	1.270258	0.911579
B 04	1	0.688417	1.670085	0.767947	1.764852	1.366241	1.007446	1.210831
B 05	1	1.257109	0.498096	1.435726	1.068854	2.115469	0.306614	1.113645
B 06	1	0.628554	1.347788	1.335559	1.789709	1.454385	0.744634	1.216772
B 07	1	1.107453	1.259889	0.934891	1.093711	1.145879	1.182654	1.120746
B 08	1	0.748279	1.347788	0.634391	1.565996	0.484795	1.051248	0.972083
B 09	1	1.257109	1.054791	0.96828	1.690281	0.396651	1.182654	1.091628
B 10	1	0.838072	0.996191	1.368948	1.715138	1.895108	1.09505	1.318085
B 11	2	0.927866	0.732493	0.534224	1.292568	1.366241	0.700832	0.925704
		1.107453	1.171989	1.30217	1.44171	3.922433	2.671923	1.93628

B 12	2							
B 13	2	0.927866	1.552886	1.001669	1.764852	0.617012	2.365309	1.371599
B 14	2	0.568692	0.615294	1.101836	1.590853	0.617012	2.759527	1.208869
B 15	2	0.868004	0.673894	0.367279	1.839423	1.806963	1.883487	1.239842
B 16	2	0.808141	0.878992	0.500835	1.516281	1.983253	0.963644	1.108524
B 17	2	1.107453	1.259889	1.30217	1.416853	1.983253	1.664477	1.455682
B 18	2	1.616283	1.318488	1.335559	0.84514	0.57294	0.65703	1.057573
B 19	2	0.868004	1.289188	0.534224	1.665424	1.630674	1.489269	1.24613
B 20	2	1.316971	1.377088	1.535893	1.118568	1.101807	0.963644	1.235662
B 21	3	1.167315	1.025491	0.300501	0.720855	1.498457	0.788436	0.916843
B 22	3	0.389105	0.966891	0.166945	1.043997	1.322168	0.43802	0.721188
B 23	3	0.808141	0.908292	1.001669	1.118568	0.705156	1.883487	1.070886
B 24	3	1.167315	1.230589	0.634391	0.720855	0.308506	1.182654	0.874052
B 25	3	0.299312	1.611485	1.402337	1.292568	1.013662	0	0.936561
B 26	3	0.568692	0.644594	0.100167	0.869998	0.661084	0.481822	0.554393
B 27	3	0.50883	0.527395	0.367279	0.472284	0.881446	0.175208	0.48874
B 28	3	0.748279	0.732493	1.035058	0.944569	0.440723	0.175208	0.679388
B 29	3	0.419036	0.380897	0.233723	0.795426	0.881446	1.051248	0.626963
B 30	3	0.119725	1.08409	1.068447	0.84514	0.528867	0.481822	0.688015
C 01	1	0.448967	0.556695	0.400668	1.168282	0.528867	0.613228	0.619451
C 02	1	0.119725	0.644594	0.701169	0.646284	0.396651	0.700832	0.534876
C 03	1	0.26938	0.351597	0.400668	0.919712	1.101807	0.350416	0.565597
C 04	1	0.059862	0.615294	0.467446	0.894855	1.189952	0.21901	0.574403
C 05	1	0.299312	0.703194	0.701169	0.994283	0.220361	0	0.486386
C 06	1	0.359174	0.878992	0.934891	1.292568	0.661084	0.43802	0.760788
C 07	1	0.179587	0.996191	0.200334	1.317425	0.837373	0.569426	0.683389
C 08	1	0.26938	1.08409	0.200334	1.267711	1.189952	0.394218	0.734281
C 09	1	0.029931	0.878992	0.100167	0.994283	1.234024	0.262812	0.583368
C 10	1	1.227177	1.054791	0.233723	1.242854	0.705156	0.481822	0.824254
C 11	2	0.389105	1.435687	0.200334	1.267711	1.057735	0.525624	0.812699
C 12	2	0.868004	1.054791	0.367279	1.01914	1.322168	1.839685	1.078511
C 14	2	1.047591	0.849692	0.066778	1.491424	1.630674	0.131406	0.869594
C 15	2	0.838072	3.135072	4.207012	1.367139	0.528867	0.744634	1.803466
C 16	2	1.915594	0.644594	1.602671	1.44171	0.793301	1.182654	1.263421
C 17	2	1.855732	1.259889	0.734558	1.491424	2.51212	0.963644	1.469561
C 18	2	1.077522	1.259889	0.567613	1.789709	1.895108	1.31406	1.317317
C 19	2	1.047591	1.699385	0.934891	1.466567	1.234024	1.971091	1.392258
C 20	2	1.197246	1.552886	1.469115	1.764852	2.688409	0.262812	1.48922
C 21	3	0.77821	0.966891	0.534224	1.118568	1.189952	0.394218	0.830344
C 22	3	0.718348	0.058599	0.767947	1.242854	0.793301	0.700832	0.713647
C 23	3	0.957797	0.322297	0.267112	1.491424			
C 24	3	0.658485	0.732493	0	1.168282	0.96959	1.051248	0.76335
C 25	3	0.209518	0.585995	0.200334	1.093711	0.705156	0.350416	0.524188
C 26	3	0.029931	0.322297	0.267112	1.118568	0.837373	0.832238	0.56792
C 27	3	0.448967	0.908292	0.200334	1.068854	0.132217	0.788436	0.591183
C 28	3	0.26938	1.816584	0.467446	1.61571	0.661084	0.832238	0.94374

C 29	3	0.359174	0.498096	0.200334	1.267711	0.925518	0.569426	0.63671
C 30	3	1.496558	0.673894	0.534224	1.789709	1.145879	0.963644	1.100651

APPENDIX II

MICROWAVES

Microwaves are very short waves of electromagnetic energy that travel at the speed of light (186,282 miles per second). Microwaves used in microwave ovens are in the same family of frequencies as the signals used in radio and television broadcasting.

Microwave chemistry is the science of applying microwave irradiation to chemical reactions. Microwaves act as high frequency electric fields and will generally heat anything with a mobile electric charge. Polar solvents are heated as their component molecules are forced to rotate with the field and lose energy in collisions. Semiconducting and conducting samples heat when ions or electrons within them form an electric current and energy is lost due to the electrical resistance of the material.

The theory of electromagnetic energy can be illustrated by what happens when a pebble is tossed into a quiet pond. The pebble striking the still surface causes the water to move up and down in the form of ripples, or waves, that radiate in ever-widening circles over the surface of the pond. These waves, which move up and down at right angles to the direction they are traveling, are called transverse waves. Microwaves are examples of transverse waves.

A Phenomenal Force

Electromagnetic radiation begins with a phenomenon that occurs when electric current flows through a conductor, such as a copper wire. The motion of the electrons through the wire produces a field of energy that surrounds the wire and floats just off its surface. This floating zone or cloud of energy is actually made up of two different fields of energy, one electric and one magnetic. The electric and magnetic waves that combine to form an electromagnetic wave travel at right angles to each other and to the direction of motion. If the current flowing through the wire is made to oscillate at a very rapid rate, the floating electromagnetic field will break free and be launched into space. Then, at the speed of light, the energy will radiate outward in a pulsating pattern, much like the waves in the pond. It is theorized that these waves are made up of tiny packets of radiant energy called photons. Streams of photons, each carrying energy and momentum, travel in waves like an undulating string of cars on a speeding roller coaster.

As illustrated by the frequency spectrum shown below, microwaves used in microwave ovens, similar to microwaves used in radar equipment, and telephone, television and radio communication, are in the *non-ionizing* range of electromagnetic radiation. Non-ionizing radiation is very different from ionizing radiation. Non-ionizing radiation is very different because of the lower frequencies and reduced energy, it does not have the same damaging and cumulative properties as ionizing radiation. Microwave radiation (at 2450 MHz) is non-ionizing, and in sufficient intensity will simply cause the molecules in matter to vibrate, thereby causing friction, which produces the heat that cooks the food.

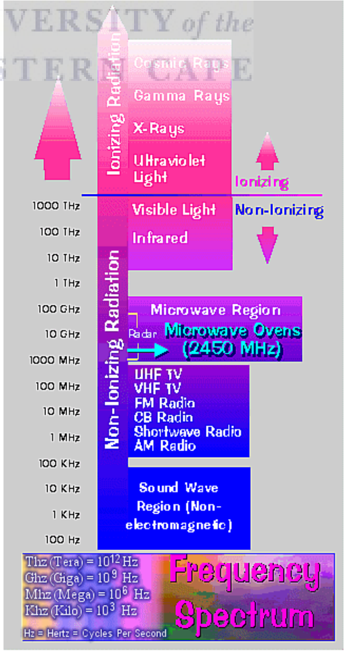

Figure II.1: Frequency spectrum of microwaves.

A microwave oven consists of:

- a high voltage transformer, which passes energy to the magnetron
- a cavity magnetron,
- a magnetron control circuit (usually with a microcontroller),
- a waveguide, and
- a cooking chamber

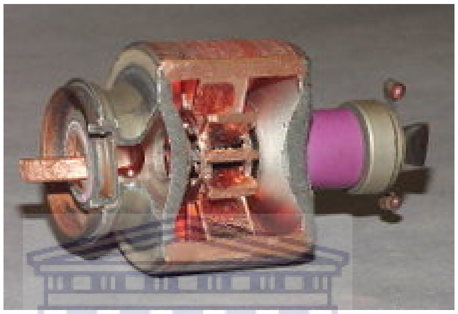

Figure II. 1: Magnetron with section removed (magnet is not shown)

A microwave oven works by passing nonionizing microwave radiation, usually at a frequency of 2.45 GHz (a wavelength of 12.24 cm), through the objects.Water, fat, and other substances absorb energy from the microwaves in a process called dielectric heating. Many molecules (such as those of water) are electric dipoles, meaning that they have a positive charge at one end and a negative charge at the other, and therefore rotate as they try to align themselves with the alternating electric field induced by the microwaves. This molecular movement creates heat as the rotating molecules hit other molecules and put them into motion.

Microwave heating is able to heat the target compounds without heating the entire furnace or oil bath, which saves time and energy. It is also able to heat an object throughout the volume (instead of through its outer surface), in theory producing more uniform heating. However, due to the design of most microwave ovens and to absorption by the object being heated, the microwave field is usually non-uniform and localized superheating occurs. Some compounds absorb microwave radiation differently than others. This selectivity allows some parts of the object being heated to heat more quickly or more slowly than surrounding parts.

A common misconception is that microwave ovens heats objects from the "inside out". In reality, microwaves are absorbed in the outer layers of food in a manner somewhat similar to heat from other methods. The misconception arises because microwaves penetrate dry nonconductive substances at the surfaces, and thus often deposit initial heat more deeply than other methods. Depending on water content, the depth of initial heat deposition may be several centimeters or more with microwave ovens, in contrast to broiling (infrared) or convection heating, which deposit heat thinly at the food surface. Depth of penetration of microwaves is dependent on food composition and the frequency, with lower microwave frequencies penetrating better.

Efficiency

A microwave oven only converts part of its electrical input into microwave energy. A typical consumer microwave oven uses 1,100 W AC and produces 700 W of microwave power, an efficiency of 64%. The other 400 W are dissipated as heat, mostly in the magnetron tube. Additional power is used to operate the lamps, AC power transformer, magnetron cooling fan, food turntable motor and the control circuits. This waste heat, along with heat from the food, is exhausted as warm air through cooling vents.