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Survival of bacterial pathogens on vinyl chiropractic treatment beds

A dissertation submitted to the
Faculty of Health Sciences, University of Johannesburg,
as partial fulfilment for the Master’s Degree in Technology: Chiropractic by

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DECLARATION

I, Marni Kruger, declare that this dissertation is my own, unaided work. It is being submitted as partial fulfilment of the Master's Degree in Technology, in the program Chiropractic at the University of Johannesburg. It has not been submitted before for any other degree or examination in any other Technikon or University.

__________________________________
Marni Kruger

On the ________ day of the month of _________________ 2017.
DEDICATIONS

"Let me not be so vain to think that I am the sole author of my victories and victim of my defeats."

I dedicate this research to my parents and siblings, Gert, Ina, Wilmari and Dewald,

and to Lian,

my Constant

and my soulmate, Luchelle.
ACKNOWLEDGEMENTS

"Tell me and I forget, teach me and I may remember, involve me and I learn."

To my supervisors, Dr Chris Yelverton, Prof TG Barnard and Mrs Clarissa van der Loo and my statistician, Juliana van Staden.

Thank you.
ABSTRACT

Purpose: This research study was to determine the bacterial survival of bacterial strains associated with human infections on vinyl chiropractic treatment beds, with and without disinfection.

Method: Bacterial survival kinetics was used to determine the effect of natural, versus disinfection related die-off of the bacteria on vinyl chiropractic treatment beds.

Procedure: The study made use of three portable, vinyl chiropractic treatment beds, that was placed in an isolated room on campus. These beds were divided into six blocks using masking tape, signifying the three interventions tested and their controls. The blocks were further divided into four blocks, for the four time intervals tested. Four bacterial strains, *Klebsiella pneumonia*, *Staphylococcus aureus*, *Escherichia coli* and *Pseudomonas aeruginosa*, were applied to the beds, one strain per day, water, alcohol and a soap based product was used to clean and disinfect three of the blocks, the others were used as a control and to monitor the natural die-off of the strains. All data were recorded by the researcher and analysed by Statkon.

Results: The results indicated that there is no observable decrease in bacterial numbers over a six-hour period if no intervention is applied to the beds. The study also showed that alcohol and Distel are both equally effective disinfectants for vinyl chiropractic treatment beds. Both of them proved to cause a three-log$_{10}$ reduction within five minutes, with no bacterial growth in six hours.

Conclusion: Alcohol and Distel both proved to be effective disinfectants on these types of beds. Since there is no observable decrease of bacterial numbers over six hours, a cleaning and disinfection protocol for the vinyl chiropractic treatment beds is important to lower the risk of infection of
patients and practitioners. Finally, it is important to apply a disinfectant frequently, to avoid bacterial accumulation.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>DECLARATION</td>
<td>ii</td>
</tr>
<tr>
<td>AFFIDAVIT</td>
<td>iii</td>
</tr>
<tr>
<td>DEDICATIONS</td>
<td>iv</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>v</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>x</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>xi</td>
</tr>
<tr>
<td>LIST OF APPENDICES</td>
<td>xii</td>
</tr>
<tr>
<td>CHAPTER 1: INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Background and Chiropractic Profession</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Healthcare Associated Infections</td>
<td>1</td>
</tr>
<tr>
<td>1.3 Intervention Strategies</td>
<td>2</td>
</tr>
<tr>
<td>1.4 Aim</td>
<td>2</td>
</tr>
<tr>
<td>1.5 Outcomes</td>
<td>2</td>
</tr>
<tr>
<td>1.6 Benefits of the Study</td>
<td>2</td>
</tr>
<tr>
<td>CHAPTER 2: LITERATURE REVIEW</td>
<td>4</td>
</tr>
<tr>
<td>2.1 The Chiropractic Profession</td>
<td>4</td>
</tr>
<tr>
<td>2.1.1 Chiropractic treatment beds</td>
<td>4</td>
</tr>
<tr>
<td>2.1.2 Chiropractic Patients</td>
<td>6</td>
</tr>
<tr>
<td>2.2 Healthcare-associated Infections</td>
<td>7</td>
</tr>
<tr>
<td>2.2.1 Incidence and Impact</td>
<td>7</td>
</tr>
<tr>
<td>2.2.2 Factors Influencing Infection</td>
<td>8</td>
</tr>
<tr>
<td>2.2.2.1 Host Characteristics</td>
<td>8</td>
</tr>
<tr>
<td>2.2.2.2 Microbial Properties</td>
<td>11</td>
</tr>
</tbody>
</table>
2.2.2.3 Environmental Factors..............................................13

2.2.3 Pathogens Implicated in Healthcare-associated Infections .. 15
  2.2.3.1 Klebsiella pneumonia............................................19
  2.2.3.2 Escherichia coli..................................................19
  2.2.3.3 Staphylococcus aureus........................................19
  2.2.3.4 Pseudomonas aeruginosa.................................20

2.3 Intervention Strategies.................................................20
  2.3.1 Approach to Sterilisation and Disinfection......................20
  2.3.2 Sterilisation..........................................................21
    2.3.2.1 Moist Heat......................................................21
    2.3.2.2 Dry Heat.........................................................21
    2.3.2.3 Flash.............................................................22
    2.3.2.4 Low-temperature Sterilisation Techniques..............22
  2.3.3 Disinfection..........................................................23
    2.3.3.1 Alcohol..........................................................23
    2.3.3.2 Distel High Level Disinfectants for Labs..............27
  2.3.4 Factors Influencing Sterilisation and Disinfection..........29
    2.3.4.1 Micro-organism Factors.................................28
    2.3.4.2 Concentration of Disinfectants and Exposure Time.28
    2.3.4.3 Physical and Chemical Factors..........................29
    2.3.4.4 Organic Matter..............................................29
    2.3.4.5 Choosing an Appropriate Disinfectant Agent........29
  2.3.5 Suggested Protocol for Chiropractic Treatment Bed
    Disinfection..................................................................32
  2.3.6 Biocidal Textiles ....................................................32
LIST OF FIGURES

Figure 2.1 A typical chiropractic bed used within the University of Johannesburg Chiropractic Clinic.................................5

Figure 3.1 Example of what the portable chiropractic treatment beds looked like after the various blocks were measured and divided with the masking tape............................................35

Figure 3.2 Insertion of Count-Tact® agar plate into the Count-Tact® applicator ...............................................................36

Figure 3.3 Sampling with Count-Tact® plates and applicator..........................................................36

Figure 4.1 Graph showing the typical bacterial numbers obtained for the reference strains tested on the beds over a six-hour period ..................................................................................40

Figure 4.2 Graph showing the typical bacterial numbers obtained for the reference strains tested on the beds over a six-hour period after wiping of the bed with a paper towel.........................41

Figure 4.3 Graphs showing a) the percentage log_{10} and b) log_{10} reduction of the bacterial reference strains after treatment with 70% (v/v) alcohol..........................................................42

Figure 4.4 Graphs showing a) the percentage log_{10} and b) log_{10} reduction of the bacterial reference strains after treatment with Distel High Level Disinfectants for Labs..................46

Figure 4.5 Bacterial counts after treatment with alcohol (a) and with Distel (b). The organisms are indicated by the same symbol in the untreated control (green), wiping control (red) and test (black samples).......................................................48
LIST OF TABLES

Table 2.1  Affected Patients and Transmission of Common Healthcare-associated Infections………………………………………………16

Table 2.2  The Bactericidal Effect of Chemical Disinfectants…………………25

Table 2.3  Advantages and Disadvantages of Using Alcohol as a Surface Disinfectant ……………………………………………………28

Table 2.4  The ideal characteristics for surface disinfectants………………31

Table 2.5  Biocidal Textile Ingredients Proven to Limit Microbial Contamination………………………………………………………….32

Table 4.1  Results for the Friedman test when the control, alcohol and Distel treatments are compared……………………………………...42

Table 4.2  Results for the Wilcoxon test when the treatment, alcohol and Distel treatment times are compared……………………………..43

Table 4.3  Mann- Witney U test results when comparing the effectiveness of alcohol and Distel…………………………………47
LIST OF APPENDICES

Appendix A- Research Ethics Committee Approval Letter .................. 77
Appendix B- Permission Letter to Use the Chiropractic Training Room… 78
Appendix C- Consent Forms ......................................................... 79
Appendix D- Plagiarism report ..................................................... 81
Appendix E- Turnitin submissions information and similarity score...... 82
CHAPTER 1: INTRODUCTION

1.1 Background and Chiropractic Profession

Over the last 120 years Chiropractic has been made available in over 100 countries. It is a leading profession concerned with diagnosis and non-allopathic treatment of neuromusculoskeletal conditions (Chapman-Smith, 2008; Meeker and Haldeman, 2002). Chiropractors make use of treatment beds, that are typically covered in cloth or vinyl with patients treated on the beds whilst lying on their backs or abdomens. In the past, it has been proven that these beds may act as vectors for the transmission of potentially harmful pathogens (Bidero, Prakash and Bergin, 2006; Evans, Ramcharan, Floyd, Globe, Ndetan, Williams and Ivie, 2009; Evans, Breshears, Husbands and Rupert, 2007). This being known, only a small number of practitioners have a cleaning protocol they use routinely (Puhl, Reinhart, Puhl and Selinger, 2011).

1.2 Healthcare Associated Infections

One in seven patients entering South African hospitals will be subjected to a healthcare associated infection (Revelas, 2012). There are a couple of factors that influence infection, and the likelihood of it being transmitted: the general health of the patient, the microbial properties of the pathogens and the environment in which it finds itself (Parija, 2009). In the list of organisms that cause infections in healthcare environments, a few bacterial species are to blame, and include *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* (Hidron, Edwards, Patel, Horan, Sievert, Pollock and Fridkin 2008). It has been shown that some of these organisms may persist on environmental surfaces from half an hour up to 16 months (Williams, Avery, Killham and Jones, 2005; Wilks, Michels and Keevil, 2005; Scott and Bloomfield, 1990; Abrishami, Tall, Bruursema, Epstein and Shah, 1994).
1.3 Intervention Strategies

In the approach to cleaning and disinfection, the Centres of Disease Control and Prevention have used the Spaulding classification to predict whether an object will act as a vector in the case of contamination; critical, semi-critical and noncritical (Spaulding, 1972). There are many methods of disinfection that may be implemented once it is determined how critical disinfection of the object in question is. In the case of vinyl chiropractic treatment beds, a noncritical item, they should be cleaned with a soap based product to remove all organic matter and thereafter disinfection should follow (Evans, Breshears, Campbell, Husbands and Rupert, 2007). The recommendation on frequency of disinfection ranges between three times in a day, or after each patient (Evans, Breshears, Campbell, Husbands, Rupert 2007; Evans, Ramcharan, Floyd, Globe, Ndetan, Williams and Ivie, 2009). There are factors that may influence the effectiveness of disinfection agents, this needs to be kept in mind when choosing an appropriate agent (CDC, 2008).

1.4 Aim

This research study aimed to determine the bacterial survival of four bacterial reference strains associated with human infections on vinyl chiropractic treatment beds, with and without disinfection.

1.5 Outcomes

This study aims to demonstrate if any microbial death occurs, with and without treatment over the span of six hours on vinyl chiropractic treatment beds.

1.6 Benefits of the Study

Possible benefits of this study are as follows:

- The demonstration of the bacteria survival on vinyl chiropractic beds, to highlight the importance of a routine cleaning regime.
• To illustrate whether alcohol and/or soap based cleaning products should be recommended for cleaning the vinyl treatment beds.

• Aid the research needed to understand the possible spread of pathogens in clinical settings in the field of Chiropractic.
CHAPTER 2: LITERATURE REVIEW

2.1 The Chiropractic Profession

Chiropractic, is a profession concerned with the treatment of neuromusculoskeletal conditions, by primarily making use of joint manipulation to treat these conditions. Chiropractors focus particularly on joint dysfunction and the effect it has on the general health of patients, by performing joint, muscle and soft tissue examination (Chapman-Smith, 2008; Meeker and Haldeman, 2002).

The role of Chiropractic in the treatment of neuromusculoskeletal conditions in the healthcare is debatable since they have attributes of primary health care practitioners, however, many categorise it to limited medical professionals (Meeker and Mootz, 2005). The term integration is used when a medical practitioner adopts scientifically proven complementary and alternative (CAM) methods to treat patients (Snyderman and Weil, 2002). These models include exercise, diet and other methods of prevention, complementing conventional medicine and setting a new paradigm (Bell, Caspi, Schwartz, Grant, Gaudet, Rychener, Maizes and Weil, 2002). Alternatively, a multidisciplinary practice may give patients the best of both worlds (Meeker and Mootz, 2005).

2.1.1 Chiropractic treatment beds

Typical chiropractic beds (seen in Figure 2.1) are covered in cloth or vinyl. Vinyl has been proven to limit bacterial survival over seven days when inoculated with vancomycin-resistant enterococci (Bidero, Prakash and Bergin, 2006). In comparison, material or non-porous coverings pose a greater risk of harbouring bacteria than vinyl (Noskin, Bednarz, Suriano, Reiner and Peterson, 2000; Evans, Campbell, Husbands, Breshears, Ndetan and Rupert, 2008), the capacity to retain oxygen and moisture in conjunction with the ideal temperature conditions between the skin and the
textiles provide a perfect environment for bacterial proliferation (Noble, 1981).

Figure 2.1  A typical chiropractic bed used within the University of Johannesburg Chiropractic Clinic.

Past research conducted on chiropractic treatment beds have indeed revealed that they were contaminated with pathogenic microbes and allergens, such as Gram-positive and -negative cocci and bacilli and Methicillin-resistant *Staphylococcus aureus* (MRSA), including standard fungi, primarily on the headrests, armrests and thoracoabdominal portions of the beds (Bidero, Prakash and Bergin, 2006; Evans, Ramcharan, Floyd, Globe, Ndetan, Williams and Ivien, 2009; Evans, Breshears, Husbands and Rupert, 2007). These areas are most likely affected due to the position of the patient during treatment.

Patients are positioned on their stomachs with faces resting on paper towel covered headpieces, or on their backs, during the average 30-minute consultation. The paper towels prevent skin secretions, discharges from the nose and mouth and make-up to come into contact with the treatment bed. It does not act as an effective barrier against transmission of bacteria, as the bacteria may pass through the paper towel onto the bed (Evans, Breshears, Campbell, Husbands and Rupert, 2007).

In a study to determine the attitude towards bed disinfection, most Chiropractors acknowledged that treatment beds could act as a horizontal transmitter of disease. They were also in favour of disinfecting the beds to
prevent this. Only 38% of those surveyed reported a routine cleaning protocol, and 27% cleaned on a weekly basis. In a similar study done with chiropractic students, between 66 to 80% of the students reported rarely or never cleaning their treatment beds (Puhl, Reinhart, Puhl and Selinger, 2011). This thus poses a risk to patients, especially immune compromised or vulnerable, of contracting potentially harmful infections from chiropractic treatment beds.

2.1.2 Chiropractic Patients

According to locally performed research at the Durban University of Technology, the patients attending their chiropractic teaching clinic had similar characteristics to international research (with regards to patients’ age, gender, occupation and main complaint) (McDonald, 2014; Mahomed, 2007).

It is indicated that patients that receive treatment by Chiropractors are most likely to be female, middle aged, white and employed at the time of treatment (Al-Windi, 2004; Ailliet, Rubinstein and de Vet, 2010; Barnes, Powell-Griner, McFann and Nahin, 2004; Fleming, Rabago, Mundt and Fleming, 2007; Mahomed, 2007; Lishchyna and Mior, 2012; Coulter and Shekelle, 2005; French, Charity, Forsdike, Gunn, Polus, Walker, Chondros and Britt, 2013 and Thoresen, 2006).

Nahin, Dahlhamer, Taylor, Barnes, Stussman, Simile, Blackman, Chesney, Jackson, Miller and McFann (2007) stated that patients who make use of complementary and alternative medicine, like Chiropractic, are more likely to have positive health behaviours. This is measured by the CDC by using five variables: leisure time activity, smoking status, drinking status, body weight status and whether the patient had a flu vaccine in the last year (Adams and Schoenborn, 2006). Thus, patients who exercised regularly, described themselves as former smokers, current or former drinkers and those of normal weight were more likely to make use of complementary or alternative medicine (Nahin, Dahlhamer, Taylor,
Barnes, Stussman, Simile, Blackman, Chesney, Jackson, Miller and McFan, 2007). This shows that the typical chiropractic patients do not have the typical characteristics that make them fall victim to healthcare associated infections.

2.2 Healthcare-associated Infections

The Centre of Disease Control and Prevention defines healthcare-associated infections (HAI) as a condition resulting from the presence of an infectious agent, or its toxin. The infection arises during stay at a health care facility, or 48-hours after discharge. There must be no evidence that indicates that the infection was present, or in the incubation period at the time of the patient’s admission to the facility. Infections acquired by visitors or staff are also considered as healthcare-associated infections (Horan, Andrus and Dudeck, 2008; Moor and Ferguson, 2006). The rate of infection within healthcare facilities varies greatly among the different departments (Shook, 1995; Vincent, 2003).

2.2.1 Incidence and Impact

An international study conducted in over 75 countries demonstrated that infection specifically within intensive care units is a major cause of morbidity and mortality globally. There was also a clear correlation between the length of patient stay and infection; it also demonstrated the inverse relation between the amount of health care expenditure by the government and the prevalence of infection (Vincent, Rello, Marshall, Silva, Anzueto, Martin, Moreno, Lipman, Gomersall, Sakr and Reinhart, 2009). Longer hospital stays are indicative of greater financial burden. In 2007 the district hospital in Limpopo had 609 patients that stayed longer than the average length of stay, most commonly due to infection (Madale, Hoque and van der Heever, 2011).

Around one in seven patients entering the doors of South African hospitals are at risk of acquiring a healthcare-associated infection (Revelas, 2012).
A study at Groote Schuur Hospital (Cape Town, South Africa) attempted to describe the distribution of organisms and of antibiotic susceptibility from blood cultures. It determined that within a period of a year, and 653 incidents of illness, 73% were hospital acquired (McKay and Bamford, 2015).

2.2.2 Factors Influencing Infection

The factors that determine whether exposure to a microbe will result in prolonged colonisation involve host characteristics, microbial properties and environmental factors. Nutritional and environmental conditions must be favourable for microbes to survive (Parija, 2009). These factors can be divided into three categories; host characteristics, microbial properties and environmental factors.

2.2.2.1 Host Characteristics

The following are factors that contribute to the health and wellbeing of patients; age, gender, ethnicity, health status and socioeconomic standing:

Geriatric patients fall victim to healthcare-associated infections due to immune senescence, changes in non-adaptive immunity (thinning skin and diminished cough reflex), presence of chronic disease (atherosclerosis, cancer and diabetes mellitus) and functional impairment (immobility and incontinence) (Eilers, Veldman-Ariesen, Haenen and van Benthem, 2012). All these in conjunction with the use of chronic medication will increase older patients’ susceptibility to developing infections (Strausbaugh, 2001). Neonates are susceptible to healthcare associated infection due to a lack of acquired immunity; they are exposed to pathogens in the maternal genital tract along with the postnatal environment. Among these, premature babies who possess underdeveloped innate immunity and delicate, easily damaged skin, are at higher risk (Zaidi, Huskins, Thaver, Bhutta, Abbas and Goldmann, 2005; Srivastava and Shetty, 2007). In a study to determine gender and age differences in healthcare-associated

Male gender has been proven to be a risk factor for the development of a healthcare-associated infection. This may be due to greater bacterial colonisation on male skin or weak adherence of wound dressing due to coarser, thicker hair. The fact that no specific gender in younger children has a higher risk for development of healthcare associated infections supports the second hypothesis (Cohen, Choi, Hyman, Furuya, Neidell and Larson, 2013). Females demonstrate marked humoral and cellular immune responses and a better developed thymus during procreative years in comparison to males (Taub, 2008).

Asian and Hispanic patients admitted to hospital in America have higher rates of healthcare associated infections compared to white patients. The study concluded that it is unlikely due to economic and educational disparities, rather due to language barriers, indicating that the rate of healthcare-associated infections may be directly or indirectly associated with poor communication (Bakullari, Metersky, Wang, Eldridge, Eckenrode, Pandolfi, Jaser, Galusha and Moy, 2014).

Obesity, heavy smoking, alcoholism, malnutrition, trauma, chronic/underlying diseases, such as diabetes mellitus, HIV-positive status (Heinzelmann, Scott and Lam, 2002; Moor and Ferguson, 2006; Budd and Shipton, 2004) and cancer affecting lymphocytes or granulocytes, or patients undergoing irradiation therapy (Friese, 2007) have all been implicated as risk factors for developing healthcare-associated infections.

Malnutrition is a known risk factor, this might be due to the fact that undernourished patients have elongated hospital stay, but it is unknown whether improving dietary intake will prevent healthcare-associated infections (Thibault, Makhlouf, Kossovoy, lavindrasana, Chikhi, Meyer, Pittet, Zingg and Pichard, 2015). In comparison, obesity or a higher body
mass index (Smits, Lopes, Das, Kumar, Cliby, Smits, Bekkers, Massuger and Galaal, 2016) is a risk factor most likely due to under-dosing of antimicrobial medication in the treatment or prevention of healthcare-associated infections (Huttunen, Karppelin and Syrjänen, 2013). Innate and adaptive immunity is affected by vitamin A deficiency and may account for vitamin A-deficient patient mortality. The natural regeneration of mucosal linings, neutrophil and macrophage function is deficient. Development of T-helper and B-cells are impeded, affecting the anti-body mediated immune function (Stephensen, 2001).

During physical and psychological stress, neuroendocrine factors such as growth hormone (GH), prolactin and nerve growth factor (NGF) are released, resulting in diminished natural killer cell activity and antibody production, as well as reactivation of dormant viral infections (Taub, 2008).

Compared to a sedentary lifestyle, moderate physical activity may support immune function, whereas excessive, high-intensity exercise may impair immune function (Matthews, Ockene, Freedson, Rosal, Merriam and Hebert, 2002; Ronsen, Pedersen, Oritsland, Bahr and Kjeldsen-Kragh, 2001; Ekblom, Ekblom and Malm, 2006), this may be linked to increased levels of stress hormones (Moynihan, Callahan, Kelley and Campbell, 1998).

Cigarette smoking affects the innate immunity. Ciliary epithelium undergoes histological changes, decreasing the ability of airway clearance. It leads to a decreased amount of surfactant release, altered T-lymphocyte function and diminished phagocytic function of macrophages leading to susceptibility to infection (Mehta, Nazzal and Sadikot, 2008; Arnson, Shoenfeld and Amital, 2010).

Alcohol abuse has many effects on the immune system. It affects the mononuclear phagocytes, impairing adherence and phagocytosis (Bermudez and Young, 1991). It also decreases the number of dendritic cells, impairing virus-specific adaptive immune responses of CD4+ and
CD8+ lymphocytes (Laso, Vaquero, Almeida, Marcos and Orfao, 2007; Siggins, Bagby, Molina, Dufour, Nelson and Zhang, 2009). By interfering with the expression of natural killer cell proteins, alcohol abuse affects the ability to destroy target cells and may facilitate alcohol-associated tumour development (Pan, Sun, Jaruga, Hong, Kim and Gao, 2006).

Williams, Mohammed, Leavell and Collins (2010) have speculated that patients with lower socioeconomic standings are more likely to be exposed to social and physical stressors. During 2006 almost half of the population in South Africa was subjected to poverty, which goes hand in hand with poor sanitation and healthcare services (Charasse-Pouélé and Fournier, 2006). Higher prevalence of HIV has been reported in patients of poor socioeconomic standings (Wabiri and Taffa, 2013).

2.2.2.2 Microbial Properties

Frequent portals of entry are where mucous membranes and skin meet, i.e. gastrointestinal-, respiratory-, genital- and urinary tracts. Skin usually provides a barrier, but cuts and burns may allow bacteria to overcome this primary defence against infection (Carroll, Miller, Morse and Mietzner, 2015).

The definition of transmission is any mechanism by which an organism is spread to another person or through the environment. Direct transmission of infection has three modes:

- Immediate or direct transmission through a susceptible portal of entry, such as touching or sexual intercourse.
- Contact of a host-susceptible tissue with an agent such as a rabid animal or contaminated soil.
- Trans-placental infection (Miller and Diep, 2008; Davis, Iverson, Baron, Vasse, Silbergeld, Lautenbach, and Morris, 2012; Scott, Duty and Callahan, 2008; Wagenvoort, Sluijsmans and Penders, 2000; Oller and Mitchell, 2009).
Three primary mechanisms of indirect transmission are vehicle-borne, vector-borne and biological.

- Vehicle borne describes any material, such as food or water that may be used to transport infectious agents into a suitable portal of entry. Bedding and other objects are also included. *S. aureus* has been proven to survive on inanimate objects for prolonged periods. This indicates that surfaces may act as vectors for spread of MRSA (Miller and Diep, 2008; Davis, Iverson, Baron, Vasse, Silbergeld, Lautenbach, and Morris, 2012; Scott, Duty and Callahan, 2008; Wagenvoort, Sluijsmans and Penders, 2000; Oller and Mitchell, 2009). A case-control study found that household environments were more likely to be contaminated with MRSA, if a household member had a recent MRSA infection, compared to control households (Uhlemann, Knox, Miller, Hafer, Vasquez, Ryan, Vavagiakis, Shi and Lowy, 2011).

- Vector-borne transmission may be mechanical, such as in the case when an insect carries the infectious agent on its feet or in its gastrointestinal tract, this form of transmission does not require multiplication of the agent in the insect (Bennett, Dolin and Blaser, 2014).

- Biological transmission requires propagation, cyclic development or a combination is required for biological indirect transmission to occur. Finally, airborne transmission occurs with aerosol dissemination to a suitable portal of entry of a host, this excludes droplets that settle out causing direct transmission of infection (Bennett, Dolin and Blaser, 2014).

To infect a host, a certain number of pathogens are required; this may vary between species of pathogens (Leggett, Cornwallis and West, 2012). Pathogenicity is defined as the capability of a pathogen to produce disease in a host. They do so using their virulence, i.e. the degree of pathogenicity. The outcome will depend on the virulence of the pathogen and the resistance of the host. Bacteria have determinants of virulence, firstly adherence factors, bacteria that don’t attach to host cells will get
swept away by mucous. They have specific surface molecules that allow them to overcome net surface charge. Secondly, the bacteria must invade the host cells, for example through junctions in the epithelial cells. Once inside, the bacteria may disperse or multiply and produce toxins, either entero- or endotoxins or, alternatively, enzymes (Carroll, Miller, Morse and Mietzner, 2015; Todar, 2008). The number of micro-organisms needed to cause infection in immunocompromised patients are even less, making them extremely susceptible to HAI (Hayden, Blom, Lyle, Moore and Weinstein, 2008).

Due to the amount of antibiotics used to treat diseases over the last 70 years, along with the amount of anti-microbial agents used in household and agricultural settings, many multi-resistant organisms such as, *P. aeruginosa* and *Klebsiella* spp. have become of interest for healthcare workers (Levy, 2002). As with antibiotics, the anti-microbial agents cause gene mutations leading to strains that are more resistant to sterilisation and disinfection (Russell, 1997; Russell, 1998; McDonnell and Russell, 1999), however other research states that there is no evidence to suggest this (Gilbert and McBain, 2003).

### 2.2.2.3 Environmental Factors Influencing Survival of Microorganisms

Humidity may influence the survival kinetics of pathogens. Bacterial behaviour in humidity is linked to the design of the bacterial wall. Gram-negative bacteria, such as *Pseudomonas* spp., *Enterobacter* spp. and *Klebsiella* spp. (Tang, 2009; Kramer and Assadian, 2014), have double-layer lipid structures, containing a peptidoglycan layer in their cell walls, making them vulnerable to dry conditions, and requiring higher humidity to survive. Gram-positive pathogens, such as *S. aureus* (McDade and Hall, 1964) can tolerate dry conditions better (Kramer and Assadian, 2014). In order to create a biofilm, which allow bacteria to be 500 times more
tolerant to anti-microbial agents (Costerton, Lewandowski, Caldwell, Korber and Lappin-Scott, 1995), a certain amount of humidity is needed (Flemming and Wingender, 2010).

Bacterial biofilms are populations of bacteria that alter their phenotypes to adhere to surfaces, or one another. This causes them to have altered growth patterns, and to be resistant to drugs and anti-microbial agents (Costerton, Lewandowski, Caldwell, Korber and Lappin-Scott, 1995). Biofilms are essential in the persistence of bacteria on environmental surfaces (Donlan, 2002; Bryers, 2008). However, it has not been determined whether it affects risk of transmission (Vickery, Deva, Jacombs, Allan, Valente and Gosbell, 2012).

Microorganisms have optimum temperatures for growth, lower temperatures tend to inhibit growth by limiting the metabolism and higher temperatures causes denaturing of enzymes and proteins, and thus have a biocidal effect (Harisha, 2006). Temperatures above 24⁰C tend to limit the airborne bacterial survival rate (Tang, 2009).

Of the swabs taken 66% from constantly used machines in a healthcare environment were found to harbour potentially harmful pathogens in a 2006 review. Most of the isolates were normal skin flora, that have the ability to cause illness is immunocompromised patients (Schabrun and Chipchase, 2006). Machines such as interferential current, ultrasound and the coupling medium used along with it may act as horizontal transmitters of disease in a chiropractic practice (Ohara, Itoh and Itoh, 1998; Schabrun, Chipchase and Rickard, 2006).

Infection transmission with myofascial dry needling has considerably decreased since emphasis has been placed on disposable needles and disinfection of skin prior to the procedure. This therapy applied by trained physicians has been described as safe, with serious complications rarely reported (Unverzagt, Berglund and Thomas, 2015; Vulfsons, Ratsmanksy and Kalichman, 2012).
2.2.3 Pathogens Implicated in Healthcare-associated Infections

According to the 2008 research study done in America, the 10 most common pathogens that cause HAI (84%) are: coagulase-negative staphylococci, *Staphylococcus aureus*, *Enterococcus* spp, *Candida* spp, *Escherichia coli*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *Enterobacter* spp, *Acinetobacter baumannii*, and *Klebsiella oxytoca* (Hidron, Edwards, Patel, Horan, Sievert, Pollock and Fridkin 2008). The CDC lists the following as healthcare-associated infections: *Acinetobacter*, *Burkholderia cepacia*, *Clostridium difficile*, *Clostridium sordellii*, Enterobacteriaceae (carbapenem-resistance), Gram-negative bacteria Hepatitis, Human Immunodeficiency Virus (HIV), Influenza, *Klebsiella* spp, Methicillin-resistant *Staphylococcus aureus*, *Mycobacterium abscessus*, *Norovirus*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, Tuberculosis (TB), Vancomycin-intermediate *Staphylococcus aureus* and Vancomycin-resistant *Staphylococcus aureus*, Vancomycin-resistant *Enterococci* spp (VRE) (CDC, 2008). A summary of some of the bacteria that persist on environmental surfaces, their transmission routes and affected patients is given in Table 2.1.

The bacteria used during the experiment will be discussed further:
### Table 2.1  Affected Patients and Transmission of Common Healthcare-associated Infections

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Affected patients</th>
<th>Transmission</th>
<th>Survival on Environmental Surfaces</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Acinetobacter</em></td>
<td>Extremely ill, hospital bound patients (Maragakis and Perl, 2008).</td>
<td>Spread by person-to-person contact and contaminated soil and water (Maragakis and Perl, 2008).</td>
<td>Three days to five months (Jawad, Snelling, Heritage and Hawkey, 1996; Wendt, Dietze, Dietz and Rüden, 1997; Neely, 2000; Webster, Towner and Humphreys, 2000).</td>
</tr>
<tr>
<td><em>Clostridium</em></td>
<td>Older patients on antibiotic treatment (Pépin, Valiquette, Alary, Villemure, Pelletier, Forget, Pépin and Chouinard, 2004).</td>
<td>Transmission occurs through faeces, and any surface that may come into contact with it (Pépin, Valiquette, Alary, Villemure, Pelletier, Forget, Pépin and Chouinard, 2004).</td>
<td>Three to five months (Kim, Fekety, Batts, Brown, Cudmore, Silva and Waters, 1981; Otter and French, 2008).</td>
</tr>
<tr>
<td><em>Klebsiella</em></td>
<td>Immunocompromised patients such as alcoholics (Carpenter, 1990).</td>
<td>Nasopharynx presence ranges from 1-6% in normal population (Davis and Matsen, 1974; Rosenthal and Tager, 1975).</td>
<td>Two hours to more than 30 months (Neely, 2000; Scott and Bloomfield, 1990)</td>
</tr>
</tbody>
</table>
Table 2.1 continued  Affected Patients and Transmission of Common Healthcare-associated Infections

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Affected patients</th>
<th>Transmission</th>
<th>Survival on Environmental Surfaces</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Escherichia coli</em></td>
<td>May cause meningitis in infants (Carroll, Miller, Morse and Mietzner, 2015).</td>
<td>Usually part of the normal intestinal microbiota, causes infection when it comes into contact with other tissues (Procop and Pritt, 2014; Carroll, Miller, Morse and Mietzner, 2015).</td>
<td>One and a half hours to 16 months (Williams, Avery, Killham and Jones, 2005; Wilks, Michels and Keevil, 2005; Scott and Bloomfield, 1990; Abrishami, Tall, Bruursema, Epstein and Shah, 1994).</td>
</tr>
<tr>
<td><em>Staphylococcus aureus</em></td>
<td>Known as AIDS defining infections causing recurrent pyogenic bacterial infections (Carroll, Miller, Morse and Mietzner, 2015).</td>
<td>The main sources of bacteria are shedding human lesions, human skin and respiratory tract (Carroll, Miller, Morse and Mietzner, 2015).</td>
<td>Seven days to seven months (Neely, 2000; Scott and Bloomfield, 1990; Kampf, Dietze, Große-Siestrup, Wendt and Martiny, 1998; Wagenvoort and Penders, 1997).</td>
</tr>
<tr>
<td>Bacteria</td>
<td>Affected patients</td>
<td>Transmission</td>
<td>Survival on Environmental Surfaces</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><em>Pseudomonas aeruginosa</em></td>
<td>Hosts with compromised defences, such as patients with neutropenia and cystic fibrosis patients (Carroll, Miller, Morse and Mietzner, 2015).</td>
<td>Present in moist environments in hospitals, colonize as saprophytes on normal individuals (Carroll, Miller, Morse and Mietzner, 2015).</td>
<td>Six hours – 16 months (Neely, 2000; Scott and Bloomfield, 1990; Kampf, Dietze, Große-Siestrup, Wendt and Martiny, 1998; Panagea, Winstanley, Walshaw, Ledson and Hart, 2005).</td>
</tr>
</tbody>
</table>
2.2.3.1 *Klebsiella pneumoniae*

*Klebsiella*, a Gram-negative bacillus (Bhatia and Ichhpujani, 2008) may cause meningitis, pneumonia, wound/surgical site-, and bloodstream infections. The most common type of infection is *K. pneumoniae*, seen in immunocompromised patients such as alcoholics (Carpenter, 1990). Nasopharynx presence ranges from 1-6% in normal population (Davis and Matsen, 1974; Rosenthal and Tager, 1975). *K. pneumoniae* affects the upper airways and right upper and lower lung lobes. Clinical features include fever, chills, coughing with tachypnoea and cyanosis. Production of thick bloody sputum is characteristic (Procop and Pritt, 2014).

2.2.3.2 *Escherichia coli* (*E. coli*)

*Escherichia coli* are Gram-negative non-spore forming bacteria (Bhatia and Ichhpujani, 2008), which is usually part of the normal intestinal microbiota, causes infection when it comes into contact with other tissues, such as urinary tract, causing urinary tract infections. Clinical features include severe abdominal cramps with bloody or non-bloody diarrhoea, *E. coli* is a leading cause of diarrhoea in infants in developing countries (Procop and Pritt, 2014; Carroll, Miller, Morse and Mietzner, 2015). *E. coli* may be eradicated by 60°C moist heat within half an hour (Bhatia and Ichhpujani, 2008).

2.2.3.3 *Staphylococcus aureus*

*Staphylococcus aureus* infections will affect every person at least once in their lifetime; it may cause pneumonia, meningitis, empyema, endocarditis, or sepsis. The main sources of bacteria are shedding human lesions, human skin and respiratory tract. In 20-50% of humans, nasal carriage of *S. aureus* occurs. The main concern is the rise of anti-microbial resistant strains of *S. aureus*, which is not limited to hospital settings only anymore (Carroll, Miller, Morse and Mietzner, 2015). In 46% of households with children diagnosed with methicillin-resistant *Staphylococcus aureus*
(MRSA), the strain was identified, most commonly from linen (18%). This may indicate that there is a risk of horizontal transmission in the chiropractic clinic if practitioners fail to wash towels used to cover beds (Fritz, Hogan, Singh, Thompson, Wallace, Whitney, Al-Zubeidi, Burnham, Fraser, 2014).

2.2.3.4 *Pseudomonas aeruginosa*

*Pseudomonas aeruginosa* is a healthcare associated pathogen that usually causes infection in hosts with compromised defences, such as patients with neutropenia. It causes infection of open wounds and burns causing blue-green pus. The infections are usually related to instruments used in medical procedures and may lead to sepsis if the microbe enters the blood stream. Due to the fact that *P. aeruginosa* thrives in moist conditions, special care should be taken with wet areas (Carroll, Miller, Morse and Mietzner, 2015), like in cases where chiropractors use sinks and moist heat during treatment.

2.3 Intervention Strategies

To reduce the risk of transmission of these abovementioned infections, intervention strategies should be put in place as it is known that disinfection and sterilisation reduces the likelihood of the transmission of HAI (Hayden, Bonten, Blom, Lyle, van de Vijver and Weinstein, 2006; Boyce, Havill, Otter, McDonald, Adams, Cooper, Thompson, Wiggs, Killgore, Tauman and Noble-Wang, 2008; Dancer, White, Lamb, Girvan and Robertson, 2009 and Gebel, Exner, French, Chartier, Christiansen, Gemein, Goroncy-Bermes, Hartemann, Heudorf, Kramer, Maillard, Oltmanns, Rotter and Sonntag, 2013).

2.3.1 Approach to Sterilisation and Disinfection

The Centre for Disease Control and Prevention uses the Spaulding Classification to determine the likelihood that an instrument would transfer infection in the case that it should be contaminated. The categories are
critical, semi-critical and non-critical (Spaulding, 1972). It has been proposed that treatment beds should be classified as non-critical or semi-critical since patients come into contact with it and could act as a vector for healthcare-associated infections (Evans, Breshears, Campbell, Husbands and Rupert, 2007). Special care should be taken when working with chemicals for sterilisation and disinfection, and the necessary precautions should be taken to prevent any harm to the user (Hansen, 1983). There are different methods of sterilisation and disinfection of objects and surfaces and the next sections discuss the uses for these methods, and whether they would be suitable in sterilisation or disinfection of vinyl chiropractic treatment beds.

2.3.2 Sterilisation

Sterilisation efficacy is achieved when repeat cultures are positive after disinfecting the surface that is being tested, or free of all viable organisms (Griffith, Cooper, Gilmore, Davies and Lewis, 2000; Sykes, 1965). The process of sterilisation destroys all microorganisms and may include methods of high and low temperature and liquid immersion (Rutala and Weber, 2013).

2.3.2.1 Moist Heat

Steam or moist heat allows for several changes within cells to achieve sterilisation. Breakdown of the cell DNA and RNA and protein coagulation occurs, causing alteration of the appearance of the cell (Block, 2001). Steam is harmless to the environment; it can be easily controlled and achieves quick results, and is effective through medical packaging. Keeping in mind that steam may cause damage, it cannot be used on heat sensitive instruments (Rutala and Weber, 2013).

2.3.2.2 Dry Heat

Dry heat, such as hot air ovens or high-vacuum infrared sterilisers can be used on equipment that is moisture sensitive, however, metal may
undergo oxidation at high temperature. Dry heat may take considerable time to achieve sterilisation (Darmady, Hughes, Jones, Prince and Tuke, 1961).

2.3.2.3 Flash

This method makes use of a gravity displacement steriliser, which is a modification of steam sterilisation, that uses 12.2-12.7 kg of pressure at 132°C for around three minutes, however, the time required is dependent on the object (Rutala, 1991). Post-sterilisation contamination is the main concern with flash sterilisation, since the objects are placed on a tray (Rutala, Gergen, and Weber, 1993), thus this method is primarily used for patient-care items that cannot be packaged (Mangram, Horan, Pearson, Silver and Jarvis, 1999).

The three abovementioned methods, all make use of heat to achieve the sterilisation, since the vinyl treatment beds are heat sensitive, it would not make a suitable method of sterilisation.

2.3.2.4 Low-temperature Sterilisation Techniques

New low temperature sterilisation techniques have been developed to overcome the limitations related to the other methods. Vaporised hydrogen peroxide, with and without gas plasma and ozone, affect the vital components of cells and has been proven to eliminate *Mycobacterium tuberculosis*. It is more effective in the vaporised form than liquid form (Kahnert, Seiler, Stein, Aze, McDonnell and Kaufmann, 2005; Schneider, 2013). Nitrogen dioxide gas disrupts cellular function by causing single-strand breaks in DNA, it has been shown to affect *Geobacillus stearothermophilus* (*G. stearothermophilus*) spores, but it has a degree of toxicity, making it an unfeasible method of disinfection for vinyl chiropractic treatment beds. It has shown practical feasibility in low resource environments (Schneider, 2013; Shomali, Opie, Avasthi and Trilling, 2015).
2.3.3 Disinfection

Table 2.2 below contains a summary of the bactericidal effect, and human toxicity, of different disinfectants. This table can be used to determine which disinfectants would be suitable to use on chiropractic treatment beds. Disinfectants commonly used on vinyl chiropractic treatment beds will be discussed in more detail in the following sections.

The disinfectants used in this study will be discussed in further detail.

2.3.3.1 Alcohol

Ethyl or isopropyl alcohol, when used at concentrations of 60-90%, is an effective anti-microbial, but it is not sporicidal. It does, however, prevent sporulation and germination of spores and thus should be considered for hard-surface disinfection and skin antiseptics, (Trujillo and Laible, 1970; McDonnell, 2007) but not for sterilisation of surgical materials (Nye and Mallory, 1932).

When diluted below 50%, the bactericidal, tuberculocidal, fungicidal, and virucidal properties of cleaning agents decline significantly. However pure alcohol should be avoided, since dilution with water facilitates diffusion through the cell membrane, ensuring the rapid denaturation of proteins (Morton, 1950; Block, 2001; McDonnell, 2007). Isopropyl is to some extent more effective against bacteria, and ethyl against viruses (Jokar, and Mohebbi, 2011; McDonnell, 2007). Alcohol promotes the microbial reduction of 99.9% to 99.99999%, the presence of the organic matter saliva on surfaces (Graziano, Graziano, Pinto, Bruna, Souza and Lascala, 2013), but it is not recommended as a surface cleaner (Crawford, Yu, Keegan and Yu, 2000).

Research suggests that spraying alcohol and then wiping the contaminated surface is not as effective as using alcohol impregnated wipes (Panousi, Williams, Girdlestone, Hiom and Maillard, 2009). Alcohol
is a suitable disinfectant for chiropractic treatment beds, since it dries quickly when applied to surfaces.
<table>
<thead>
<tr>
<th>Chemical</th>
<th>Bactericidal effect</th>
<th>Reference</th>
<th>Human toxicity</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glutaraldehyde</td>
<td>Very active</td>
<td>Russell, 1994</td>
<td>Sensory irritants, sensitisation of skin and respiratory system</td>
<td>Takigawa and Endo, 2006</td>
</tr>
<tr>
<td>Chemical</td>
<td>Bactericidal effect</td>
<td>Reference</td>
<td>Human toxicity</td>
<td>Reference</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------------------</td>
<td>---------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Peracetic acid</td>
<td>Very active</td>
<td>Hernandez, Metro, Puzo, Matas, Burgués, Vázquez, Castella and Ausina, 2003</td>
<td>Hazardous when it comes into contact with skin, eyes and respiratory tract</td>
<td><a href="https://www.sciencelab.com/msds.php?msdsId=9926439">https://www.sciencelab.com/msds.php?msdsId=9926439</a>. Last accessed 22/11/16</td>
</tr>
<tr>
<td>Phenolic compounds</td>
<td>Very active</td>
<td>Sagripanti, Eklund, Trost, Jinneman, Abeyta, Kaysner and Hill, 1997</td>
<td>Toxic if inhaled, may cause burns if it comes into contact with the skin</td>
<td><a href="http://www.unl.edu/cahoonlab/Phenol%20MSDS.pdf">http://www.unl.edu/cahoonlab/Phenol%20MSDS.pdf</a>. Last accessed 22/11/16</td>
</tr>
<tr>
<td>Chlorhexidine</td>
<td>Active</td>
<td>Jones, 1997</td>
<td>Direct contact of chlorhexidine may damage the eyes and skin. Chronic exposure may lead to liver damage.</td>
<td><a href="https://toxnet.nlm.nih.gov/cgi-bin/sis/search/a?dbs+hsdb:@term+@DOCNO+7196">https://toxnet.nlm.nih.gov/cgi-bin/sis/search/a?dbs+hsdb:@term+@DOCNO+7196</a>. Last accessed 22/11/16</td>
</tr>
</tbody>
</table>
Table 2.2 (continued) The Bactericidal Effect of Chemical Disinfectants

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Bactericidal effect</th>
<th>Reference</th>
<th>Human Toxicity</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary ammonium compounds (QAC)</td>
<td>Less active</td>
<td>Ioannou Hanlon and Denyer, 2007.</td>
<td>Exposure to diluted concentrations of QAC may cause mild irritation to the skin, it may also cause allergic reactions.</td>
<td><a href="http://www.inchem.org/documents/pims/chemical/pimg022.htm">http://www.inchem.org/documents/pims/chemical/pimg022.htm</a>. Last accessed 22/11/16</td>
</tr>
</tbody>
</table>
Table 2.3 Advantages and Disadvantages of Using Alcohol as a Surface Disinfectant (McDonnell, 2007; Rutala and Weber, 2014).

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost-effectiveness</td>
<td>Little or no sporcidal activity</td>
</tr>
<tr>
<td>Low odour and toxicity</td>
<td>Flammability</td>
</tr>
<tr>
<td>Bactericidal, tuberculocidal, fungicidal, virucidal</td>
<td>Use may lead to dryness and crack of surfaces and skin</td>
</tr>
<tr>
<td>Fast acting</td>
<td>Affected by organic matter</td>
</tr>
<tr>
<td>Noncorrosive</td>
<td>Slow acting against non-enveloped viruses</td>
</tr>
<tr>
<td>Non-staining</td>
<td>No cleaning properties</td>
</tr>
<tr>
<td></td>
<td>Evaporates rapidly, influencing contact time</td>
</tr>
</tbody>
</table>

2.3.3.2 Distel High Level Disinfectant for Laboratories

Distel High Level Disinfectant for Laboratories is a non-alcohol based disinfectant, containing Quaternary Ammonium Compounds, used for laboratory surfaces that is effective on glass, metal, plastic, rubber and fabric. It is bactericidal, tuberculocidal, fungicidal, virucidal and denatures DNA and RNA. It has been proven to cause a $5 \text{ Log}_{10}$ reduction with the following bacterial strains: *Enterococcus hirae*, *Escherichia coli*, MRSA, *Pseudomonas aeruginosa* and *Staphylococcus aureus*. (http://www.starlab.de/download/STARLAB-PDS-Distel-Microbiological-Tests-v3.pdf. Last accessed 22/11/16).
Quaternary Ammonium Compounds such as alkyl dimethyl benzyl ammonium chloride, alkyl didecyl dimethyl ammonium chloride and dialkyl dimethyl ammonium chloride are fungicidal, bactericidal, and virucidal against enveloped viruses only (Best, Sattar, Springthorpe and Kennedy, 1990; Ioannou Hanlon and Denyer, 2007; Terleckyj and Axler, 1987). The mode of action is inactivation of energy-producing enzymes and disruption of the cell membrane (Merianos, 2001).

2.3.4 Factors Influencing Sterilisation and Disinfection

2.3.4.1 Micro-organism factors (number/location, innate resistance)

Selection of suitable disinfectants or methods of sterilisation is paramount. It is known that most disinfectants, except for glutaraldehyde, are ineffective against spore forming bacteria. Spores, mycobacteria and Gram-negative organism’s resistance are closely linked to the cellular impermeability, preventing the biocides from reaching the target organelles (Russell, 1998). It is unclear whether resistance to antiseptics should be considered a clinical problem (Harbarth, Tuan Soh, Horner and Wilcox, 2014). It must be emphasised that the number of micro-organisms influences the effectiveness of disinfectants. In cases where larger numbers are present, such as sputum, the exposure time or amount of disinfectant used should be increased (Kortenbout, 1982).

2.3.4.2 Concentration of Disinfectants and Exposure Time

In general, with exception to iodophors, increased concentration of disinfectant will result in greater efficacy and reduced time required to achieve the goal of disinfection (Russell and McDonnell, 2000; Russell, 2004). The time required to achieve disinfection varies greatly between different chemicals, for example, 70% isopropyl alcohol takes five minutes to eradicate $10^4 \text{M. tuberculosis}$, whereas 3% phenolic requires up to three hours to achieve the same effect (Spaulding, 1968), thus choosing the appropriate agent is paramount.
2.3.4.3 Physical and Chemical Factors

Physical and chemical factors such as relative humidity, pH, temperature and water hardness, may influence the effectiveness of disinfection procedures. Water hardness, (presence of magnesium or calcium) results in the formation of insoluble precipitates that influence the effectiveness of disinfectants (CDC, 2008). Higher pH might influence the cidal activity of disinfectants by altering the cell surface, glutaraldehyde and quaternary ammonium compounds have increased effectiveness, whereas phenols, hypochlorites, and iodine have decreased effectiveness (Russell, 2004). Relative humidity above 50% effects ultraviolet germicidal irradiation, by reducing the inactivation rate (Peccia, Werth, Miller and Hernandez, 2001).

2.3.4.4 Organic Matter

The effectiveness of disinfectants could be reduced by organic matter (serum, blood, pus or other bodily secretions) that may act as a physical barrier, or cause chemical reactions that leave little or no active components (Lewis and Arens, 1995; Gélinas and Goulet, 1983; Muscarella, 1995; Russel and McDonnell, 2000; Kortenbout. 1982). This brings to light the importance of a proper cleaning procedure, ensuring that the surface is cleaned before disinfecting, along with the use of face paper.

2.3.4.5 Choosing an appropriate disinfectant agent

In order to choose an appropriate disinfection agent, one should keep in mind that the appropriate concentration to achieve maximum disinfection should be used. Failure to do so will result in survival of less-sensitive bacteria. It is important to remember that Gram-positive bacteria do not need as long to be eradicated, compared to Gram-negative organisms. Warmer temperatures also allow quicker chemical reactions, allowing the disinfectants to work better. Disinfectants with lower surface tension are of
greater value. Deterioration of disinfectants occur, thus should be replaced.

Keeping in mind the factors that would influence surface disinfection, outlined in the paragraphs above, Table 2.4 summarises what characteristics would make for an ideal disinfectant.

**Table 2.4 The ideal characteristics for surface disinfectants**

<table>
<thead>
<tr>
<th>Properties of ideal disinfectants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wide anti-microbial spectrum, especially against organisms known to cause HAI</td>
</tr>
<tr>
<td>Effective in the presence of organic matter</td>
</tr>
<tr>
<td>Compatible with other detergents and chemicals</td>
</tr>
<tr>
<td>Residual anti-microbial film should remain on the surface</td>
</tr>
<tr>
<td>Low cost or economical</td>
</tr>
<tr>
<td>Good cleaning properties</td>
</tr>
<tr>
<td>Remains wet, to ensure full contact time is reached</td>
</tr>
</tbody>
</table>

(Molinari, Gleason, Cottone and Barrett, 1987; Rutala and Weber, 2008).
2.3.5 Suggested Protocol for Chiropractic Treatment Bed Disinfection

After choosing the ideal agent, the following steps should be taken to lower the risk of infection transmission in chiropractic practices:

- Face paper should be used and discarded after each patient, as organic matter may decrease the effectiveness of surface disinfectants (Lewis and Arens, 1995; Gélinas and Goulet, 1983; Muscarella, 1995).

- If any organic matter, such as bodily secretions or make-up is present, the surface should be cleaned with soap and water.

- A surface disinfectant should be used as the final step (Evans, Breshears, Campbell, Husbands and Rupert, 2007).

Attaway, Fairey, Steed, Salgado, Michels and Schmidt (2012) showed that bacterial load decreased after initial cleaning and progressively increased to 30% of the initial concentration in the six-hour period that followed. The treatment beds should be sanitised before the first patient arrives, midday and at the end of the last session and clinical judgement should be used to warrant additional cleaning (Evans, Breshears, Campbell, Husbands, Rupert, 2007). The Chiropractic and Osteopathic College of Australasia recommend the treatment beds should be disinfected after each patient, even if face paper is used, since certain microbes such as *S. aureus* have been proven to be contained within the paper (Evans, Ramcharan, Floyd, Globe, Ndetan, Williams and Ivie, 2009).

2.3.6 Biocidal Textiles

Biocidal textiles could prove to have merit in the prevention of healthcare associated infection transmission in Chiropractic practices. Some examples of the ingredients are listed in Table 2.5.
## Table 2.5 Biocidal Textile Ingredients Proven to Limit Microbial Contamination

<table>
<thead>
<tr>
<th>Biocidal Textile Active Ingredient</th>
<th>Application</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cliniwave®</td>
<td>Cliniwave® treated polyester</td>
<td>O’Hanlon and Enright, 2009</td>
</tr>
<tr>
<td>Chitosan</td>
<td>Chitosan is covalently bonded to textile fibres</td>
<td>Lim and Hudson, 2004</td>
</tr>
<tr>
<td>Nanoscale silver and silver salts</td>
<td>Silver and silver salts are one of the ingredients used for anti-microbial textiles researched in this study</td>
<td>Windlera, Height and Nowack, 2013</td>
</tr>
<tr>
<td>Triclosan</td>
<td>Triclosan was applied to the material and exposed to different conditions such as urine to simulate wearing conditions</td>
<td>Orhan, Kut and Gunesoglu, 2007</td>
</tr>
</tbody>
</table>

Most studies show biocidal textiles reduce microbial contamination (Bearman, Rosato, Elam, Sanogo, Stevens, Sessler and Wenzel, 2012; Renaud, Dore, Frenery, Coronel and Dusseau, 2006; Taylor, Phillips and Hastings, 2009; Schweizer, Graham, Ohl, Heilmann, Boyken and Diekema, 2012). In a study to show the effectiveness of copper coated films in the prevention of MRSA transmission to bed sheets, the result showed that there was significantly more colony forming units on the non-film-coated control sheet areas (Niiyama, Sasahara, Mase, Abe, Saito and Katsuoka, 2013).
In conclusion, currently, most chiropractic beds are covered in vinyl, however, there is some merit in investigating these biocidal materials as coverings for these beds. It could contribute to the safety of the practitioner and patients.
CHAPTER 3: METHODOLOGY

3.1 Study Design

This study was an exploratory quantitative research study. Bacterial survival kinetics was used to determine the effect of natural, versus disinfection related die-off of the bacteria. An exploratory quantitative research method was best suited, the researcher had to determine what the trend would be and the effect it would have on the society. By using this method, the researcher may predict what the outcome would be in a clinical setting.

3.2 Sampling Protocol

Prior to performing the sampling, the researcher received an approval letter from the Research Ethics committee (REC-01-45-2016 seen in Appendix A). Permission from Dr Chris Yelverton (Appendix B) to make use of the training rooms and consent for the use of the chiropractic beds (Appendix C) was also obtained.

3.2.1 Sample Sites

The study made use of three (3) vinyl, portable chiropractic treatment beds, that were placed in the chiropractic training rooms of the University of Johannesburg, Doornfontein Campus. The beds were covered in the same vinyl to ensure reproducibility. The beds were cleaned with 70% (v/v) alcohol and tested to ensure that there were no bacteria on the bed before the study started. The beds were divided into six (6) blocks using masking tape as shown in Figure 3.1. The blocks were named CC (Control Control), CT (Control Treatment), AT (Alcohol Treatment), AC (Alcohol Control), DT (Distel Treatment) and DC (Distel Control). A pre-cut block of 10x10cm was used to further divide the six blocks into four, for each sample time interval (block 1-4). The role of each block is discussed below.
Figure 3.1 Example of what the portable chiropractic treatment beds looked like after the various blocks were measured and divided with the masking tape.

3.2.2 Sample Group Characteristics

The inclusion criteria for the beds used in this study were that the chiropractic treatment beds had to be covered in the same vinyl material. The beds were kindly made available for the study by students and kept in a confined room with limited access to students during the study period. After the experiments were completed, the beds were thoroughly cleaned and returned to the students once none of the four reference strains could be detected with culturing.

3.2.3 Sampling Procedure

The samples were collected using the Irradiated Count-Tact® 3P™ agar (CT3P) plates (Biomerieux, France) used for the routine monitoring of hospital clean rooms. Prior to using the beds for sampling, they were cleaned using 70% (v/v) ethanol and a baseline sample were taken. The paper towels used on the beds were also sampled in order to determine whether they had contributed to the contamination. All samples were taken using the Count-Tact® Applicator to ensure that an even and constant pressure of 500g was distributed over the whole plate for 10 seconds (Figure 3.2 and 3.3 – obtained from suppliers website). All plates were incubated for 72 hours at 33°C. Triplicate samples were collected.
from each bed and each organism for each time interval of disinfection protocol in order to have monitored for reproducibility and repeatability of the method.

Figure 3.2 Insertion of Count-Tact® agar plate into the Count-Tact® applicator

Figure 3.3 Sampling with Count-Tact® plates and applicator

3.2.3.1 Natural Die-off of Bacterial Strains

Over several days, one strain per day, the following strains, with specific starting concentrations, were applied to the beds using a sterile cotton swab (S. aureus (1.087 x 10^{15}), K. pneumoniae (6.69 x 10^{14}), E. coli (1.193 x 10^{15}) and P. aeruginosa (9.98 x 10^{14})). The CC block monitored the natural die-off of the strains. The CT block was wiped using sterile distilled water to determine whether wiping with paper towels (as done with the soap or alcohol in a clinic setting) would have caused any change in bacterial numbers. Samples were taken in intervals, initially, after the
solutions had dried (block 1), 30 minutes (block 2), two (2) hours (block 3) and six (6) hours (block 4).

3.2.3.2 Die-off related to disinfection protocols

The die-off related to the disinfection protocols was monitored in segments AT and DT (Figure 3.1). After application of the bacteria, the AT and DT blocks were cleaned using alcohol (AT) and Distel High Level Disinfectant for Laboratories (DT; Tristel, United Kingdom) and a paper towel, respectively. The AC and DC blocks were used as a control and they were sampled in the same manner as described above.

3.2.4 Bacterial strains growth and maintenance

American Type Culture Collection (ATCC) strains were used for all experiments. The strains were E. coli ATCC 25922, K. pneumoniae ATCC 31488, P. aeruginosa ATCC 10145 and S. aureus ATCC BAA-1026. For ease of use, type strains were grown on blood agar plates overnight at 37°C and used to prepare the bacterial solutions, with the specific volumes described in Section 3.2.3.1, for this study.

3.3 Bacterial testing and confirmation

At least 5 colonies from each strain were sampled at various stages to confirm that the correct strain was still being used. Bacterial isolates were plated onto 5% sheep blood agar plates (National Health Laboratory Services) to monitor the formation of haemolysis, and each strain was further characterised using the VITEK®2 Compact (bioMérieux, Inc.) by applying the methods and consumables specified by the manufacturer.

3.5 Data analysis

The data was entered into a Microsoft 2016 Excel sheet, and the statistical analysis was conducted in IBM SPSS Statistics 22 by STATKON. Analysis parameters used for the description of the number of bacteria on the beds were Chi-squared tests, nonparametric methods of analysis and matched
Wilcoxon test as described by Exley, Cumming and Ensink (2014). Graphs were drawn using GraphPad Prism v6.
CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

This chapter provides findings, analysis and observations based on the data collected by the researcher, in order to better understand the survival of bacterial pathogens on vinyl chiropractic treatment beds, with and without disinfection.

4.2 Natural die-off related to bacteria on vinyl treatment beds

In the researcher’s experience, there is little to no emphasis on treatment bed hygiene and the health risk it poses to the patient. Within the clinic, there is no cleaning and disinfection protocol in place. This is supported by a study done by Perdijk (in preparation, 2017) in the same clinic that showed the lack of clinician understanding for the need of bed hygiene and the isolation of potential human bacterial pathogens from the beds. This begged the question, is there any reduction in the bacterial numbers on these beds when they are not disinfected?

The first question we needed to understand was how bacterial reference strains would naturally act on the beds. According to the results of this study, as seen in Figure 4.1 there is no reduction over a six-hour period when no intervention protocol is applied to the beds. This is supported by Neely (2000) who reported that there is prolonged persistence of bacteria on plastic, similar to the vinyl material used in this research study. However, Bidero, Prakash and Bergin (2006), showed that vinyl has been proven to limit bacterial survival over seven days when inoculated with vancomycin-resistant enterococci. The survival may further be attributed to the room conditions in which the experiments took place. It was winter (with outside temperatures between 4-6°C) and there has been evidence to suggest that bacteria persist longer on surfaces in colder weather (Williams, Avery, Killham and Jones, 2005). Finally, the high inoculum used in the case of this study (average of four hundred fifty-five trillion, five
hundred billion bacteria) have been reported to the increased lifespan of bacteria (Neely, 2000; Costerton, Lewandowski, Caldwell, Korber and Lappin-Scott, 1995; Donlan, 2002; Bryers, 2008).

![Graph showing the typical bacterial numbers obtained for the reference strains tested on the beds over a six-hour period.](image)

**Figure 4.1** Graph showing the typical bacterial numbers obtained for the reference strains tested on the beds over a six-hour period.

What the researcher did observe in the clinic is that the students cover their treatment beds with a towel, and giving it a quick wipe with it before the next patient arrives. It is important to note that re-using towels of consecutive patients may increase the risk of infection transmission since material or non-porous coverings pose a greater risk of harbouring bacteria than vinyl (Noskin, Bednarz, Suriano, Reiner and Peterson, 2000; Evans, Campbell, Husbands, Breshears, Ndetan and Rupert, 2008). The capacity of the material to retain oxygen and moisture in conjunction with the ideal temperature conditions between the skin and the textiles provide a perfect environment for bacterial proliferation (Noble, 1981).

To test if this action could contribute to the reduction of bacterial numbers the theory was tested by wiping the bed with paper towels before taking the sample. In this study, it was clear that wiping the beds with sterile water and a paper towel caused a 20.2% reduction in the bacterial numbers after five minutes (Figure 4.2). This means, 1/5 of the bacteria is
removed by wiping the beds which already reduces the potential risk to the patients when using this method. This is not ideal but literature does show that a reduction of 99.9999% of the original microbial population can be achieved if wiping is performed in the presence of 70% alcohol (Graziano, Graziano, Pinto, Bruna, de Souza and Lascala, 2013).

![Graph showing the typical bacterial numbers obtained for the reference strains tested on the beds over a six-hour period after wiping of the bed with a paper towel.](image)

**Figure 4.2** Graph showing the typical bacterial numbers obtained for the reference strains tested on the beds over a six-hour period after wiping of the bed with a paper towel.

### 4.3 Intervention protocols

The options for cleaning the beds can be broadly categorised as washing it with soap and water, an alcohol disinfectant or a soap based disinfectant. Since washing with soap and water is not practical, and building on the work that showed addition of an alcohol to wiping can drastically reduce bacterial counts it was decided to focus on the two latter options (Neely, 2000; Costerton, Lewandowski, Caldwell, Korber and Lappin-Scott, 1995; Donlan, 2002; Bryers, 2008). For this section, we focused on comparing an alcohol solution with a commercial product, Distel High Level Disinfectants for Labs.

The use of 70% (v/v) alcohol solution resulted in a 99.9% or 3 log$_{10}$ reduction in all four references strains tested on the beds over a six-hour
period (Figure 4.3 a and b). Results published by Graziano, Graziano, Pinto, Bruna, Souza and Lascala (2013) agrees with our findings that 70% (v/v) alcohol is an effective disinfectant. More importantly, this reduction can be seen in the first 5 minutes showing that a quick treatment between patients would already reduce the potential risk to the patients.

a)

![Graph showing percentage log reduction of bacterial strains after treatment with 70% alcohol.](image)

b)

![Graph showing log reduction of bacterial strains after treatment with 70% alcohol.](image)

Figure 4.3 Graphs showing a) the percentage log$_{10}$ and b) log$_{10}$ reduction of the bacterial reference strains after treatment with 70% (v/v) alcohol.
The Friedman test in Table 4.1 showed that statistically alcohol causes effective disinfection. Research to compare the effectiveness of isopropyl alcohol and ethanol for the disinfection of medical devices in children’s ward and neonatal intensive care units showed that isopropyl alcohol is effective against *Staphylococcus* and *E. coli*, whereas the ethanol wasn’t (Jokar, and Mohebbi, 2011). It is known that alcohol has broad spectrum anti-microbial activity and more specifically, isopropyl alcohol is slightly more effective against bacteria compared to ethyl alcohol (McDonnell and Russell, 1999).

The Friedman test (Table 4.1) was used to determine if there was a statistically significant difference in the number of bacteria at the five time periods tested (Friedman, 1937). Having established the significance, it is ideal to use the Wilcoxon Signed Rank Test as a post-hoc test in order to determine which time period significantly differ from each other (Wilcoxon, 1945). A Bonferroni adjustment is used by utilising a stricter alpha level of less than 0.005 on every possible comparison.

The three intervention protocol statistical results compared in the two tables below:

**Table 4.1** Results for the Friedman test when the control, alcohol and Distel treatments are compared.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>N</th>
<th>Chi-Square</th>
<th>Degrees of freedom</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (water)</td>
<td>12</td>
<td>48000</td>
<td>4</td>
<td>0.00</td>
</tr>
<tr>
<td>Alcohol</td>
<td>12</td>
<td>36600</td>
<td>4</td>
<td>0.00</td>
</tr>
<tr>
<td>Distel</td>
<td>12</td>
<td>36733</td>
<td>4</td>
<td>0.00</td>
</tr>
</tbody>
</table>
The Wilcoxon test (Table 4.2) showed that initially (0-5 minutes) there is a significant decrease, followed by no significant decrease in bacterial number in the time intervals that followed (5-30; 30-120; 120-360 minutes), this was also clear in Figure 4.3 a and b above. Alcohols can thus be described as rapidly acting disinfectants (McDonnell, 2007; Rutala and Weber, 2014).

**Table 4.2** Results for the Wilcoxon test when the treatment, alcohol and Distel treatment times are compared.

<table>
<thead>
<tr>
<th>Time comparisons</th>
<th>Treatment</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Control (water)</td>
</tr>
<tr>
<td>5-0 min</td>
<td>0.002</td>
</tr>
<tr>
<td>30-0 min</td>
<td>0.002</td>
</tr>
<tr>
<td>120-0 min</td>
<td>0.002</td>
</tr>
<tr>
<td>360-0 min</td>
<td>0.002</td>
</tr>
<tr>
<td>30-5 min</td>
<td>0.002</td>
</tr>
<tr>
<td>120-5 min</td>
<td>0.002</td>
</tr>
<tr>
<td>360-5 min</td>
<td>0.002</td>
</tr>
<tr>
<td>120-30min</td>
<td>0.002</td>
</tr>
<tr>
<td>360-30 min</td>
<td>0.002</td>
</tr>
<tr>
<td>360-120 min</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Next, the Distel High Level Disinfectants for Labs, a disinfectant containing quaternary ammonium compounds, was tested as a soap based alternative. Again a 99.9% or 3 log₁₀ reduction (Figure 4.4 a) was observed for all reference strains tested on the beds over six hours after disinfection with Distel.
Similar to the 70% (v/v) alcohol treatment Distel caused the $3 \log_{10}$ reduction of the reference strains within five minutes after the disinfection (Figure 4.4 b). *K. pneumoniae* seems to initially have an increased reduction, in comparison with the other strains tested, followed by a slight regrowth of bacteria. The pattern difference seen with *K. pneumoniae* may be due to experimental error. It must be noted that, according to their website, Distel has not been proven to be effective against this organism (http://www.starlab.de/download/STARLAB-PDS-Distel-Microbiological-Tests-v3.pdf. Last accessed 03/11/16). Despite this, the product was still able to drastically reduce the number of cells after 5 minutes. Other factors such as the large number of bacteria added to the beds and the ability of *K. pneumoniae* produce biofilms to protect itself against the disinfectant may have contributed to the results (Seifi, Kazemian, Heidari, Rezagholizadeh, Saee, Shirvani, and Houri, 2016). Attaway, Fairey, Steed, Salgado, Michels and Schmidt (2012) showed that bacterial load decreased after initial cleaning and progressively increased to 30% of the initial concentration in the six-hour period that followed.
Figure 4.4 Graphs showing a) the percentage $\log_{10}$ and b) $\log_{10}$ reduction of the bacterial reference strains after treatment with Distel High Level Disinfectants for Labs.

The effectiveness of products containing quaternary ammonium compounds have been proven effective against *Bacillus* species, *Micrococcus* species coagulase-negative *Staphylococci* and *diphtheroids* on contaminated computer keyboards (Rutala, White, Gergen and Weber, 2006). This has been attributed to the mode of action (disruption of bacterial cell walls) of these types of disinfectants (Merianos, 2001).

According to the Friedman test, seen in Table 4.1, statistically, Distel has effective disinfection properties on vinyl chiropractic treatment beds. The Wilcoxon test in Table 4.2 showed us that the significant reduction occurred between zero and five minutes after disinfection. After the five-
minute mark, there is no significant decrease in the number of bacteria. Chloride-based disinfectants have shown to be fast acting (Rutala, White, Gergen and Weber, 2006).

When it is taken into account that the number of bacteria used in this study is disproportionate to the amount in an actual clinic setting, it is clear that when a 99.9% (Graziano, Graziano, Pinto, Bruna, Souza and Lascala, 2013), reduction occurs, the surface is almost completely disinfected. On average, there are 96 bacteria on a 25 cm² area of chiropractic treatment bed (Perdijk- in preparation, 2017). This number is reduced to 0.08 we assume that the same rate of disinfection would occur when alcohol is used.

4.4 Summary

From the above paragraphs, and the two figures below (Figure 4.5 a and b) it can be said that the two products have very similar effectiveness on the treatment beds. The three interventions are compared in two line graphs; it evidently shows the marginal difference wiping with a paper towel makes in comparison with using a disinfectant.

A Mann-Whitney U test (Table 4.3) was performed, and results showed that there was no statistically significant difference between the two products over any of the time intervals.
Figure 4.5  Bacterial counts after treatment with alcohol (a) and with Distel (b). The organisms are indicated by the same symbol in the untreated control (green), wiping control (red) and test (black samples).

In the clinic, the average time for a follow-up consultation is half an hour, there is about a five-minute window in which the disinfection should occur, between two consecutive patients. The fact that both the products tested were as effective at five minutes as it is at six hours and they both were rapidly acting (within five minutes), make them both suitable for vinyl chiropractic treatment bed disinfectants.
Table 4.3  Mann- Witney U test results when comparing the effectiveness of alcohol and Distel.

<table>
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<th>Time comparisons</th>
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<td>0 min</td>
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<tr>
<td>5 min</td>
<td>68000</td>
</tr>
<tr>
<td>30 min</td>
<td>70500</td>
</tr>
<tr>
<td>120 min</td>
<td>56000</td>
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<tr>
<td>360 min</td>
<td>54000</td>
</tr>
</tbody>
</table>

However, for the reasons outlined in chapter two, such as cost-effectiveness, ease of use and non-staining properties of alcohol (McDonnell, 2007; Rutala and Weber, 2014), it would be more likely that practitioners would prefer using alcohol as a treatment bed disinfectant. It should, however, be kept in mind that alcohol will not effectively remove the organic matter, and in the case where a practitioner should choose alcohol as a disinfectant, it should be paired with a cleaning product.
5.1 Conclusion

The aim of this research study was to determine the bacterial survival on vinyl chiropractic treatment beds, with and without disinfectants.

The results indicated that there is no observable decrease in bacterial numbers over a six-hour period if no intervention is applied to the beds. A practitioner should have an intervention protocol to lower the risk of infection to the patient (see Section 5.2 below).

The study also showed that alcohol and Distel are both equally effective disinfectants for vinyl chiropractic treatment beds. Both of them proved to cause a three-log$_{10}$ reduction within five minutes, with little bacterial growth in six hours. Due to the fact that alcohol is cost-effective, non-staining, fast-acting, non-corrosive, and readily available, practitioners would prefer using it. More importantly, the bacteria found on the treatment beds in the University of Johannesburg Chiropractic Clinic such as *Kocuria rosea*, *Micrococcus lylae*, *Gardnerella vaginalis* and *Brucella melitensis* among others (Perdijk- in preparation, 2017) are all susceptible to alcohol (70% ethanol) disinfectants (MSDS online safety data sheets – websites listed in reference list).

In light of all the above-mentioned findings, it is important to avoid bacterial accumulation and frequently disinfect vinyl chiropractic treatment beds to keep the number of bacteria (the remaining 0.04% after disinfection) low. However, choosing the appropriate agent is of the highest importance, since the Food and Drug Administration have banned antimicrobial soaps in the US market, stating that normal soaps are just as effective (https://www.unicef.org/malaysia/FAQ_on_Handwashing_with_Soap.pdf. Accessed: 22/11/16). These soaps commonly contain triclosan and triclocarbon, and it presents a risk of the propagation of antibiotic resistant

5.2 Recommendations for Application of Study

The researcher devised a hygiene protocol, taking into account previous research and this study to decrease the risk of infection transmission by vinyl chiropractic treatment beds:

1. Vinyl beds should be cleaned with a soap-based product at least once a day to remove any organic matter.

2. In between each patient, a disinfectant should be used, along with a change of face paper.

3. The use of the same towel over the treatment bed for all patients should be avoided. The practitioner should preferably use a new towel for every patient.

5.3 Recommendations for Future Studies

The following recommendations can be considered in order to improve the validation and statistical significance of the study:

- Testing of the cleaning protocol on more beds, to increase the number of samples.

- Compare the effectiveness of the disinfectant protocol on the different materials used to cover chiropractic treatment beds (eg. Vinyl compared to leather).

- Test the disinfection protocol on other bacterial strains commonly found in a clinical setting, including fungi.
• Take more samples in smaller time intervals initially (every minute) in order to effectively determine the death value. This will show the initial effectiveness of the disinfection protocols.

• Sample over eight hours, to simulate a typical day at a chiropractic office.

• Monitor the temperature and humidity in the room used for sampling, in order to give a better understanding of why there is the persistence of bacteria without intervention.

• Conduct the study in other seasons to determine the effect of warmer temperature on the natural die-off.
REFERENCES


Clostridium difficile environmental contamination and transmission in a healthcare setting. *Infection Control and Hospital Epidemiology*. 29 (8), 723-729.


Hayden, M., Blom, D., Lyle, E., Moore, C. and Weinstein, R. (2008). Risk of hand or glove contamination after contact with patients colonized with vancomycin-resistant enterococcus or the colonized patients’ environment. Infection Control and Hospital Epidemiology. 29 (2), 149-154.


Matthews, C., Ockene, I., Freedson, P., Rosal, M., Merriam, P. and Hebert, J. (2002). Moderate to vigorous physical activity and the risk of


TO WHOM IT MAY CONCERN:

STUDENT: KRUGER, M
STUDENT NUMBER: 201100710

TITLE OF RESEARCH PROJECT: Survival of Bacterial Pathogens on Vinyl Chiropractic Treatment Beds

DEPARTMENT OR PROGRAMME: CHIROPRACTIC

SUPERVISOR: Dr C Yeiverton
CO-SUPERVISOR: Prof TG Barnard
CD-SUPERVISOR: Mrs C van der Loo

The Faculty Academic Ethics Committee has scrutinised your research proposal and confirm that it complies with the approved ethical standards of the Faculty of Health Sciences, University of Johannesburg.

The REC would like to extend their best wishes to you with your postgraduate studies.

Yours sincerely,

[Signature]
Prof M Poggenpoel
Chair: Faculty of Health Sciences REC
Tel: 011 559 6689
Appendix B- Permission Letter to Use the Chiropractic Training Room

MEMORANDUM

To: Faculty of Health Sciences Higher Degrees
   From: Dr. C Yelverton

Date: 10 May 2015

Subject: Permission to utilize chiropractic treatment beds

The Department of Chiropractic hereby grants permission for Miss M Kruger to utilize room 6438 (Chiropractic training room) during the recess period of June 2015 for the purposes of her research.

If you require any further information, please contact me.

Regards,

Dr. C Yelverton
Head, Department of Chiropractic
Faculty of Health Sciences
University of Johannesburg
Tel: +27 11 690 6248
Email: chiro@uj.ac.za
Appendix C - Consent Forms

DEPARTMENT OF CHIROPRACTIC

RESEARCH CONSENT FORM

Survival of bacterial pathogens on Chiropractic treatment beds.

Please initial each box below:

☑️ I confirm that I have read and understand the information sheet dated June 2016 for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

☑️ I understand that my participation is voluntary and that I am free to withdraw from this study at any time without giving any reason and without any consequences to me.

☑️ I agree to take part in the above study.

Nelis de Bruijn
Name of Participant

Signature of Participant

10/07/16
Date

Moran Keugen
Name of Researcher

Signature of Researcher

10/07/16
Date
Appendix C - Consent Forms (continued)

DEPARTMENT OF CHIROPRACTIC

RESEARCH CONSENT FORM

Survival of bacterial pathogens on Chiropractic adjustment beds.

Please initial each box below:

☐ I confirm that I have read and understand the information sheet dated June 2016 for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

☐ I understand that my participation is voluntary and that I am free to withdraw from this study at any time without giving any reason and without any consequences to me.

☐ I agree to take part in the above study.

Date: 18/09/2016

Name of Participant: MORNI RAUGER
Signature of Participant: [Signature]

Date: 18/09/16

Name of Researcher: [Signature]
Signature of Researcher: [Signature]
Appendix D- Plagiarism report
# Appendix E - Turnitin submissions information and similarity score

**Turnitin Originality Report**

- **Document Viewer**

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Survival of bacterial pathogens on vinyl ch... By M KRUGER

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**References**
