THE EFFECT OF DENTAL UNIT WATERLINE ANTIMICROBIALS ON THE SHEAR BOND STRENGTH OF ORTHODONTIC BRACKETS

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Distribution Statement

ABSTRACT

THE EFFECT OF DENTAL UNIT WATERLINE ANTIMICROBIALS ON THE SHEAR BOND STRENGTH OF ORTHODONTIC BRACKETS

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Introduction: Dental unit waterline (DUWL) antimicrobials have been widely used to prevent the formation of microbial biofilms in the dental unit water delivery system. Although there are many DUWL antimicrobials on market, their effects on the bond strength of orthodontic brackets are still controversial. **Objectives:** To evaluate the effects of three common DUWL antimicrobials on the shear bond strength (SBS) of orthodontic brackets. **Methods:** A total of 56 extracted human molar teeth were randomly assigned to one of four groups (14 teeth/group): 1) Control group (deionized water); 2) ICX; 3) Listerine; or 4) Chlorohexidine. Each tooth was cleaned with pumice and then blindly rinsed with the assigned DUWL antimicrobial or control. A 15-second application of 37% phosphoric acid gel was applied and blindly rinsed again with the assigned DUWL antimicrobial or control, before the bonding of standard orthodontic brackets to each tooth. Within 30 minutes of bonding, the SBS of each bracket was blindly tested using a universal testing machine (MTS Insight). One-way Analysis of Variance (ANOVA) was used to analyze the differences in SBS between 4 groups. **Results:** The mean ±standard deviation of SBS were: 1) Control: 13.43±5.19 MPa; 2) ICX: 13.71±4.18 MPa; 3) Listerine: 12.25±3.99 MPa; and 4) Chlorohexidine: 13.19±4.94

MPa. One-way ANOVA did not identify significant difference among the groups (P = 0.849). **Conclusions:** The DUWL antimicrobials used in this study did not have a significant effect on the SBS of orthodontic brackets.

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LIST OF ABBREVIATIONS

1.	ADA	American Dental Association
2.	CDC	Centers for Disease Control and Prevention
3.	CFU	Colony Forming Unit
4.	DUWL	Dental Unit Waterline
5.	EPA	Environmental Protection Agency
6.	MPa	Megapascals
7.	OSAP	Organization for Safety and Asepsis Procedures
8.	SBS	Sheer Bond Strength

CHAPTER I: INTRODUCTION

In order to provide safe and effective dental care, infection control guidelines have been developed and are continuously updated. One aspect of dental infection control is dental unit waterline (DUWL) management. DUWL antimicrobials have been widely used to prevent the formation of microbial biofilms in the dental unit water delivery system. Although there are many dental unit waterline antimicrobials on market, their effects on the bond strength of orthodontic brackets have not been studied in depth (Hernandez-Feldpausch 2016, Bishara 2005).

So, why do we use waterline antimicrobials in the first place? In 2012, a case report by Ricci described how an 82-year-old woman died of Legionnaire's disease. The woman was healthy and had no existing disease prior to contraction. A subsequent investigation found that she had only left her house to attend two appointments at a dental office. Water samples from the dental office's tap water and dental unit waterlines were positive for the same strain of bacteria which was found in the patient's bronchial aspirate. The sample from the dental practice's cold-water tap contained 1.5×10^3 CFU/L, the sample from the tap of the dental unit waterline contained 4×10^3 CFU/L, and the sample from the high-speed turbine of the dental unit waterline contained 6.2×10^4 CFU/L (Ricci 2012). After the investigation, the dental unit waterline was disinfected with hydrogen peroxide and it received an additional shock chlorination. After this treatment, the contamination was controlled and the waterlines tested at less than 100 colony-forming units. To prevent cases like this from happening again, there are guidelines and recommendations regarding the proper maintenance dental unit waterlines.

The Environmental Protection Agency (EPA) has long evaluated the quality of our drinking water. Per EPA and Centers for Disease Control and Prevention (CDC) guidelines, the maximum amount is 500 colony-forming units per mL for drinking water (CDC.gov, EPA.gov). In 1995, the American Dental Association released a statement that recommended a goal of less than 200 colony-forming units per mL (ADA.org). According to the EPA, it can be expected that drinking water will have at least some contaminants. However, the aim of these regulations is to keep the amount of these contaminants at levels that are compatible with health (EPA.gov).

CHAPTER II: REVIEW OF LITERATURE

While complete elimination of biofilms and bacterial contamination is ideal, there is evidence that this may not be economically or technically feasible with present technology (OSAP.gov). So why do colony forming units develop? Colony forming units develop as a result of biofilm. Biofilm is a collection of heterotrophic, or mixed, gram-negative aerobic bacteria. Fungi, yeasts, protozoa, and amoebae may also be present in the biofilm. The microorganisms in biofilm function as a symbiotic colony (O'Donnell 2011).

The early colonizers of biofilm adhere to the tubing wall. Secondary colonizers commence growth, giving rise to the colony. The microorganisms excrete a protective polymeric matrix that affords protection to more pathogenic species. They also produce substances that may reduce the efficacy of disinfectants. The external surface layer of microorganisms in biofilm grows rapidly and some of these differentiate into robust planktonic or free-living cells designed to travel and initiate new biofilm colonies (O'Donnell 2011).

So why does biofilm develop? The cause of biofilm is multifactorial. One of the causes of biofilm development is water stagnation. Since water stagnates when dental waterlines are not in use, stagnation periods can encourage growth of biofilm (O'Donnell 2011).

The second cause is the flow of the water in the tubing. The flow of water in the tubing is laminar, which means the flow rate along the walls of the tubing is virtually zero. A thin immobile layer of fluid, called the hydrodynamic boundary layer, exists along the tubing walls. Microorganisms, especially bacteria, can use the hydrodynamic boundary layer to adhere to the tubing walls. This begins the biofilm colony lifecycle (O'Donnell 2011).

The third cause of biofilm is the failure of antiretraction valves in dental waterlines tubing. This can result in retraction of oral fluids into the system expanding the range of microorganisms in the biofilm (O'Donnell 2011).

Currently, there are a number of products on the market to reduce the amount of biofilm in dental unit waterlines. Certain devices aim to treat the source water while others are chemical products which aim to remove and prevent biofilm. Products such as Chlorhexidine, ICX tablets, Listerine, and DentaPure are a few examples of the chemicals that can be added to dental unit waterlines to reduce biofilm aggregation and formation.

The most extensively evaluated substances are chlorine compounds, including sodium hypochlorite, also known as household bleach. Unfortunately, many of the compounds which have shown promise in controlling biofilms can also corrode or degrade dental unit materials. Moreover, these chemicals can react with dental unit materials, or with the biofilms, to produce disinfectant by-products which may have unanticipated effects on dental materials, clients, and healthcare workers (Von Fraunhofer 2004).

In our efforts to decontaminate the water that we use, it is also important to know how these chemical products might influence the outcome of certain dental procedures. In the modern dental practice, composite resins are often bonded to teeth. Any addition of a foreign chemical might disrupt the bonding process.

In 2005 Bishara examined the effect of DentaPure, an iodine based compound, on the shear bond strength of orthodontic brackets. APC Victory Series orthodontic brackets (3M Unitek, Monrovia, CA) and the Transbond XT adhesive (3M Unitek) were used in the study. All teeth were debonded within 30 minutes from the initial time of bonding. A crosshead speed of 5.0 mm per minute was used. The mean shear bond strength for the iodine group was 6.5 ± 3.5 MPa and the control group was 4.7 ± 3.1 MPa. A t-test ($P = 0.09$) indicated that there were no significant differences between distilled water control group and the iodine group.

In 2001 Knight et al evaluated the effect of Scope mouth rinse on the shear bond strength of resin-based composite. In the study, a 5% dilution of Scope was compared to distilled water and untreated municipal water. Enamel and dentin bond strengths were tested in all three groups. Although the Scope mouth rinse group had the lowest mean shear bond strengths for both enamel and dentin bonds, there was no statistically significant difference among the groups.

These findings were similar to a 2001 study by Roberts et al. The 2001 study by Roberts also examined the effect of Listerine on shear bond strength. It was noted that Listerine had an adverse effect on shear bond strength. It was suggested that the essential oils such as thymol, menthol, and eucalyptol, which are active ingredients in Listerine might have contributed to the low shear bond strengths. It was noted that the mode of failure in both the Listerine group for Roberts and the Scope group for Knight was an adhesive failure at the resin-dentin interface.

A 2012 study by Sreenivasa examined the shear bond strength of composite and dentin. In the study the groups were: Group 1 (Distilled water), Group 2 (Alpron), Group 3 (CitriSil), and Group 4 (Chlorhexidine). Citrisil and Chlorhexidine groups showed affected bond strength whereas Alpron did not vary with bond strength. Citrisil is sodium citrate which forms citric acid when dissolved. It is speculated that the silver constituent could probably influence in decreasing the bond strength and another factor could be attributed to the interaction of the antimicrobials with either the conditioned dentin or the dentin bonding agent and relative acidity of the citric acid. Chlorhexidine is a well-known antimicrobial agent which is a Bisbiguanide. It has a broad spectrum and is effective against a wide range of microorganism. Chlorhexidine contains essential oils which may explain its lower bond strengths. Alpron contains phenoxyethanol, PHMB (biguanide), EDTA, sodium tosylchloramide, and phenylalanine. These results are similar to a 2005 study by Betke that indicated that there was no significant effect on dentin bond strength.

In 2007 Ritter found that ICX did not have a significant effect on the shear bond strength of composite to dentin. ICX is a tablet that contains sodium percarbonate, silver nitrate, and cationic surfactants (USAF 2012). It does not contain essential oils or other non-polar chemicals which might disrupt the bonding process. In 2004 Von Fraunhofer stated that shear bond strength may be enhanced due to the oxidizing percarbonate agent and cationic surfactants contained in the ICX tablet.

CHAPTER III: MATERIALS AND METHODS

Methodology

A total of 56 de-identified, molar, caries-free extracted human teeth were obtained from the Walter Reed National Military Medical Center Oral Surgery Clinic. The teeth were stored in deionized water since extraction for the duration of the study. Each tooth specimen was randomly assigned to one of four treatment groups (Table 1; n=14 specimens per group). This was done blindly to avoid bias.

In this study, four treatment groups were used. Group 1 served as the control and was assigned deionized water. Group 2 was assigned prepared per the manufacturer's guidelines using one ICX tablet in 2 liters deionized water. Group 3 was assigned a 10% dilution of Listerine and deionized water. Group 4 was assigned a 10% dilution of Chlorhexidine and deionized water. These solutions were prepared, placed into plain containers, and randomly assigned a number in order to avoid bias when preparing the samples.

The teeth were first prepared by removing the root tips with a high-speed handpiece. The tooth was then embedded in self-curing acrylic resin and randomly assigned to one of four surface treatment groups. This was done blindly to avoid bias. Each tooth was positioned in the center of a plastic mold such that the buccal surface of the clinical crown protruding out of the mold. The mold was filled with self-curing acrylic resin and allowed to bench cure.

In order to simulate a clinical bonding procedure, the surface of each tooth was cleaned with pumice. To remove the pumice, each tooth was rinsed with the 100 mL of the assigned dental unit waterline antimicrobial over a time interval of 30 seconds. The tooth was air dried and then a 37% phosphoric acid gel was applied for 15 seconds. To remove the phosphoric acid, the tooth was again rinsed with 100 mL of the assigned dental unit waterline antimicrobial over a time interval of 30 seconds. The tooth was then air dried to a frosty white appearance per the manufacturer's recommendations.

With a microbrush, one coat of Assure Universal Bonding Resin was applied and lightly air dried to evaporate the solvent. The pre-coated Victory MBT bracket was placed firmly onto the tooth surface followed by removal of excess adhesive. The appliance was light-cured for 5 seconds from the mesial and 5 seconds from the distal with an Elipar S10 LED curing light. All groups followed the same protocol using their respective antimicrobial irrigants.

Within 30 minutes of bonding the shear bond strength of each bracket was tested using the MTS Insight, a universal testing machine. This was done to most accurately simulate clinical bonding. Each acrylic block was secured into the mounting device and an occluso-gingival load was applied to the bracket-tooth interface. A crosshead speed of 1.0 mm per minute was used. All results were recorded in Newtons. The orthodontic bracket used in this study has a surface area of 14.5161 mm^2 per the manufacturer. The measurement in Newtons was divided by the surface area of the bracket to calculate the shear bond strength in megapascals (MPa).

Data Analysis:

Median (± standard deviation) of SBS values (MPa) for all groups was presented and compared with a one-way analysis of variance. Statistical analysis was accomplished using IBM SPSS Statistics Version 25 computer software (IBM, Armonk, NY). The significance level was set at $\alpha < 0.05$.

CHAPTER IV: RESULTS

The results of the study are presented in Appendix A and Appendix B. A one-way analysis of variance was used to analyze the data collected. Results of this analysis did not identify a significant difference among the groups. The p-value was found to be 0.849.

The mean of the control group was 13.4 MPa and a standard deviation of 5.2 Mpa. The mean of the ICX group was 13.7 MPa and a standard deviation of 4.2 Mpa. The mean of the Listerine group was 12.2 MPa, and a standard deviation of 3.9 Mpa. The mean of the Chlorhexidine group was 13.2 MPa, and a standard deviation of 4.9 MPa.

CHAPTER V: DISCUSSION

In 2010 Maryanchik recommended that a minimum bond strength of 6 to 8 MPa is adequate for most clinical orthodontic needs and is considered adequate to withstand masticatory and orthodontic forces. In 2001 Minors found that a force of 13 MPa will debond most orthodontic brackets. This is similar to the mean shear bond strength found in this study.

In the 2005 Bishara study the mean shear bond strength of orthodontic brackets was approximately 6 MPa and the standard deviation was approximately 3 MPa. Having a mean of 6 MPa and having a standard deviation that was approximately one half the mean may have been due to the crosshead speed used. In Bashara's study, a crosshead speed of 5.0 mm/minute used. A review of other shear bond strength studies, including Knight 2001, demonstrated that a crosshead speed of 1.0 mm per minute was used for most studies. This is why a crosshead speed of 1.0 mm per minute was used in this study.

As a basis of comparison, Knight in 2001 found that the mean bond strength of composite to enamel was 26 MPa and composite to dentin was 25 MPa. Since orthodontic brackets are usually made of stainless steel, the bond strength of orthodontic brackets was expected to be lower than composite.

In 2004 Von Fraunhofer indicated that ICX tablets contain sodium percarbonate, silver nitrate, and cationic surfactants. He stated that bonding may be enhanced by the oxidizing percarbonate agent. It was noted that in this study ICX, while not statistically significant, had the highest mean of 13.7 MPa.

In 2000 Roberts and in 2012 Sreenvasa found that Chlorhexidine and Listerine had a significant decrease on bonding. They both stated that this may be due to the presence of essential oils, which may have an adverse effect on bonding. It was noted that in this study, while not statistically significant Chlorhexidine (13.2 MPa) and Listerine (12.2 MPa) had the lowest shear bond strength.

CHAPTER VI: CONCLUSION

ICX, Listerine, and Chlorhexidine, when compared to deionized water, did not have a significant effect on the shear bond strength of orthodontic brackets.

APPENDIX A: DATA COLLECTION SHEET

Sample #	Group 1 Control	Group 2 ICX	Group 3 Listerine	Group 4 CHX
1	13.02	16.47	11.67	11.60
2	24.43	14.61	16.29	11.00
3	13.94	13.09	21.32	18.40
4	19.48	7.50	11.87	10.68
5	6.68	14.26	14.99	10.95
6	8.39	16.89	15.39	20.30
7	11.52	5.15	11.83	18.07
8	5.24	21.16	6.26	10.69
9	15.68	13.99	10.64	14.74
10	11.10	14.24	7.73	20.14
11	11.12	18.84	10.62	4.94
12	18.86	13.14	6.96	9.49
13	15.63	10.53	13.08	17.07
14	12.98	12.01	12.81	6.60

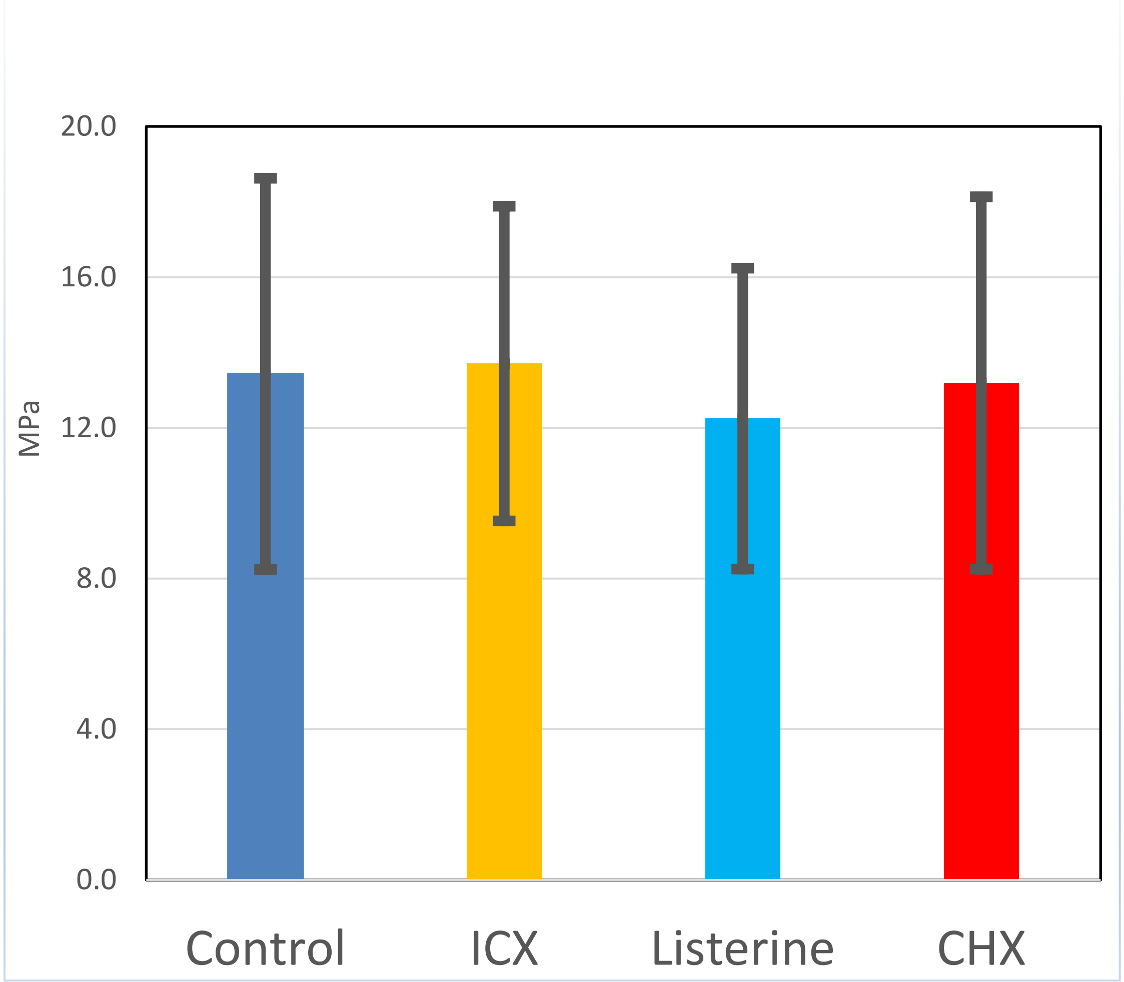
Note: All units in MPa.

APPENDIX B: TABLE 1

	Group 1 Control	**Group 2 ICX**	**Group 3 Listerine**	**Group 4 CHX**
Median	13.00	14.11	11.85	11.30
Mean	13.43	13.71	12.25	13.19
STD	5.19	4.18	3.99	4.94
Min	5.24	5.15	6.26	4.94
Max	24.43	21.16	21.32	20.30
Range	19.19	16.02	15.06	15.36

Note: All units in MPa.

APPENDIX C – GRAPH 1 – SHEAR BOND STRENGTH MEAN AND STANDARD DEVIATION



Note: All units in MPa.

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