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THESIS APPROVAL PAGE FOR MASTER OF SCIENCE IN ORAL BIOLOGY

Title of Thesis: "The Effect of Vaping on Force Degradation of Orthodontic Elastomeric Chains"

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Master of Science Degree
June 30, 2020

THESIS/MANUSCRIPT APPROVED: DATE:

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6. Clearance: ☑ Paper ☐ Article ☐ Book ☐ Presentation ☐ Other
7. Title: The effect of vaping on force degradation of orthodontic elastomeric chains
8. Intended Publication/Meeting: The Angle Orthodontist
9. Required by: 18 June 2020
10. Date of Submission: 10 Jun 2020

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The effect of vaping on force degradation of orthodontic elastomeric chains

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Introduction and Literature Review

Vaping, the use of electronic cigarettes or "e-cigs", is a recent development that may have far reaching consequences for public health. E-cigs vaporize a liquid which often contain nicotine, various flavorings, additives, and trace metals; and are at risk of exploding.[1-3] According to the Center for Disease Control (CDC) 2017 youth risk behavior survey, 13.2 percent of the youth population in the United States vaped at least once in the last thirty days.[4] Although a consensus has not been reached on the risks and benefits of vaping, research has been undertaken to better understand the health effects of e-cigs.[5]

Within the dental field, the periodontal effect of vaping has been studied most thoroughly. Wadia et al found increases in gingival inflammation after switching from smoking to vaping.[6] Additionally, Willershausen et al found that menthol additives inhibit gingival fibroblasts.[7] Other studies found effects on tumor necrosis factor (TNF) and cytotoxicity. [8,9] More generally, nicotine is known to affect bone remodeling and tooth movement. [10,11]Orthodontic implications of vaping are less well known.

An area of orthodontics that was well studied prior to the modern vaping trend is force degradation of elastomerics in response to the oral environment. Ash and Nikolai found that force degraded more in the oral environment than in air or water.[12]Kardach et al found that force reduced by 50 percent with plastic chains, while memory chains only lost 20 percent of their initial force after one week.[13] Ramanzanzadeh et al found that at higher force levels of 300 gram elastics showed significant force decay after exposure to sodium fluoride rinses.[14] Additional effects on color of elastics and force differences between various brands of elastics are also well documented.[15-19] However, it is not presently known if vaping causes force degradation in a similar manner to saliva or sodium fluoride.

It is clear that a large portion of potential adolescent patients may use e-cigs. Additionally, research shows that many compounds can have effects on orthodontic elastics. For these reasons it is prudent to study the effects of vaping on the force degradation of elastic chain (e-chain) to educate patients about vaping. Decreased force levels could prolong treatment time.

The purpose of the study is to compare the force degradation of e-chain exposed to vapors from an e-cig and artificial saliva and e-chain exposed to artificial saliva alone. The null hypothesis is that there is no difference in force degradation between e-chain exposed to e-cigarette vapors and control samples not exposed to e-cigarette vapors.

Materials and Methods

This study compared vaping exposure in a simulated oral environment (experimental) versus non-vaping (control) by examining e-chain force exertion prior to initiating exposure and after exposure to e-cigarette vapors at 24 hours, one week, two weeks, and four weeks. An Instron® 5943, (Instron®, Norwood, MA), was used to measure force levels at the specified distance of 48 millimeters (mm) prior to exposing the samples. This distance was utilized because it is the median maxillary anterior measurement on the Bolton Table and represents a clinically relevant situation of consolidating anterior space.[20] Vaping pen and vapor product were Juul vapors (JUUL Labs, San Francisco, CA), as they hold a majority of the market share for e-cigarettes in the United States.[21] Juul "Classic Tobacco" flavor, 5% nicotine pods were utilized. The study samples were divided into four groups of 20 samples. Control groups were stored in artificial saliva and experimental groups were stored in a separate artificial saliva bath and exposed to e-cigarette vapors. Group 1 (G1) was a control group with 3M Unitek AlastiK C module chain (3M, St. Paul, MN), injection molded, non-latex, C-1 grey, 3.6 mm centroid to centroid; Group 2 (G2) was a second control group with Ormco Generation II Power Chain (Danaher Corporation, Washington D.C.), grey, open space; Group 3 (G3) was an experimental group with AlastiK chain; Group 4 (G4) was a second experimental group with Power Chain. All samples were stored at room temperature in the original packaging prior to the initial force measurement.

Artificial saliva was made according to a recipe that has been found to be effective for in vitro studies.[22] The recipe pH was set at 7.2 with the following composition: $NaCl_2$ 4.29 mM, KCl 17.98 mM, $CaCl_2$ 1.10 mM, $MgCl_2$ 0.08 mM, H_2SO_4 0.50 mM, $NaHCO_3$ 3.27 mM, Na_3PO_4 3.90 mM, distilled water.

A 3D digital model was printed from Verodent MED670 polyjet material (Stratasys Inc., Eden Prairie, MN) and printed by Stratasys Objet Eden260V 3D printer (Stratasys Inc., Eden Prairie, MN). To prevent the polyjet material bending when heated, each model was duplicated in acrylic. Each model tested 10 chains using paired buttons 48 mm apart from each other with each pair 5 mm apart from the next chain. Two models were used in each group tested for a total of 20 chains per group. E-chain was cut into six link segments with an extra half link on each end to avoid damage to the end links.[14] The acrylic plates with attached e-chain were stored in artificial saliva at 37^{o} Celsius and 5% CO_2 using a Thermo Forma Steri-Cycle CO_2 Incubator Model 370 (Thermo Fisher Scientific, Austin, TX.) The samples were stored in the incubator from immediately after the initial force measurement until the experiment was completed. Samples were removed for force measurements and vapor exposures at the prescribed time points then immediately returned to the saliva bath and incubator. Robinson et al found that participants averaged 78 2-second puffs per day, so samples in Groups 3 and 4 were exposed to vapor 78 times with 2-second puffs at 5 second intervals once daily.[23]

The vapor exposure was produced by inserting a vaping pen into a 2.55 Liter Sterilite container (Sterilite Corporation, Townsend, MA) containing the experimental models. The vaping pen was activated automatically by suction manually applied at the set intervals, and the vapors blown into a canister containing the samples, and then the suction from the fume hood was allowed to evacuate the vapor. Vapor exposure was confirmed visually to ensure that vapor filled the cannister. The exposures were timed with a stop watch and tracked with a tally counter. The entire apparatus was contained within a Hamilton Safeaire PL 260 PN 51287 fume hood (Hamilton Laboratory Solutions, LLC, Manitowoc, WI).

Data for force measurements at each time point was recorded in Microsoft Excel (Microsoft Corp, Redmond, WA) and backed up to the cloud via Microsoft OneDrive. The outcome data measured for four different groups will be compared utilizing two-way repeated measures analysis of variance (ANOVA). The sample size was estimated based on the medium effect size (= ΔMeans/SD=0.6) in force measurement (At least one of the group mean differences assumed = 88, SD = 150) for a 2-sided test with a significance level α of 0.05. A total of 80 samples (20 per group) will achieve 80% power. Continuous variables will be assessed for normality by the Shapiro-Wilks test. Normally distributed continuous data will be presented as mean and standard deviation, and two-way repeated measures ANOVA will be performed. Otherwise, non-normally distributed data will be presented as median and interquartile range (IQR) and will be analyzed using Friedman's rank test to examine changes in outcomes over time.

Results

Table I	**T1=Initial T2=24 hours T3=1 week T4=2 weeks T5=4 weeks**	**N**	**Mean(Newtons)**	**Std Dev (Newtons)**	**Lower 95% Confidence Level (CL) for Mean (Newtons)**	**Upper 95% CL for Mean (Newtons)**
Group 1	**T1**	20	3.5580000	0.0973112	3.5124569	3.6035431
	T2	20	1.9340000	0.0689317	1.9017390	1.9662610
	T3	20	1.6840000	0.0561389	1.6577262	1.7102738
	T4	20	1.5265000	0.0455695	1.5051728	1.5478272
	T5	20	1.4340000	0.0484931	1.4113045	1.4566955
	Ch_T21	20	-1.6240000	0.1056509	-1.6734461	-1.5745539
	Ch_T31	20	-1.8740000	0.1192256	-1.9297993	-1.8182007
	Ch_T41	20	-2.0315000	0.1039370	-2.0801440	-1.9828560
	Ch_T51	20	-2.1240000	0.1056010	-2.1734228	-2.0745772
Group 2	**T1**	20	3.3455000	0.0644389	3.3153417	3.3756583
	T2	20	2.5040000	0.0673092	2.4724983	2.5355017
	T3	20	2.3810000	0.0632372	2.3514041	2.4105959
	T4	20	2.2195000	0.0598661	2.1914818	2.2475182
	T5	20	2.0990000	0.0621458	2.0699149	2.1280851
	Ch_T21	20	-0.8415000	0.0765902	-0.8773453	-0.8056547
	Ch_T31	20	-0.9645000	0.0806209	-1.0022318	-0.9267682
	Ch_T41	20	-1.1260000	0.0671526	-1.1574284	-1.0945716
	Ch_T51	20	-1.2465000	0.0705822	-1.2795335	-1.2134665

Table I	T1=Initial T2=24 hours T3=1 week T4=2 weeks T5=4 weeks	N	Mean(Newtons)	Std Dev (Newtons)	Lower 95% Confidence Level (CL) for Mean (Newtons)	Upper 95% CL for Mean (Newtons)
Group 3	**T1**	20	3.7625000	0.1360679	3.6988183	3.8261817
	T2	20	1.9800000	0.0578564	1.9529223	2.0070777
	T3	20	1.6995000	0.0619401	1.6705111	1.7284889
	T4	20	1.6760000	0.0456992	1.6546121	1.6973879
	T5	20	1.5235000	0.0523425	1.4990030	1.5479970
	Ch_T21	20	-1.7825000	0.1322229	-1.8443822	-1.7206178
	Ch_T31	20	-2.0630000	0.1324307	-2.1249795	-2.0010205
	Ch_T41	20	-2.0865000	0.1286887	-2.1467282	-2.0262718
	Ch_T51	20	-2.2390000	0.1278939	-2.2988562	-2.1791438
Group 4	**T1**	20	3.4230000	0.1891004	3.3344983	3.5115017
	T2	20	2.4785000	0.0940479	2.4344842	2.5225158
	T3	20	2.1725000	0.0733323	2.1381794	2.2068206
	T4	20	2.2280000	0.0720818	2.1942647	2.2617353
	T5	20	2.0280000	0.0727360	1.9939585	2.0620415
	Ch_T21	20	-0.9445000	0.1571615	-1.0180538	-0.8709462
	Ch_T31	20	-1.2505000	0.1709871	-1.3305244	-1.1704756
	Ch_T41	20	-1.1950000	0.1575303	-1.2687264	-1.1212736
	Ch_T51	20	-1.3950000	0.1657360	-1.4725668	-1.3174332

Table I contains the data collected during the experiment. Two-way repeated measures analysis of variance (ANOVA) was performed to test the main effects of group and time and the interaction effect between group and time. The result indicated that there was significant main effects for group ($F(3, 76) = 320.72$, $p < .0001$) and time ($F(4,304) = 10728.0$, $p < .0001$) and also a significant interaction effect between group and time ($F(12, 304) = 276.41$, $p < .0001$). The Tukey post hoc test results indicated that AlastiK scores (G3 significantly higher than G1) were significantly higher than Power Chain scores (G2 and G4) at T1 (Baseline); however, Power Chain scores (G2 and G4) were higher than AlastiK score (G1 and G3) at T2 (24 hours); at T3 (Week 1), Power Chain scores (G2 and G4) were higher than AlastiK score (G1 and G3), but a significant difference was found between G2 and G4 (G2 was significantly higher than G4; at T4 (Week 2), Power Chain scores (G2 and G4) were higher than AlastiK score (G1 and G3), but a significant difference was found between G1 and G3 (G3 was significantly higher than G1); and at T5 (Week 4), all four groups' scores were significantly different from each other (G2 highest > G4 > G3 > G1 lowest). The significant time effect suggests that there was a significant decrease over time. The significant interaction suggests that Alastik score decreased at a greater rate than Power Chain did.

One-way analysis of variance (ANOVA) was performed to test the group difference in the changes from T5 (Week 4) to T1 (Baseline). The result indicated that there was significant group effect ($F(3, 76) = 337.36$, $p < .0001$). The Tukey post hoc test results indicated that all four groups' changes were significantly different from each other (G2 smallest decrease > G4 > G1 > G3 largest decrease).

Overall, regardless of the treatment group, Power Chain performed better than AlastiK; however, the experimental group (vaping) decreased significantly more at T5 (Week 4) for both Power Chain and AlastiK chain.

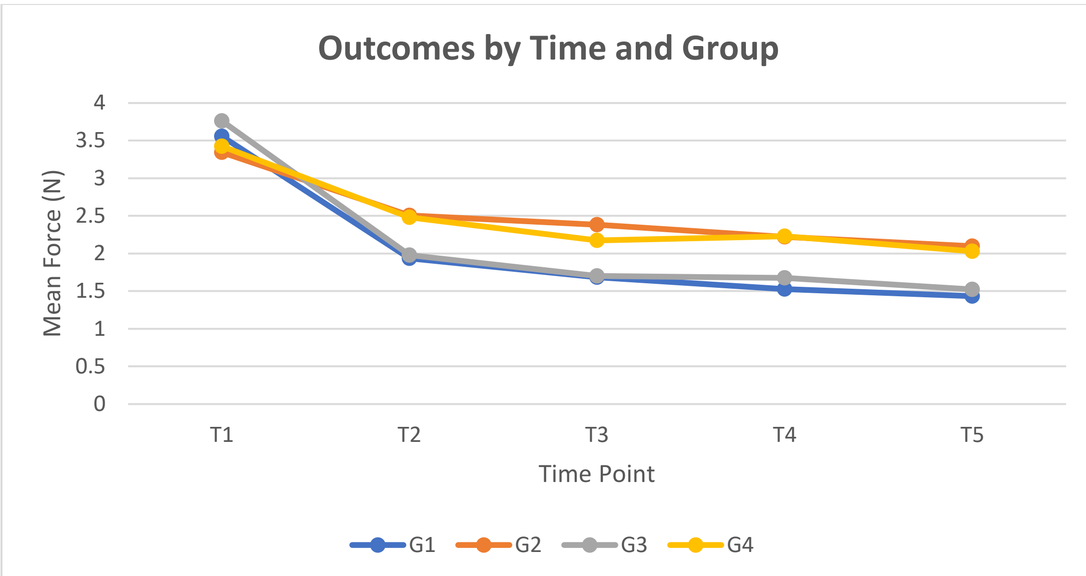

Figure 1

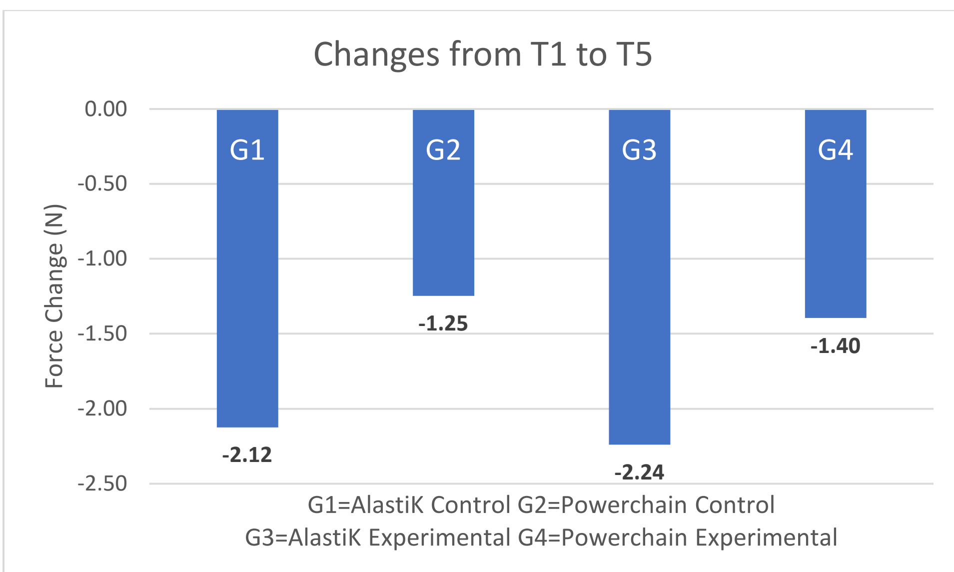

Figure 2

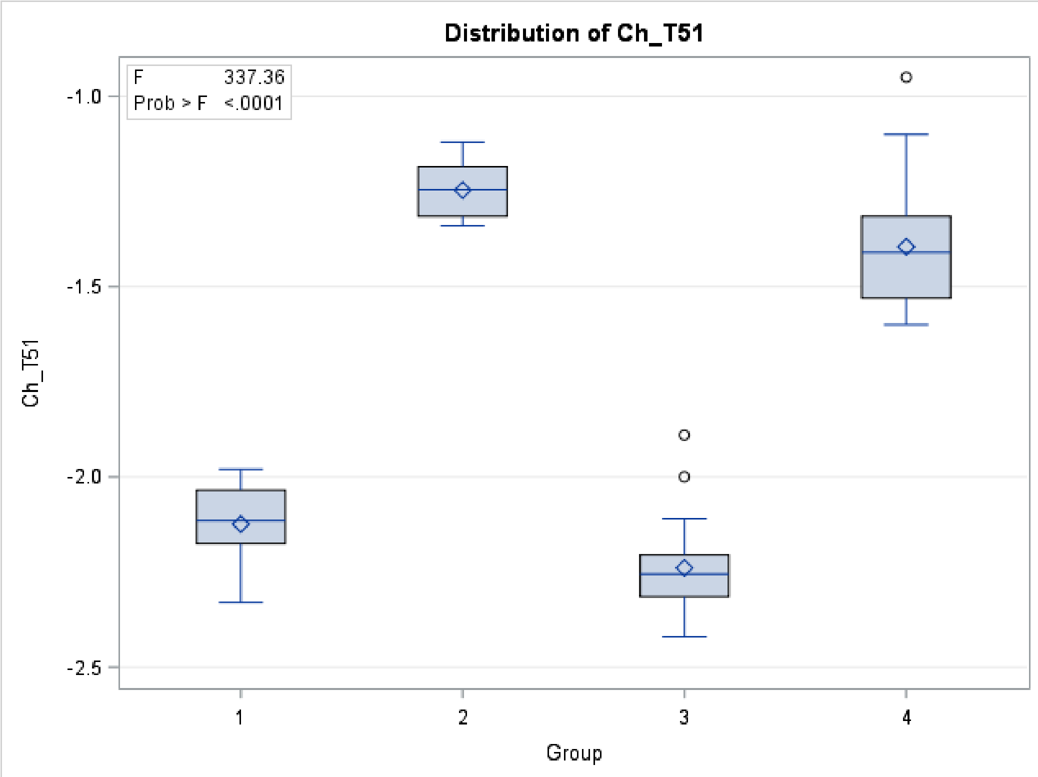

Figure 3

Discussion

The results show statistically significant differences in samples exposed to vapors compared to controls. The decrease in force was greater at four weeks after exposure to vapors compared to control groups for each brand of elastomeric chain. The difference grew as time elapsed, so it is possible that longer recall times would show continued degradation. However, the clinical significance for the difference of approximately 0.1N or approximately 10 grams of force from AlastiK chain and Powerchain is debatable. The higher forces of AlastiK chain exposed to vapors compared to the control group at 2 weeks is a confounding factor that is likely caused by a difference between the initial strength of the spool of AlastiK chain used for the control group vs the spool used for the experimental group. The change was actually greater for the experimental group in spite of the higher mean strength remaining.

Additionally, while AlastiK chain initially had higher force levels at the specified length, Powerchain maintained force levels better and surpassed AlastiK chains in force after 24 hours. A study by Nachan et al showed that various stretch lengths yielded different force results for different chemical exposures, so additional studies could be conducted with dynamic shortening of the distance to simulate tooth movement.[24]

There were several limitations to the current study. First, the study was an *in vitro* study and may not be fully representative of the oral cavity. Secondly, while the exposure schedule was based on research, the study did not account for potentially higher effects of heavy users, or users who hold the vapors in their mouths for extended times.

Additional studies should examine more properties of the materials including breaking force, toughness index, color change, and elongation. Aghaloo et al discussed research protocols and suggests the use of a universal vaping test machine. Future studies should incorporate this machine to standardize exposure beyond a visual confirmation of vapors in the experimental chamber.[25]

Conclusions

1. This *in vitro* study indicates that exposure to e-cigarette vapors can decrease the force exerted by orthodontic elastomeric chain.
2. For both vapor exposure and control groups there were significant differences in force between the two elastomeric products.
3. Discussing tobacco use with patients is an important part of the medical history review process and discussing a potential effect on orthodontic treatment with patients should be considered.
4. Additional studies are needed to more fully understand the clinical implications of vaping for orthodontic treatment.

Disclaimer

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The effect of vaping on force degradation of orthodontic elastomeric chains

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Abstract:

Objective: Electronic cigarettes, or vaping, may have far reaching consequences for dental public health. The objective of the study was to compare the force degradation of vapor exposed elastomeric chains to a control. **Materials and Methods:** Vaping in a simulated oral environment (experimental) was compared to a non-exposure sample (control) by examining e-chain force exertion prior to, and after, daily exposure to e-cigarette vapors at 24 hours, one, two, and four weeks. Both groups were stored in separate artificial saliva at 37° Celsius and 5% CO_2, stretched on acrylic duplicates of 3D printed models. Group 1 and 2, (G1 and G2) were controls with AlastiK and Power Chain respectively; Group 3 and Group 4 (G3 and G4) were vaping exposed AlastiK and Power Chain. **Results:** Two-way repeated measures analysis of variance (ANOVA) showed significant main effects for group and time, and a significant interaction effect between group and time. The Tukey post hoc test indicated significantly higher AlastiK scores than Power Chain at Baseline; and at week 4, all groups' scores were significantly different (G2 > G4 > G3 > G1). AlastiK score decreased at a greater rate than Power Chain. Changes from baseline were significant with G2 < G4 < G1 < G3. **Conclusion:** E-cigarette vapors can decrease elastomeric chain force. Vapor exposed and control groups had significant force differences between elastomeric products, with a greater rate of decrease in AlastiK. Possible prolonged orthodontic treatment is a talking point with vaping patients.

The opinions or assertions contained herein are the private ones of the authors and are not to be construed as official or reflecting the view of the DoD or the USUHS

Introduction

Vaping, the use of electronic cigarettes or "e-cigs", is a recent development that may have far reaching consequences for public health. E-cigs vaporize a liquid which often contains nicotine, various flavorings, additives, and trace metals[1,2]. E-cigs also are at risk of exploding and causing facial trauma.[3] According to the Center for Disease Control (CDC) 2017 Youth Risk Behavior Survey, 13.2 percent of the youth population in the United States vaped at least once in the last thirty days.[4] Although a consensus has not been reached on the risks and benefits of vaping, research has been undertaken to better understand the health effects of e-cigs.[5]

Within the dental field, the periodontal effect of vaping has been studied most thoroughly. Wadia et al found increases in gingival inflammation after switching from smoking to vaping.[6] Additionally, Willershausen et al found that menthol additives inhibit gingival fibroblasts.[7] Other studies found effects on tumor necrosis factor (TNF) and cytotoxicity.[8,9] More generally, nicotine is known to affect bone remodeling and tooth movement.[10,11]Orthodontic implications of vaping are less well known.

An area of orthodontics that was well studied prior to the modern vaping trend is force degradation of elastomerics in response to the oral environment. Ash and Nikolai found that force degraded more in the oral environment than in air or water.[12]Kardach et al found that force reduced by 50 percent with plastic chains, while memory chains only lost 20 percent of their initial force after one week.[13] Ramanzanzadeh et al found that at higher force levels of 300 gram elastics showed significant force decay after exposure to sodium fluoride rinses.[14] Additional effects on color of elastics and force differences between various brands of elastics are also well documented.[15-19] However, it is not presently known if vaping causes force degradation in a similar manner to saliva or sodium fluoride.

It is clear that a large portion of potential adolescent patients may use e-cigs. Additionally, research shows that many compounds can have effects on orthodontic elastics. For these reasons it is prudent to study the effects of vaping on the force degradation of elastic chain (e-chain) to educate patients about vaping. Decreased force levels could prolong treatment time.

The purpose of the study was to compare the force degradation of e-chain exposed to vapors from an e-cig and artificial saliva and e-chain exposed to artificial saliva alone. The null hypothesis was that there is no difference in force degradation between e-chain exposed to e-cigarette vapors and control samples not exposed to e-cigarette vapors.

Materials and Methods

This study compared vaping exposure in a simulated oral environment (experimental) versus non-vaping (control) by examining e-chain force exertion prior to initiating exposure and after exposure to e-cigarette vapors at 24 hours, one week, two weeks, and four weeks. An Instron® 5943, (Instron®, Norwood, MA), was used to measure force levels at the specified distance of 48 millimeters (mm) prior to exposing the samples. This distance was utilized because it is the median maxillary anterior measurement on the Bolton Table and represents a clinically relevant situation of consolidating anterior space.[20] Vaping pen and vapor product were Juul vapors (JUUL Labs, San Francisco, CA), as they hold a majority of the market share for e-cigarettes in the United States.[21] Juul "Classic Tobacco" flavor, 5% nicotine pods were utilized. The study samples were divided into four groups of 20 samples. Control groups were stored in artificial saliva and experimental groups were stored in a separate artificial saliva bath and exposed to e-cigarette vapors. Group 1 (G1) was a control group with 3M Unitek AlastiK C module chain (3M, St. Paul, MN), injection molded, non-latex, C-1 grey, 3.6 mm centroid to centroid; Group 2 (G2) was a second control group with Ormco Generation II Power Chain (Danaher Corporation, Washington D.C.), grey, open space; Group 3 (G3) was an experimental group with AlastiK chain; Group 4 (G4) was a second experimental group with Power Chain. These brands were chosen as they are two popular chains used in orthodontics and familiar to the experimental examiners. All samples were stored at room temperature in the original packaging prior to the initial force measurement.

Artificial saliva was made according to a recipe that has been found to be effective for in vitro studies.[22] The recipe pH was set at 7.2 with the following composition: $NaCl_2$ 4.29 mM, KCl 17.98 mM, $CaCl_2$ 1.10 mM, $MgCl_2$ 0.08 mM, H_2SO_4 0.50 mM, $NaHCO_3$ 3.27 mM, Na_3PO_4 3.90 mM, and distilled water.

A 3D digital model was printed from Verodent MED670 polyjet material (Stratasys Inc., Eden Prairie, MN) and printed by Stratasys Objet Eden260V 3D printer (Stratasys Inc., Eden Praire, MN). To prevent the polyjet material from bending when heated, each model was duplicated in Biocryl resin acrylic (Great Lakes Dental Technologies, Tonawanda, NY). Each model tested 10 chains using paired buttons 48 mm apart from each other with each pair 5 mm apart from the next chain, see figure I. Two models were used in each group tested for a total of 20 chains per group. The elastic chains were cut into six link segments with an extra half link on each end to avoid damage to the end links.[14] The acrylic plates with attached e-chain were stored in artificial saliva at 37^{o} Celsius and 5% CO_2 using a Thermo Forma Steri-Cycle CO_2 Incubator Model 370 (Thermo Fisher Scientific, Austin, TX.) The samples were stored in the incubator from immediately after the initial force measurement until the experiment was completed. Samples were removed for force measurements and vapor exposures at the prescribed time points then immediately returned to the saliva bath and incubator. Robinson et al found that participants averaged 78, two second puffs per day, so samples in Groups 3 and 4 were exposed to vapor 78 times with 2-second puffs at 5 second intervals once daily.[23]

The vapor exposure was produced by inserting a vaping pen into a 2.55 Liter Sterilite container (Sterilite Corporation, Townsend, MA) containing the experimental models. The vaping pen was activated automatically by suction manually applied at the set intervals, and the vapors blown into a canister containing the samples, and then the suction from the fume hood evacuated the vapor, see figure II. Vapor exposure was confirmed visually to ensure that vapor filled the cannister, see figure III. The exposures were timed with a stopwatch and tracked with a tally counter. The entire apparatus was contained within a Hamilton Safeaire PL 260 PN 51287 fume hood (Hamilton Laboratory Solutions, LLC, Manitowoc, WI).

Data for force measurements at each time point was recorded in Microsoft Excel (Microsoft Corp, Redmond, WA) and backed up to the cloud via Microsoft OneDrive. The outcome data measured for four different groups was compared utilizing two-way repeated measures analysis of variance

(ANOVA). The sample size was estimated based on the medium effect size (= ΔMeans/SD=0.6) in force measurement (At least one of the group mean differences assumed = 88, SD = 150) for a 2-sided test with a significance level α of 0.05. A total of 80 samples (20 per group) achieved 80% power. Continuous variables were assessed for normality by the Shapiro-Wilks test. Normally distributed continuous data were presented as mean and standard deviation, and two-way repeated measures ANOVA was performed with SAS version 9.4 (Statistical Analysis Software, Cary, NC).

Results

Table I contains the data collected during the experiment. Each group at each timepoint consisted of 20 samples. Two-way repeated measures analysis of variance (ANOVA) was performed to test the main effects of group and time and the interaction effect between group and time. The result indicated significant main effects for group ($F(3, 76) = 320.72$, $p < .0001$) and time ($F(4,304) = 10728.0$, $p < .0001$) and also a significant interaction effect between group and time ($F(12, 304) = 276.41$, $p < .0001$). The Tukey post hoc test results indicated that AlastiK scores (G3 significantly higher than G1) were significantly higher than Power Chain scores (G2 and G4) at T1 (Baseline); however, Power Chain scores (G2 and G4) were higher than AlastiK scores (G1 and G3) at T2 (24 hours); at T3 (Week 1), Power Chain scores (G2 and G4) were higher than AlastiK score (G1 and G3), but a significant difference was found between G2 and G4 (G2 was significantly higher than G4; at T4 (Week 2), Power Chain scores (G2 and G4) were higher than AlastiK score (G1 and G3), but a significant difference was found between G1 and G3 (G3 was significantly higher than G1); and at T5 (Week 4), all four groups' scores were significantly different from each other (G2 highest > G4 > G3 > G1 lowest). The significant time effect suggests that there was a significant decrease over time, see Figure IV. The significant interaction suggests that AlastiK score decreased at a greater rate than Power Chain did.

One-way analysis of variance (ANOVA) was performed to test the group difference in the changes from T5 (Week 4) to T1 (Baseline). The result indicated that there was significant group effect ($F(3, 76) = 337.36$, $p < .0001$). The Tukey post hoc test results indicated that all four groups' changes were significantly different from each other (G2 smallest decrease > G4 > G1 > G3 largest decrease): see Figure V and VI.

Overall, regardless of the treatment group, Power Chain had higher sustained force than AlastiK; however, the experimental group (vaping) decreased significantly more at T5 (Week 4) for both Power Chain and AlastiK chain.

Discussion

The results show statistically significant differences in samples exposed to vapors compared to controls. The decrease in force was greater at four weeks after exposure to vapors compared to control groups for each brand of elastomeric chain. The difference grew as time elapsed, so it is possible that longer recall times would show continued degradation. However, the clinical significance for the difference of 0.1N or approximately 10 grams of force from AlastiK chain and Power Chain is debatable. The higher forces of AlastiK chain exposed to vapors compared to the control group at 2 weeks is a confounding factor that is likely caused by a difference between the initial strength of the spool of AlastiK chain used for the control group versus the spool used for the experimental group. The change was actually greater for the experimental group in spite of the higher mean strength remaining. The *null* hypothesis was rejected due to the statistically significant difference in force degradation between elastomeric chain exposed to e-cigarette vapor and controls.

Additionally, while AlastiK chain initially had higher force levels at the specified length, Power Chain maintained force levels better and surpassed AlastiK chains in force after 24 hours. The difference in behavior between the two brands is possibly due to the material thickness. Power Chain is thinner and thus absorbs less saliva, possibly making it less influenced by compounds to which it is exposed. A study by Nachan et al showed that various stretch lengths yielded different force results for different chemical exposures, so additional studies could be conducted with dynamic shortening of the distance to simulate tooth movement.[24]

There were several limitations to the current study. First, the study was an *in vitro* study and may not be fully representative of the oral cavity. Secondly, while the exposure schedule was based on research, the study did not account for potentially higher effects of heavy users, or users who hold the vapors in their mouths for extended times. Finally, the exposure was confirmed visually but was not quantifiable with this research model.

Additional studies should examine more properties of the materials including breaking force, toughness index, color change, and elongation. Aghaloo et al discussed research protocols and suggested the use of a universal vaping test machine. Future studies should incorporate this machine to standardize exposure beyond a visual confirmation of vapors in the experimental chamber.[25]

Conclusions

1. This *in vitro* study indicates that exposure to e-cigarette vapors can decrease the force exerted by orthodontic elastomeric chain.
2. For both vapor exposure and control groups there were significant differences in force between the two elastomeric products.
3. Discussing tobacco use with patients is an important part of the medical history review process and discussing a potential effect on orthodontic treatment with patients should be considered.
4. Additional studies are needed to more fully understand the clinical implications of vaping for orthodontic treatment.

Disclaimer

The views expressed in this article are those of the authors and do not reflect the official policy of the Department of Defense or other departments of the United States government. The opinions or assertions contained herein are the private ones of the authors and are not to be construed as official or reflecting the view of the DoD or the USUHS. The authors do not have any financial interest in the companies whose materials are discussed in this article.

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Figure Legends

Figure I: Model Design

Elastic chains were stretched on an acrylic jig and stored in artificial saliva in an incubator.

Figure II: Experimental Set-Up

Vapor was drawn from the vaping pen into an ambubag, then expressed into a container holding the experimental samples. The vapor was evacuated by the fume hood.

Figure III: Vapor Visualization

Visual confirmation that vapor filled the chamber.

Figure IV: Outcomes by Time and Group

Illustrates the force degradation of each group over time.

Figure V: Group Change over Time

Represents the change in mean force output for each group.

Figure VI: Force Change by Distribution

Change in force from Initial to 4 weeks, with distribution in each group.