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In-vitro Effectiveness of Herbal Mouthwashes on the Force Degradation of Two Orthodontic E-chains

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Background: Plaque build-up around fixed orthodontic appliances might lead to clinical problems. Even though mouthwashes are recommended during orthodontic treatment, the magnitude of force loading and unloading in elastomeric chains is significantly affected by alcohol-containing mouthwashes.

Aim: To evaluate and compare the efficacy of herbal mouthwashes on the force degradation of two orthodontic E-chains.

Materials and Methods: Chlorhexidine, Hiora-K and Triphala were used in the study. Ninety pieces of closed clear E-chains with five loops each of AO and 3M companies were collected and divided into three groups (n=30) namely Chlorhexidine, Hiora-K and Triphala. Each group was divided into two sub-groups based on the E-chain brands (n=15). On day 1, the original force was recorded by stretching the E-chain up to 25mm using universal testing machine and the load was recorded in kilograms and converted to grams. The E-chains were subjected to their respective mouthwashes daily for one minute. The force was again recorded on the 21st and 30th days. The obtained data were subjected to statistical analysis using SPSS 16.0 version.

Results: The 3M E-chain showed a significant(p=0.000) difference compared with AO. Hiora and Triphala showed lesser force degradation than Chlorhexidine (p=0.013). Further, there was a significant (p=0.001) reduction in force degradation from baseline to the first month.

Conclusion: Force degradation was more significant from the1st to the 21st day. 3M E-chain showed less force decay than AO E-chain. Hiora-K and Triphala mouthwash groups showed less force decay than the Chlorhexidine.

Keywords: AO; 3M e-chain; chlorhexidine; force degradation; Hiora-K and Triphala mouthwash.

1. INTRODUCTION

The force systems employed in orthodontic biomechanics aimed to facilitate tooth movement [1]. Numerous researchers attempted to establish the optimal force required for tooth movements, however, the outcomes were ambiguous. Few clinicians recommend applying forces ranging from 115 to 310 g to reposition teeth for better outcomes [2].

Since 1960, the straight wire approach has employed elastomeric materials such as stainless-steel ligatures and elastomeric chains (E-chains) to exert retraction forces on the teeth [3]. Multiple operations, including midline correction, space closure, rotation correction, and intermaxillary jaw discrepancy adjustments, are performed using them [4]. E-chains provided some advantages such as effectiveness, comfort, affordability, hygiene, low cost, ease of sterilization, and lack of patient compliance [5]. E-chains have drawbacks, including force depreciation and colour discolouration in the case of transparent E-chains. They generally change their physical characteristics when activated and do not produce constant force levels over time, [1] which is termed force degradation. The inability of elastomeric chains to sustain a constant force level over an extended period has received considerable attention. Elastic stretch and chain slippage are the two methods by which this force reduction occurs. Chain elongation is a reversible process in which individual polymer molecules unwind, straighten and stretch when a force is applied to the chain whereas, chain slip occurs when force is maintained. As a result, the polymer molecules move past each other and permanently deform the material [6]. Stress relaxation causes a sudden decrease in force, which leads to a gradual loss of efficacy. A force degradation of 50 to 75% was seen after 24hrs of stretching, 10% after three weeks. Only 30 to 40% of the initial force remained after four weeks [7]. The stresses applied by E-chains are influenced by the chain configurations (open or closed), speed, stretch, oral environment, saliva pH variations, enzymes, food and drink, and other materials that enter the oral cavity [8].

In orthodontics, plaque around fixed appliances can cause clinical problems such as gingival inflammation, demineralization of the surrounding tooth enamel and compromise oral hygiene. Mouthwashes are recommended during treatment [9], which should be gargled twice a day for 30 sec with a total of 20 ml and then expelled [10]. Mouthwashes containing alcohol significantly affect the magnitude of force loading and unloading in elastomeric chains, particularly in open-type chains. In contrast, the extent of strength reduction was little affected by non-alcohol mouthwash [11]. The commercial mouthwashes have several adverse effects, including ulceration, inflammation and burning tongue sensation. Chlorhexidine, a bis-biguanide agent and antiseptic mouthwash, is the most commonly used mouthwash by orthodontic patients [12,13]. However, it has several side effects, including increased calculus deposition, mucosal desquamation, taste disturbance and tooth discoloration [14].

Mouth rinses produced from Ayurvedic drugs are also advised to reduce bleeding and gingival inflammation [15]. Herbal mouthwashes have gained popularity as a chlorhexidine substitute recently as they are safer and chemical-free [12]. Herbal mouthwashes like Triphala and Hiora-K are more frequently used to reduce gingival inflammation and accumulation of plaque [16]. We aimed to assess and compare the impact of herbal mouthwashes on the force decay of E-chains, as there is no literature available on their effect.

2. MATERIALS AND METHODS

The current in *invitro* study was performed by taking institutional consent (IECVDC/2021/ PG01/ODFO/IVT/39) to evaluate the force degradation of E-chains when immersed in different mouthwashes.

2.1 Methodology

Ninety pieces of closed clear E-chains with five loops from AO (American Orthodontics, USA) and 3M (3M-Unitek, India) were taken with 45 from each. The spaced E-chains and E-chains from other companies were excluded. A transparent clear acrylic plate was poured to reinforce the pins. The distance between the pins was 25mm, approximately equal to the distance between the upper first molar and the upper canine. A sample of each e-chain was taken and stretched between the pins.

The 90 pieces were divided into three main groups, G1: Chlorhexidine (Hexidine, Icpa Health Products Ltd, Mumbai) mouthwash, G2: the Hiora-K (Himalaya Hiora-K, Himalaya Drug Company, Bengaluru) and G3: the Triphala (Dabur Triphala Churna, Dabur India Ltd, New Delhi). Triphala mouthwash was prepared by dissolving 60g of Churna into1 L of distilled water. Each group was subdivided into 2 subgroups(n=15) from each brand.

The initial stretching force of E-chains was measured using Universal Testing Machine (Model- AE-UTM-LC2, Advanced Equipments, India). The machine has two vertical jaws where the acrylic block with the E-chains embedded was placed in the lower jaw. The E-chains were set at the base of the machine so that the sharp end of the rod was incised into the area between the loops of E-chains. The tests were carried out with a 98mm/min crosshead speed. The Universal Testing Machine (UTM) was attached to an electronic console that displayed the forces acting between the jaws. The E-chains were stretched to a length of 11mm to their original length (14mm) so that a total of 25mm was stretched. The magnitude of the original force of each e-chain was recorded in kilograms (Kg) at the baseline. This force was converted into grams (1Kg=1000gms).

Then the acrylic plates were immersed in their respective mouthwashes for 1min/day to simulate the application of mouthwash by the patient. After immersion, all the E-chains were rinsed with distilled water and stored in artificial saliva. On the 21st day, samples were stretched again to a total of 25mm, and the force degradation of E-chains was measured. Similarly, after four weeks from zero-time, the force was measured for each e-chain for different mouthwashes. The percentage of force degradation of E-chains in different mouthwashes was calculated using the formula:

$$\% FD = 100 \times [(IF-Ft) / IF]$$

IF = Initial force.
Ft = Force at a specific time.

2.2 Statistical Analysis

Statistical analyses were performed using statistical software, IBM SPSS version 24.0 International Business Machines Corporation-Statistical Package for the Social Sciences. Descriptive analysis was carried out for groups and subgroups. A three-way analysis of variance (ANOVA) was used to identify the significant differences between the two types of elastomeric chains immersed in three respective types of mouthwash at three different time intervals on force degradation. A pairwise comparison of force degradation at different time intervals and in different solutions was done using post hoc analysis.

3. RESULTS

The mean force of the AO and 3M E-chains immersed in different mouthwashes (Table 1) showed a gradual decrease from baseline to one-month time interval. A significant ($p < 0.005$) mean force decrease was demonstrated by both the E-chains from baseline to the21st day immersion in different mouthwashes.

The percentage of force degradation was highest (62.7%) in Chlorhexidine group G1at the end of the first month for AO E-chain and the least percentage (47.5%) was recorded in the TriphalaG3 (Table 2). In the 3M E-chain, the highest percentage (48.5%) of force degradation was in G1 and G3 at the end of the first month and the least percentage (45.2%) was in G1(Table 2).

Comparing the decay of the forces among the E-chains, 3M chains showed a significant difference ($F(1) = 40.925$, $p = 0.000$) compared with AO. Hiora (G2) and Triphala(G3) showed lesser ($F(2) = 4.384$, $p = 0.013$)force degradation than Chlorhexidine. Further, there was a significant reduction in force degradation from baseline to 1 month ($F(1) = 11.201$, $p = 0.001$). But there was no significant three-way interaction ($F(2) = 0.671$, $p = 0.512$) (Table 3).

Table 1. The mean and standard deviations of force degradation in different groups

E-chains	Solutions	Time intervals	Mean (In grams)	Standard deviation	Standard error	95% Confidence	
						Lower Bound	Upper Bound
AO	HIORA	BASELINE	393.7467	25.04418	5.807	382.311	405.182
		21 DAYS	200.1333	.48795	10.058	180.326	219.940
		1 MONTH	199.7333	.79881	10.058	179.926	219.540
	CHX	BASELINE	393.7467	25.04418	5.807	382.311	405.182
		21 DAYS	166.5333	48.70203	10.058	146.726	186.340
		1 MONTH	146.5667	51.68582	10.058	126.760	166.374
	TRIPHALA	BASELINE	393.7467	25.04418	5.807	382.311	405.182
		21 DAYS	206.4200	58.78212	10.058	186.613	226.227
		1 MONTH	186.1000	51.33462	10.058	166.293	205.907
3M	HIORA	BASELINE	400.4467	1.28233	5.807	389.011	411.882
		21 DAYS	233.6800	48.79883	10.058	213.873	253.487
		1 MONTH	205.9733	25.57665	10.058	186.166	225.780
	CHX	BASELINE	400.4467	1.28233	5.807	389.011	411.882
		21 DAYS	233.6933	81.74108	10.058	213.886	253.500
		1 MONTH	219.2400	41.45588	10.058	199.433	239.047
	TRIPHALA	BASELINE	400.4467	1.28233	5.807	389.011	411.882
		21 DAYS	239.8400	50.48328	10.058	220.033	259.647
		1 MONTH	206.0800	25.54456	10.058	186.273	225.887

Table 2. Percentage of force degradation of E-chains

	CHX			Hiora-K			Triphala		
	Baseline	21st day	30th day	Baseline	21st day	30th day	Baseline	21st day	30th day
AO	100%	57.7%	62.7%	100%	49.1%	49.2%	100%	47.5%	52.7%
3M	100%	41.6%	45.2%	100%	41.6%	48.5%	100%	40.1%	48.5%

Table 3. Three-way ANOVA was done to examine the effect of E-chains, solutions, and time intervals on the force degradation

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
E-chains	62102.880	1	62102.880	40.925	0.000*
Solutions	13305.227	2	6652.614	4.384	0.013*
Time	16996.393	1	16996.393	11.201	0.001*
E-Chain &Solution	22081.724	2	11040.862	7.276	0.001*
E-chain &Time	1551.735	1	1551.735	1.023	0.313
Solution &Time	1376.235	2	688.117	.453	0.636
E-chain &Solution &Time	2035.832	2	1017.916	.671	0.512

4. DISCUSSION

The present study investigated the effect of three different types of mouthwashes (Chlorhexidine, Hiora-K, and Triphala) on the force decay of AO and 3M orthodontic elastomeric chains. The 3M E-chain has shown a significant difference in the force degradation from AO as it retained higher force till the 21st and 30th day while the AO E-chain displayed a significant force degradation. Additionally, the force degradation was significantly decreased in both E-chains from the 0 to the 30th day.

Various factors, including the contents of the mouthwash, the amount of force exertion, spacing between the pins, duration of immersion, and the pH of the mouthwashes, play significant roles in the force degradation of the E-chains.

Immersion of the E-chains in alcohol-containing mouthwashes significantly causes force degradation. The presence of ethanol (13.6%) in Chlorhexidine mouthwash contributes to force loss compared to Hiora-K and Triphala mouthwashes. Eliades *et al.* reported that the immersion of polyurethane orthodontic elastomeric materials in a 75% ethanol/water mixture caused structural and molecular modifications leading to the decay of the specimen [17]. The force degradation in the E-chains immersed in Chlorohexidine may be attributed to the presence of alcohol as an ingredient in it compared to the other mouthwashes.

As advised by Storey [18], Boester [19], and Hixon [20], the possibility of hyalinization and root resorption will be observed when the applied force is greater than 100 to 300g. For AO and 3M closed E-chains, it is preferred that the initial force should not exceed 300g in magnitude. In a study by Chadi Antoine Kassir et al*.* [21], the transparent closed AO E-chain demonstrated force degradation of 25.3% after three weeks and 36.6% after four weeks of immersion in distilled water and artificial saliva. The current study's force degradation of AO E-chain was more i.e., 47.5%- 57.7% after three weeks and 49.2% - 62.7% after four weeks. However, the type of immersion medium was different in the present study compared to their study.

In the research by Claudia Kochenborger et al. [1], the 3M E-chain showed the highest percentage of force degradation compared to other E-chains. With 16mm spacing between steel pin's, the force applied initially was 150g, and by day 21st, there had been a 57% of force degradation in artificial saliva. However, in the current research, the initial force obtained was 400.4 g and the steel pins spacing was adjusted to 25 mm, which is approximately equal to the distance between the upper first molar and the upper canine.

One of the major challenges in correlating the findings of this study to clinical conditions is the insufficiency of appropriate *invivo* investigations. Ash and Nikolai [22] demonstrated that, in contrast to the oral cavity environment (*in vivo*), the loss of elastomeric chain force was reduced under laboratory (*in vitro*) conditions. According to a study by Rock et al*.* [23] elastomeric chains kept in the oral environment maintained only 43%–52% of their initial force after four weeks, but chains placed in the air retained 70%–75% of their initial force [24].

To provide relevant clinical results, the orthodontist must understand the behaviour of these elastomeric materials in a dynamic oral environment. As a result of force degradation and irreversible deformation, orthodontic elastomeric chains are to be clinically replaced every 3–4 weeks. Orthodontists should be aware that an acidic pH can hydrolyze elastomeric material, leading to irreversible deformation and force degradation in orthodontic elastomeric chains. This study did not represent the *in vivo* degradation as it was conducted under *in vitro* static settings. Hence, additional research must be done in clinical conditions with various dietary practices, microbial activity, and mechanical stretching in oral environments [25].

5. CONCLUSION

Force degradation was less within one month among AO and 3M orthodontic E-chains when herbal and non-herbal mouthwashes were used. 3M E-chain and Herbal mouthwashes retained a greater amount of force compared to AO and non-herbal mouthwashes.

ETHICAL APPROVAL

The current study is an *invitro* study was performed by taking institutional consent (IECVDC/2021/PG01/ODFO/IVT/39).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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