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RESEARCH ARTICLE

FORCE DECAY OF LATEX AND NON-LATEX ORTHODONTIC ELASTICS- AN IN VITRO STUDY

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ABSTRACT

Introduction: Elastics and elastomers has been extensively used in orthodonticd. Force decay over a period of time is a major problem in the clinical usage of latex elastics and non-latex. This loss of force makes it difficult for the clinician to determine the actual force transmitted to the dentition Hence, the aim and objective of this study was to evaluate the force decay of latex and non-latex elastic of different brands and different sizes at 8 hours and 24 hours after having been subjected to constant stretching in both wet and dry .**Material and Methods:** Latex and non latex elastics (Figure 1)were used of size 1\4inch and 3\16inch inner diameter and were of medium force (4.5 oz) obtained from three manufacturers namely - Forest dent, American orthodontics (wild life series - gorilla, eagle, jelly fish and sand dollar), Jaypee orthodontics. The mechanical testing conducted on 480 samples of each type of elastics and force decay measured and was compared to that specified by the manufacturer. Difference between brand, composition, and wet/dry condition was analyzed using SPSS (version 21.0) using ANOVA analysis. **Conclusion:** Force decay was more in the wet media than dry media after stretching for 8 hrs and 24 hron Force decay was maximum in Foresta dent when compared with other brands in the dry media after 8 hrs of stretching. Forrce decay was maximum in American Orthodontics when compared with other brands in the wet media after 8 hrs of stretching.3

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INTRODUCTION

Elastics and elastomers has been extensively used in orthodontics since the advent of the specialty. They are routinely used as active component of force in orthodontic treatment. Their use combined with patient compliance provides the clinician with the ability to correct both antero-posterior and vertical discrepancies (Asbell, 1990). Elastics arr generally of two types namely latex and non-latex. Latex has been extensively used in orthodontics since the advent of the specialty. Latex elastics are used in intra arch and inter arch mechanics for final detailing of the occlusion and fixation of the maxilla and mandible together after orthognathic surgery. The advantages of latex elastics are their low cost and greater ability to return to their original dimensions after substantial deformation (Hanson, 2004). Natural latex is an isoprene polymer of high molecular weight with small quantities of protein and fatty acids. Being too weak in its natural state, it has to be processed.

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Latex as such, is probably not an allergen, but the addition of ammonia during processing produces proteins that are potentially allergenic (Lopez, 2012). Workers in the professional health fields are at risk for these hypersensitivity reactions; their prevalence of latex allergy has been reported between 3% and 17%. A process that impacts the extracTable protein in latex is prevulcanization. The production of prevulcanized latex involves mixing natural rubber latex with stabilizers and vulcanizing chemicals. The mixture is then heated to temperatures reaching 70°C. Stabilizers and cross-linking agents such as zinc oxide, dialkyldithiocarbamate accelerators, and sulfur are added to the natural rubber latex during heating. The advantage of this process is that it produces latex with superior mechanical properties, such as increased strength and elastic rebound. However, the process adds some potentially toxic compounds (Hanson, 2004). According to ADA Council on Scientific Affairs, 1999 it was estimated that between 0.12 to 6 per cent of the general population and 6.2 per cent of dental practitioners are hypersensitive to latex. Latex exposure often produce contact dermatitis, stomatitis with acute swelling, erythematous buccal lesions, dermatologic reactions, respiratory reactions, and systematic reactions in extreme, anaphylactic shock. As the incidence of latex allergic reactions increased in early 90's, non-latex elastics have been made available for orthodontic use (Lopez *et al.*, 2012). They are composed of proprietary polyurethane elastomers which rely on entanglements, rather than covalent crosslinks, to limit force relaxation. The mechanical performance of these polyurethane materials has been poor compared with that of latex materials. Various studies were conducted to compare the force extension characteristic and force decay properties of latex elastics and non-latex elastics. These studies reported that the general mechanical properties of the non-latex elastics were not comparable to those of the latex elastics, however the non latex elastics showed more viscoelastic properties than both the latex elastics of same brand and non latex elastics of different brand. The two non-latex elastics also had different dimensions and different initial force generation properties for the equivalent marketed size and force level, as well as different force decay properties over time (Russell *et al*., 2001; Pithon *et al*., 2013). Hence ,al the studies till date vary with regard to the materials and methods employed, leading to varying conclusions regarding these elastics mechanical properties Therefore, the aim of this study was to evaluate the force decay of latex and non-latex elastic of different brands and different sizes at 8 hours and 24 hours after having been subjected to constant stretching in both wet and dry medium.

MATERIALS AND METHODS

The study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics.

Material used: Latex and non latex elastics (Figure 1) were used of size 1\4inch and 3\16inch inner diameter and were of medium force (4.5 oz) obtained from three manufacturers namely –

- Forestadent,
- American orthodontics (wild life series - gorilla, eagle, jelly fish and sand dollar)
- Jaypee orthodontics.

The mechanical testing (Figure 2&3) was conducted on 480 samples of each type of elastics (Table I). The samples obtained were well within shelf life. They were refrigerated in plastic covers provided by the manufacturers and kept away from sunlight to prevent any deterioration.

METHODOLOGY:

Color coded pins were mounted on four wooden blocks (Figure 5) and separated by the distance of 1.9 cm for elastics of size ¼" and 1.45 cm for 3/16" elastics.
Color coding of stainless steel pins

BRANDS LATEX NON-LATEX

- Forestadent Blue Red
- Jaypee Black White
- A O Green Yellow

Two types of test were carried out:

- In dry testing method elastics were stretched to three times their inner diameter at room temperature, various mechanical tests were performed after 8 hours, and 24 hours
- In wet testing method the elastics were submerged in artificial saliva and were stretched to three times their inner diameter and various mechanical tests were done after 8 and 24 hours.

After the specific interval elastics were transferred to the universal testing machine (Figure 3) for mechanical testing from the acrylic measuring board. Force evaluations were carried out using a Universal Testing Machine with a load cell of 1Kn/100Kgf and crosshead speed of 30 mm/minute. The elastics were stretched between two hooks, one on the fixed base and the other on the machine head. The machine head was stopped when the elastic was stretched to three times its inner diameter. Its peak force was measured in newton. The decay force was measured and was compared to that specified by the manufacturer. Difference between brand, composition, and wet/dry condition was analyzed using SPSS (version 21.0)

RESULTS

This study was designed to study the force decay of latex and non-latex orthodontic elastics. It was carried out on a total of 480 elastics equally divided under 3 different brands and 2 different sizes. The statistical analysis was done using SPSS (Statistical package for social sciences) software. Difference between brand, composition, and wet/dry condition was analyzed using SPSS (version 21.0) by ANOVA analysis. ANOVA test was used to establish the presence of significant difference between initial force and force after 8hrs and 24hrs in wet condition. The descriptive statistics for the force values including the mean, standard deviation, and range were tabulated (Table I). Depending upon the material used, they were divided into latex and non-latex elastics which were then compared. Three brands of elastics were further categorized into dry and wet media, depending on the type of media chosen for ageing the elastics. The effect of media on the force decay of elastics was seen. Each of the different size and brand of latex and non-latex elastics in dry or wet media was tested at 8 hrs and at 24 hrs to check the force decay as shown in Table II,III,IV. Table V and Graph 1 showed the interbrand mean force values significant difference across test times at 8 hours and 24 hours.

DISCUSSION

Elastics and elastomerics are used as an active component of orthodontic treatment such as retraction, cross-bite correction, space closure (Wong, 1976). The use of latex elastics in clinical practice is mainly estimated on force extension values given by the various manufacturers for various sizes of elastics. The standard force index utilized by suppliers imply that at three times the original lumen size, elastics will exert the force mentioned on the package (Baty, 1994). Force degradation happens over time among most types of traction aids currently available. In oral cavity various factors can influence force generation and force degradation of traction aids, such as saliva, temperature fluctuation, pH variation, fluoride ions release, oxygen content, free radicals, salivary enzymes and masticatory forces (Gioka, 2006). The amount of tooth movement is directly proportional to the pressure (force per unit area of periodontal ligament) applied to a tooth when the pressure is above a minimal threshold and below the optimal force levels.

Table 1. descriptive statistics including mean, standard deviation and range

Brand	Material	Group	Elastic	Mean	SD	Range
AMERICAN ORTHODONTICS (AO)	Latex	I	AODL1/4i8h	1.473	0.04	0.13
		II	AODL1/4i24h	1.392	0.05	0.15
		III	AODL3/16i8h	1.486	0.04	0.13
		IV	AODL3/16i24h	1.403	0.03	0.1
		V	AOWL1/4i8h	1.476	0.03	0.08
		VI	AOWL1/4i24h	1.401	0.3	0.09
		VII	AOWL3/16i8h	1.408	0.6	0.13
		VIII	AOWL3/16i24h	1.414	0.3	0.12
	Non-Latex	IX	AODNL1/4i8h	1.442	0.03	0.12
		X	AODNL1/4i24h	1.362	0.05	0.17
		XI	AODNL3/16i8h	1.368	0.09	0.27
		XII	AODNL3/16i24h	1.366	0.03	0.1
		XIII	AOWNL1/4i8h	1.408	0.07	0.22
		XIV	AOWNL1/4i24h	1.368	0.03	0.1
		XV	AOWNL3/16i8h	1.412	0.06	0.18
		XVI	AOWNL3/16i24h	1.37	0.03	0.1
FORESTADENT (FD)	Latex	XVII	FDL1/4i8h	1.498	0.05	0.16
		XVIII	FDL1/4i24h	1.441	0.06	0.18
		XIX	FDL3/16i8h	1.459	0.05	0.17
		XX	FDL3/16i24h	1.437	0.05	0.18
		XXI	FWL1/4i8h	1.376	0.03	0.1
		XXII	FWL1/4i24h	1.316	0.04	0.14
		XXIII	FWL3/16i8h	1.362	0.03	0.14
		XXIV	FWL3/16i24h	1.346	0.02	0.08
	Non-Latex	XXV	FDNL1/4i8h	1.421	0.04	0.16
		XXVI	FDNL1/4i24h	1.385	0.06	0.16
		XXVII	FDNL3/16i8h	1.421	0.04	0.14
		XXVIII	FDNL3/16i24h	1.414	0.04	0.12
		XXIX	FWNL1/4i8h	1.323	0.03	0.12
		XXX	FWNL1/4i24h	1.288	0.05	0.18
		XXXI	FWNL3/16i8h	1.333	0.04	0.12
		XXXII	FWNL3/16i24h	1.321	0.03	0.1
JAYPEE (JP)	Latex	XXXIII	JPDL1/4i8h	1.725	0.11	0.39
		XXXIV	JPDL1/4i24h	1.674	0.04	0.14
		XXXV	JPDL3/16i8h	1.612	0.19	0.53
		XXXVI	JPDL3/16i24h	1.549	0.10	0.32
		XXXVII	JPWL1/4i8h	1.704	0.04	0.12
		XXXVIII	JPWL1/4i24h	1.507	0.12	0.42
		XXXIX	JPWL3/16i8h	1.696	0.04	0.16
		XL	JPWL3/16i24h	1.59	0.06	0.18
	Non-Latex	XLI	JPDNL1/4i8h	1.548	0.13	0.46
		XLII	JPDNL1/4i24h	1.588	0.05	0.19
		XLIII	JPDNL3/16i8h	1.507	0.15	0.46
		XLIV	JPDNL3/16i24h	1.538	0.07	0.24
		XLV	JPWNL1/4i8h	1.519	0.09	0.25
		XLVI	JPWNL1/4i24h	1.456	0.06	0.22
		XLVII	JPWNL3/16i8h	1.552	0.07	0.26
		XLVIII	JPWNL3/16i24h	1.49	0.07	0.22

(L, latex; NL, non-latex; D, Dry test; W, Wet test; 1/4i, ¼ INCH; 3/16i, 3/16INCH; 8h, 8Hours; 24h, 24 Hours)

Table II : differences in force levels between wet and dry medium at 8 hrs and 24 hrs.

	Time			
	8h force	p value	24h force	p value
AMERICAN ORTHODONTICS LATEX	DRY>WET	0.0007	DRY>WET	0.013
AMERICAN ORTHODONTICS NON LATEX	DRY>WET	0.0002	DRY>WET	0.0002
FORESTADENT LATEX	DRY>WET	0.0004	DRY>WET	0.014
FORESTADENT NON LATEX	DRY>WET	0.0004	DRY>WET	0.03
JAYPEE LATEX	DRY>WET	0.003	DRY>WET	0.043
JAYPEE NON LATEX	NS	1.20	DRY>WET	0.006

Table III : Differences in force levels between latex and non-latex elastics at 8 hrs and 24 hrs.

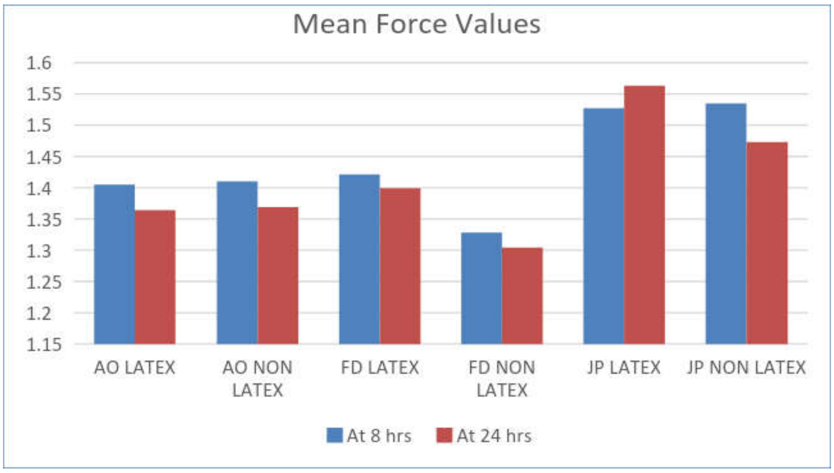
	Time			
	8h force	p value	24h force	p value
AMERICAN ORTHODONTICS DRY	NS	0.43	NS	0.21
AMERICAN ORTHODONTICS WET	NS	0.41	NS	0.34
FORESTADENT DRY	NS	3.7	NS	2.64
FORESTADENT WET	NS	1.9	NS	4.4
JAYPEE DRY	NS	0.211	LATEX>NON LATEX	0.03
JAYPEE WET	NS	0.41	LATEX>NON LATEX	0.0001

Table IV : Differences in force levels between various brands at 8 hrs and 24 hrs.

	Time			
	8h force	p value	24h force	p value
LATEX DRY	JP>AO>FROS	0.0002	NS	5.8
LATEX WET	JP>FROS>AO	0.0003	NS	1.44
NON LATEX DRY	NS	9.98	NS	1.2
NON LATEX WET	NS	5.75	NS	1.65

Table V: inter brand mean force values significant differences across test times. (in newtons) at 8hours and 24 hours

	Force (N)		
	Manufacturer	At 8 hrs	At 24 hrs
AO LATEX	1.25	1.405	1.364
AO NON LATEX	1.25	1.41	1.369
FD LATEX	1.25	1.421	1.399
FD NON LATEX	1.25	1.328	1.304
JP LATEX	1.25	1.527	1.563
JP NON LATEX	1.25	1.535	1.473



Graph 1. Inter brand mean force values significant differences across test times (in newtons)

Figure 1. Elastics used in the study

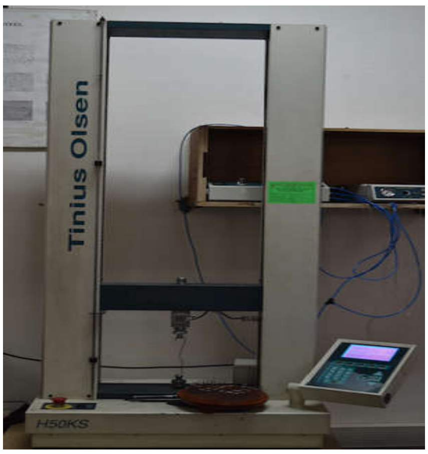


Figure 2. Universal testing machine

Figure 3. Elastics stretched in universal testing machine

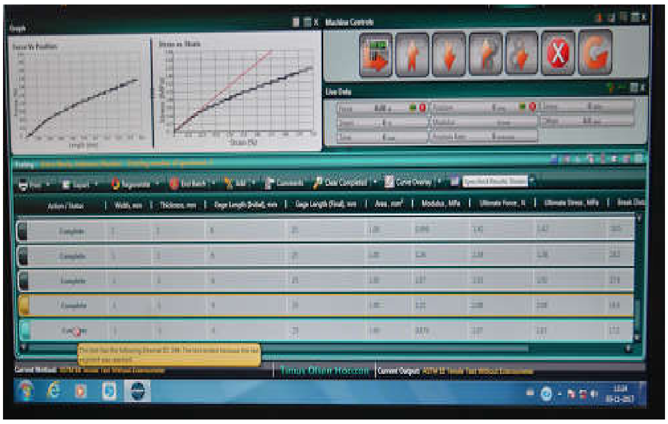


Figure 4. Reading in Universal testing machine

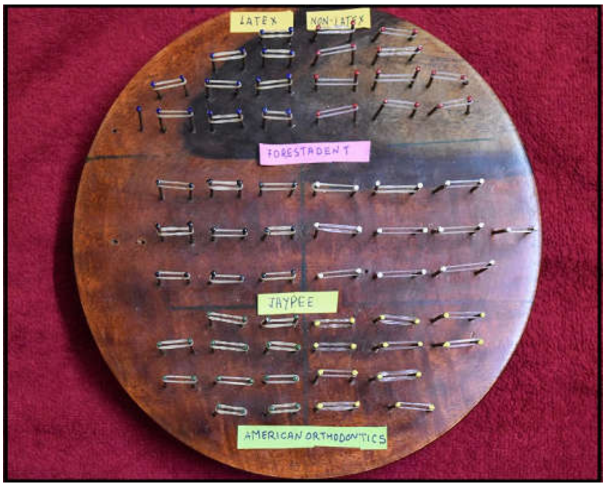


Figure 5. Elastics stretched on a plate

The force derived from elastics depends on the magnitude of the initial force, the length of time since activation, and the rate of force decay. Therefore, depending on the effects of these three factors, the elastic may be applying an ineffective force for some period before the patient returns for the next scheduled visit. The orthodontist must be able to choose an elastic band with force-extension characteristics that are most sui Table for the particular tooth movement required. This means that the orthodontist must know the force-extension characteristics of the range of elastics at his/her disposal. Manufacturers specify elastics according to a standard index indicating the force delivered at an extension that is 3 times the lumen size. However, such specifications may not represent the true index and so not correlate with clinical intentions for the elastics. Force decay over a period of time is a major problem in the clinical usage of latex elastics and non-latex. This loss of force makes it difficult for the clinician to determine the actual force transmitted to the dentition. It is the intent of the clinician to maintain optimal force values over desired period of time. Hence knowledge of force decay of elastics and synthetic elastomers will help to determine their clinical usage. In the present study, three different brands namely American orthodontics, Forest dent, and Jaypee were taken and compared. Latex and non-latex elastics of diameter ¼" and 3/16"of all the three companies were tested in dry and wet condition at 8hrs and 24hrs for force decay(Table II).According to Beattie and Monaghan, in clinical practice, orthodontists generally recommend changing the elastics at least every day (Beattie, 2004).

Other researchers have indicated that the latex elastics only need to be replaced every 3 days, because they found no differences in the force release between 24 and 72 hours (Bales *et al*., 1977; Loriato *et al*., 2006). The elastics must remain activated for a longer period to maintain a relatively constant force. A study conducted by Santos *et al*., which also evaluated the mechanical properties of elastics with and without latex (*in vitro)*, recorded measurements at 0, 1, 4, 8, 12, and 24 hours (Dos Santos *et al*., 2009). When latex and nonlatex orthodontic elastics were examined, it was found that the nonlatex orthodontic elastics were not comparable to their latex counterparts in mechanical properties (Russell *et al*., 2001).

In the present study the elastics were aged under artificial saliva with constant pH 7.2 at 37º C to simulate the oral conditions. There is general agreement with many studies that there is large variability between samples in the same batch (Wong, 1976; Gioka, 2006; Andreasen, 1970). Likewise, large variability of these materials can be found more in dry tests when compared with wet tests. (Brawley found that the pH of saliva in 3405 cases ranged from 5.6 to 7.6, with a mean of 6.75.) (Robert, 1978) Even when relatively strong solutions of acid and alkali are ingested, the salivary pH quickly reverts to the individual subject's baseline pH. In the present study, when American Orthodontics latex and non-latex elastics were tested under dry and wet conditions to find out a difference in force decay, the results were significant for 8 hrs as well as 24 hrs of stretching(Table II). Forestadent latex and non-latex elastics were also tested under dry and wet conditions to find out a difference in force decay, the results were significant for 8hrs as well as 24 hrs of stretching. However, for jaypee, the results were significant only at 24 hrs of stretching.

This was in accordance to a study by Wong, (1976)Ash and Nikolai (1978) who stated that greater force decay was observed in wet condition than dry conditions of the same temperature. Thomas *et al* also could not find a significant difference in the amount of force decay under dry and wet conditions (Thomas, 1966). The present findings suggest that exposure of the elastomer to water led first to weakening of intermolecular forces and subsequently to chemical degradation. This effect is evidently due to the presence of ester or ether backbone linkages, which are highly susceptible to hydrolysis and are the first compounds to be affected by water attack (Schollenberger and Stewart, 1971). Thus, intruding Water molecules may weaken the material, causing a reduction in the load required to maintain a fixed extension. This event is expressed as force decay in force relaxation experimental set-ups (Phua *et al*., 1987). Specifically, reduction of load requirement after one day and seven days of water storage may be the result of water sorption and the concurrent formation of hydrogen bonds between water molecules and macromolecules. Since leachable substances were not found in one- and seven-day-specimen storage water, it appears that absorbed water functioned initially as a plasticizer, and thereby facilitated slippage of molecules or chain segments past other molecules or segments. In the present study, American orthodontics and Forest dent elastics showed no significant differences at 8 hrs and 24 hrs when latex was compared with non-latex under dry and wet media (Table III). This was in accordance to a study Russell, who compared the mechanical properties of latex and non-latex orthodontic elastics and concluded that the mechanical properties of the non-latex elastics were not comparable to those of the latex elastics in both dry and wet medium.

However, jaypee latex elastics showed lesser force decay when compared to non-latex at 24hrs under dry as well as wet media. This was supports by Bertoncini *et al* who indicated that non-latex elastic become more deformed with use than latex.[19] Also according to study by Aljhani As and Aldrees AA, there was significant difference observed between latex and nonlatex groups which was due to the different structure and composition of the polymer involved (Aljhani, 2010). The nonlatex elastics, synthetic polymer, may rely more on molecular entanglement for structural integrity rather than the covalent cross-linking that is present in the natural rubber used in the latex elastics. These structural differences may lead to the long term poorer behavior of the non-latex elastics. Natural rubber is an elastomer with a structure formed by a three-dimensional reticulate structure by cross-links. Its elastic properties depend on irregular twisted arrangements of long molecular chains linked together at certain points by covalent bonds between different atoms, such as sulfur with carbon atoms (Kanchana, 2000; Tong Wang, 2007). When latex elastic loads a certain force beyond its stress limit, fatigue begins at the weak points brought by its inside or surface lack of homogeneity (Hanson, 2004). Simultaneously, friction between molecular chains also causes dynamic fatigue (Kanchana, 2000). When activated, elastomeric chains deform by both elastic stretch and slippage (De Genova, 1985; Rock, 1985). In the present study when all the 3 brands were compared under Latex dry, Latex wet, Non-latex dry and Non-latex wet subheadings (Table IV).

It was seen that the results of only Latex dry and Latex wet after 8 hrs were significant. Jaypee latex and non-latex elastics showing highest force levels in both the groups. Despite the fact that most of the orthodontic elastomeric modules currently circulated in the market share similar fabrication methods and common raw material, mainly a polyurethane-based, patent-protected composition, significant variations have been apparent with regard to force decay relaxation characteristics (De Genova, 1985). These differences may be attributed to fundamental processing variations between the manufacturers. This may involve (i) cutting versus injection-molding of modules from the raw material, (ii) effects induced from various additives incorporated in the final product, (iii) strictness of quality control procedures followed by (iv) different shapes (ellipsoid or circular modules), and (v) modular diameters. Discrepancies have also been documented in the literature through several different protocols adopted for the evaluation of the force degradation rates of elastomerics, involving dry or wet testing states (Rock *et al*., 1985), including water, artificial saliva, or fluoride media in acidic or neutral pH, (Ferriter, 1990; Von Fraunhofer, 1992) different temperatures (Brooks, 1976) and decreasing or steady force applications (Tz Chau, 1993). The analysis of force relaxation patterns for the elastomeric materials under these conditions have revealed a remarkable variation with respect to both magnitude and rate of force degradation (Ash, 1978; Kuster *et al*., 1986). As this is an in-vitro study,so for more reliable clinical implications it will require further investigations.

Conclusion

- Force decay was more in the wet media than dry media after stretching for 8 hrs and 24 hron comparison of latexex elastics and non-latex elastics of different brands.
- Force decay was non-significant on comparison of latex elastics with non-latex elastics of different brands after stretching for 8 hrs and 24 hrs in dry media and wet media.
- Forcce decay was maximum in Forestadent followed by American Orthodontics and followed by Jaypee when compared with each other in the dry media after 8 hrs of stretching,
- Forrce decay was maximum in American Orthodontics followed by Forestadent and followed by Jaypee when compared with each other in the wet media after 8 hrs of stretching.

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