

Application of Elastomeric Chains in Orthodontics: Past, Present and Future

Amir Hossein Mirhashemi,¹ Niloofar Farahmand,² and Elahe Soltanmohamadi Borujeni^{1,*}

¹Department of Orthodontics, Tehran University of Medical Sciences, Tehran, IR Iran

²Dentist, Tehran, IR Iran

*Corresponding author: Elahe Soltanmohamadi Borujeni, Department of Orthodontics, Faculty of Dentistry, Tehran University of Medical Sciences, Tehran, IR Iran. Tel: +98-9378915277, E-mail: elahe.mohamadi25@gmail.com

Received 2016 January 23; Revised 2016 February 10; Accepted 2016 April 25.

Abstract

Context: One of the most important aims in orthodontic treatment is to apply a light continuous force to achieve maximum effective tooth movement with minimal side effects (optimal tooth movement). It is obvious that elastomeric chains are the most popular method of space closure, but they undergo force decay during time. Force decay behavior of elastomeric chains is influenced by various factors. It is crucial for every practitioner to know about these products and factors affecting them.

Evidence Acquisition: So we searched English articles published in Pubmed between 2005 - 2016 with keyword "orthodontics, elastomeric chain".

Results: 25 articles were selected for comprehensive reading according to the inclusion criteria. Some factors such as aging process, production technique, pre-stretching effect, design and type of chains, in-vivo effects and microbial contamination were discussed.

Conclusions: By reviewing these articles, we know more about force decay pattern of elastomeric chains. Most of articles said the same force decay pattern for these elastomeric products. We know more about environmental conditions affect their features. This can help practitioners to use chains, in a better way.

1. Context

One of the most important aims in orthodontic treatment is to apply a light continuous force to achieve maximum effective tooth movement with minimal side effects (optimal tooth movement). It is obvious that elastomeric chains are the most popular method of space closure due to ease of application, low cost, patient and clinician comfort and etc. Besides the hygienic problem the most important problem of the chains is their force decay during the time. Nearly, 50 to 70% of their initial force is lost in the first 24 hours (1), with most of the loss within the first hour and after 2 weeks only a small percent of initial force is preserved. Force decay behavior of elastomeric chains is influenced by various factors such as design, manufacturing techniques, environmental conditions, color and etc. As this is essential for clinicians to know the properties of all materials they use, this study was done to publish a comprehensive information about chains, their characteristics and factors affecting them in orthodontic treatments.

2. Evidence Acquisition

Our strategy was to search English articles published in Pubmed between years 2005 - 2016. Search was done

with keywords "orthodontics", "elastomeric chain". Totally, 31 articles were found. According to the inclusion criteria, 25 of them were selected for comprehensive reading. According to the factors such as aging process, production techniques, pre-stretching effect, design of chains, type of chains, in vivo effects and microbial colonization the gained information are categorized and discussed.

3. Results

3.1. The Effect of Aging

Dittmer et al. (2) (2012), performed a study to investigate the effect of artificial aging on mechanical features of closed elastomeric chains. The samples were placed in Universal testing machine and stretched 4 times more than original length. They were kept in this manner for 5 seconds. Then, the length of them were decreased to 3 times more than original length and kept for 30 seconds. Specimens of 3 other groups (except control group) were kept in 37°C distilled water with tension 3 times more than original length for 1, 14 and 28 days. Then their remnant force (F min) was measured. Finally, they were stretched till they fractured (F max, L max). Results showed significant differences between L max, F max, F min in each group between

various manufactures. Artificial aging had significant effect on F min, F max, L max.

Wahab et al. (3) (2014), searched the effects of UVA rays on tensile features of elastomeric chains. UVA is used as a method for artificial aging. It assimilates long term keeping of elastomeric chains. This study was assimilating pre-stretching condition and decreasing of chain length in clinic. Tensile force of chains is significantly different and dependent on the time of exposure.

3.2. The Effect of Various Producing Techniques

Bousquet et al. (4) (2006), investigated the effect of different producing techniques in the amount of force decay of elastomeric chains. 2 type of elastomeric chains (injected molded and die-cut stamped from the same manufacture) were placed randomly in various arches and arch sides of a patient (split-mouth design). Obvious difference in force decay was not seen between different elastomeric chains during 3 weeks. Mean remnant force after 3 weeks was clinically enough to retract canine. Behavior of elastomeric chains in both arches was also similar clinically and statistically.

Oshagh et al. (5) (2010), evaluated the amount of initial force and compared the amount of force decay between the elastomeric chain and tie-back method over a period of time. The force of all samples was measured at baseline, 24 and 48 hours, and once a week thereafter for 4 weeks. The tie-back method had a lower initial force than the elastomeric chain. Difference between the force decay of the two groups at both 24 and 48 hours was statistically significant. So it was concluded that using the tie-back method for space closure, which has more appropriate initial force and slower force decay, may have a clinical value to approach a more light and continues force.

Fernandes et al. (6) (2011), evaluated the force extension relaxation of different manufacturers and diameters of latex elastics subjected to static tensile testing under dry and wet conditions. 15 elastics from 3 manufacturers were used with 3/16, 1/4, and 5/16 inch lumen size. Forces were read after 1, 3, 6, 12, and 24 hour periods. They concluded that significant differences in force extension relaxation were noted between elastics from different manufacturers. Chains showed a notable drop-off of forces during 0 to 3 hours, a slight increase in force from 3 to 6 hours, and a progressive force reduction over 6 to 24 hours.

Masoud et al. (7) (2014), with investigation of force decay in thermoplastic and thermoset elastomeric chains and between light and heavy initial forces (200 g versus 350 g) , found that in comparison with thermoset elastomeric chains, thermoplastic chains always had more force decay. Thermoset chains needed more tension to

reach desired force. There was no difference in force decay during use of chains with different initial forces.

Aldreus et al. (8) (2015), compared the force decay of clear and semi-clear elastomeric chains from eight different manufacturers and amount of discoloration after immersion in colored dietary media. There was a significant difference in the lost initial force between all the tested elastomeric chains. Semi-clear elastomeric chains showed significantly less change in color than clear elastomeric chains of the same brand. Significant differences in the mean force decay and discoloration were present between elastomeric chains.

3.3. The Effect of External Factors

Evangelista et al. (9) (2007), assessed the effect of exposure to disinfectant solutions on the tensile load at failure and glass transition temperature of orthodontic elastomeric ligatures. Elastomeric ligatures from three manufacturers were exposed to two disinfectant solutions for up to 28 days. Significant differences in tensile load at failure and glass transition temperature of the ligatures were observed among the different manufacturers and exposure time. Type of disinfectant solution was a significant factor with glass transition temperature, but it didn't affect failure load. Strength significantly decreased after one hour exposure in disinfectant solutions. Glass transition temperature was also significantly affected by disinfectant exposure, but the different disinfectants changed it in opposite directions. Finally, it was announced that exposure of elastomeric ligatures to disinfectant solution for one hour or more decreased their strength.

Teixeira et al. (10) (2008), studied the in-vitro effect of light Coke, phosphoric acid and citric acid on the force-decay pattern of 2 types of elastomeric chains. During the experiment, all elastomeric chains were kept immersed in artificial saliva at 37 masculineC to simulate the oral environment. To simulate daily consumption of light Coke, the elastomeric chains were immersed in the solutions twice a day for 15 minutes. The control group was kept immersed in artificial saliva with no further treatment. Force was measured initially, 24 hours, 7, 14, and 21 days. A statistically significant reduction of the force was seen at different time points. The greatest reduction in force occurred in the first 24 hours. The immersion treatments caused no statistically significant difference the in force of chain module.

Larrabee et al. (11) (2012), tested the in-vitro effects of increasing alcohol concentrations on the amount of elastomeric chain force decay. All groups showed significantly more force decay than the control group. It was said that alcohol causes an increase in force decay of elastomeric chain over time. A concentration dependence of alcohol on force decay of elastomeric chains was not observed.

Pithon et al. (12) (2013), searched in vitro effect of mouthwashes with and without bleaching agents on the force of elastomeric chains. From 4 groups that were selected for this study, two groups were exposed to two types of commonly used mouthwashes (Plax and Listerine), and two groups were exposed to mouthwashes containing bleaching agent (Plax Whitening and Listerine Whitening). No statistically significant differences were found between the groups in the initial period. Statistically significant differences were found between the control group and the Plax, Plax Whitening, and Listerine groups at the time intervals of 7, 14, and 21 days. In the initial period, the force was statistically significantly higher than it was in any of the other experimental periods. The control group with distilled water and the test group with Plax Whitening maintained the most force during the experimental period. It was concluded that the presence of bleaching agent has no influence on the force degradation of elastomeric chains.

Halimi et al. (13) (2013), designed a study to know about mechanical properties of elastomeric chains after stretching in various artificial saliva solutions and in air. Five brands of elastomeric chain from different manufacturers were selected. They were then immersed in pre-prepared solutions, with control samples exposed to air only. The force delivered by the elastomeric chains decayed rapidly and differently over time. This decay varied depending on multiple factors like PH of the environments. In the more acidic PH, force decay was occurred more. In artificial saliva with PH = 7 and 37 degree centigrade temperature, clear chain was shown faster force-decay than gray chain. Closed chain was shown slower force-decay in comparison to open one.

Kumar et al. (14) (2014), compared the effect of Coca-Cola, tea and Listerine mouthwash on the force delivered by elastomeric chain in vitro. They concluded that all these solutions cause an increase in force decay of elastomeric chains over time. Tea caused highest force decay followed by Listerine and Coca-Cola when compared to control group.

In a study that was done by Omidkhoda et al. (15) (2015), the effects of three different mouthwashes on the force decay of orthodontic chains were evaluated :artificial saliva, Persica, chlorhexidine 0.2% and sodium fluoride 0.05% mouthwashes. About 20% of the force decay occurred during the first 24 hour, but after that and up to the 4th week, the rate of force loss was gradual and steady. After 4 weeks, Persica and Chlorhexidine caused the lowest and the highest percentage of force loss, respectively. These two mouthwashes showed statistically significant differences at all points of time. They announced that Persica is preferred to Chlorhexidine for oral health control in

orthodontic patients.

3.4. The Effect of Different Types of Elastomeric Chains and Different Designs

Balhoff et al. (16) (2011), searched the percentage force decay of elastomeric chains utilizing three different design mechanisms and the percentage force decay of elastomeric chains from four different companies. The 6-5-3, the chain loop, and the 6-3 were the configuration mechanisms used in the study. There was a significant difference in the mean percentage force decay for the three different mechanisms. For all four companies, the 6-3 mechanical design had the smallest mean percentage force decay. There was a significant difference in the mean percentage force decay for different companies. This study suggested the 6-3 design is a more efficient means of closing extraction spaces utilizing elastomeric chains.

Dittmer et al. (17) (2010), investigated the tensile properties of orthodontic elastomeric chains of eight manufacturers with and without an intermodular link. Samples were mounted in a universal testing machine and extended four times more than the initial length and held for 5 seconds. After 5 seconds, the chain lengths were reduced to an extension of three times the initial length and held for 30 seconds before extension until failure. Forces at four times the test length (F max1), three times the initial length (F min) as well as force (F max2) and length (L max) at failure were recorded. Statistical analysis revealed significant differences in F max1, F min, F max2 and L max among the various manufacturers. The conclusion was that the tensile properties of different manufacturers differ statistically significantly.

Weissheimer et al. (18) (2013), analyzed the in vitro force degradation of four different brands of elastomeric chains. There was a statistically significant difference between the groups regarding the force degradation, mainly within the first day, as a force loss of 50% -55% was observed during that time in relation to the initial force. It was said that all groups showed force degradation over time, regardless of their trademarks, a force loss of 59% - 69% was observed in the first hour.

Kanuru et al. (19) (2014) investigated the amount of space closure by movement of canines into the extraction spaces using four brands of elastomeric chains for 6 weeks. They said that although all brands of the elastomeric chains produced space closure of canines, it was observed that not much of a significant difference existed among the products tested.

3.5. Pre-Stretching Effect

Kim et al. (20) (2005), evaluated the effects of pre-stretching on time-dependent force decay of elastomeric

chains. 5-unit and 6-unit modules were pre-stretched 100% for 1 and 24 hours, 2 and 4 weeks in 37 degrees centigrade distilled water. The pre-stretched and un-pre-stretched chains were then stretched to 30 mm in 37 degree centigrade water. The pre-stretched 5- and 6-unit modules yielded significantly lower initial force than the controls. All 5- and 6-unit pre-stretched and control groups showed substantial force decay during the first hour. However, at 1 hour, similar remaining forces were found in the 5-unit pre-stretched and control groups, and small differences were seen in the 6-unit groups. The rates and patterns of force decay from 1 hour to 4 weeks were quite similar between the control and the pre-stretched modules of both the 5- and 6-unit groups. It was found that the effects of pre-stretching on force decay of elastomeric chains were noted mainly in the first hour. Thus, the clinical value of pre-stretching on elastomeric chains is questionable.

3.6. In-Vivo Effect

Wang et al. (21) (2007) evaluate the characteristics of force degradation of latex elastics in clinical applications and in vitro studies. There were statistically significant differences between the different methods and observation intervals. At 24- and 48-hour time intervals, the force decreased during in vivo testing and in artificial saliva, whereas there were no significant differences in dry room conditions. Force degradation of latex elastics was different according to their environmental conditions. There was significantly more force degradation in intermaxillary traction than in intramaxillary traction. The dry room condition caused the least force loss. Totally, there were some differences among groups in the different times to start wearing elastics in intermaxillary traction but no significant differences in intramaxillary traction.

Crawford et al. (22) (2010) investigated the change in the physical properties of conventional and Super Slick elastomeric ligatures after they have been in the mouth. The two outcome measures were failure load and the static frictional resistance. The failure load for conventional ligatures and Super Slick ones was comparable after 6 weeks in situ. It was said that there were statistically significant differences in the failure loads of elastomeric chains that had not been placed in the mouth and those that had been in the mouth for 6 weeks. There were no differences in the static frictional forces produced by conventional and Super Slick ligatures either before or after they had been placed in the mouth. There appears to be a direct proportional relationship between failure load and static friction of elastomeric ligatures.

Baratieri et al. (23) (2012) tested whether intraoral exposure of elastomeric chains alters their tensile strength or not. 3 kinds of elastomeric chains, Plastic chain (PC),

Memory chain (MC) and Super slick chain (SSC), were randomly placed in 3 quadrants of 13 patient and stretched for 3 weeks. The effect of both the material and the time factors were significant. In conclusion, intraoral exposure of elastomeric chains altered their tensile strength. The greater force decay occurred within the first hour in all groups. The remaining force of the enhanced chains measured at each time interval was greater than the conventional one (PC). After 3 weeks, only the enhanced chains maintained the applied force over 100 g.

Mirhashemi et al. (1) (2012) compared elastomeric chains claimed by their manufacturers to offer high memory with traditional ones according to their force-extension diagrams. They saw force-decay rate was significantly different between traditional and memory chains. For traditional chains, there was a substantial decay in force in the first hour and 30% - 40% of the force was retained at 4 weeks. The memory chains presented more constant force and retained 60% of the force. They said that memory chains exhibited superior mechanical properties compared to traditional ones and for delivering the same force, memory chains required more elongation.

3.7. Microbial Contamination

Rembowski et al. (24) (2007) in an in vitro study surveyed the surface of elastomeric chains of different manufacturers to verify the presence of pathogenic microorganisms at the moment of unpacking and analyze a possible inhibitory effect of the elastomeric chain when exposed to microorganisms of the oral cavity. The results suggest that fabrication of elastomeric chain is in accordance with bio-hazard concepts. However, it is necessary to be careful to avoid colonization of pathogenic microorganisms.

Barker et al. (25) (2013) determined whether components of fixed orthodontic appliances as received from the manufacturers and after exposure to the clinical environment are free from microbial contamination before clinical use or not. They found that "as received" components and those exposed to the clinical environment are not free from bacterial contamination before use in patients, but this contamination is low and could not important in creating aerosols.

4. Conclusions

It is obvious that chains are one of the most important methods of space closure in orthodontics so being aware of the various factors that can affect their characteristic and force decay pattern is essential. So an alert clinician should pay enough attention to mentioned factors in his/her experience.

References

- Mirhashemi A, Saffarshahroudi A, Sodagar A, Atai M. Force-degradation pattern of six different orthodontic elastomeric chains. *J Dent (Tehran)*. 2012;**9**(4):204-15. [PubMed: 23323182].
- Dittmer MP, Demling AP, Borchers L, Stiesch M, Kohorst P, Schwestka-Polly R. The influence of simulated aging on the mechanical properties of orthodontic elastomeric chains without an intermodular link. *J Orofac Orthop*. 2012;**73**(4):289-97. doi: 10.1007/s00056-012-0086-z. [PubMed: 22771666].
- Wahab SW, Bister D, Sherriff M. An investigation into UV light exposure as an experimental model for artificial aging on tensile strength and force delivery of elastomeric chain. *Eur J Orthod*. 2014;**36**(1):47-54. doi: 10.1093/ejo/cjt002. [PubMed: 23397056].
- Bousquet JA, Tuesta O, Flores-Mir C. In vivo comparison of force decay between injection molded and die-cut stamped elastomers. *Am J Orthod Dentofacial Orthop*. 2006;**129**(3):384-9. doi: 10.1016/j.ajodo.2005.09.002. [PubMed: 16527634].
- Oshagh M, Ajami S. A comparison of force decay: elastic chain or tie-back method?. *World J Orthod*. 2010;**11**(4):45-51. [PubMed: 21490987].
- Fernandes DJ, Fernandes GM, Artese F, Elias CN, Mendes AM. Force extension relaxation of medium force orthodontic latex elastics. *Angle Orthod*. 2011;**81**(5):812-9. doi: 10.2319/120810-709.1. [PubMed: 21615209].
- Masoud AI, Tsay TP, BeGole E, Bedran-Russo AK. Force decay evaluation of thermoplastic and thermoset elastomeric chains: A mechanical design comparison. *Angle Orthod*. 2014;**84**(6):1026-33. doi: 10.2319/010814-28.1. [PubMed: 24784844].
- Aldrees AM, Al-Foraidi SA, Murayshed MS, Almoammar KA. Color stability and force decay of clear orthodontic elastomeric chains: An in vitro study. *Int Orthod*. 2015;**13**(3):287-301. doi: 10.1016/j.ortho.2015.06.003. [PubMed: 26277455].
- Evangelista MB, Berzins DW, Monaghan P. Effect of disinfecting solutions on the mechanical properties of orthodontic elastomeric ligatures. *Angle Orthod*. 2007;**77**(4):681-7. doi: 10.2319/052806-213. [PubMed: 17605480].
- Teixeira L, Pereira Bdo R, Bortoly TG, Brancher JA, Tanaka OM, Guariza-Filho O. The environmental influence of Light Coke, phosphoric acid, and citric acid on elastomeric chains. *J Contemp Dent Pract*. 2008;**9**(7):17-24. [PubMed: 18997912].
- Larrabee TM, Liu SS, Torres-Gorena A, Soto-Rojas A, Eckert GJ, Stewart KT. The effects of varying alcohol concentrations commonly found in mouth rinses on the force decay of elastomeric chain. *Angle Orthod*. 2012;**82**(5):894-9. doi: 10.2319/062211-407.1. [PubMed: 22309124].
- Pithon MM, Rodrigues AC, Sousa EL, Santos LP, Soares Ndos S. Do mouthwashes with and without bleaching agents degrade the force of elastomeric chains?. *Angle Orthod*. 2013;**83**(4):712-7. doi: 10.2319/081012-646.1. [PubMed: 23311601].
- Halimi A, Azeroual MF, Doukkali A, El Mabrouk K, Zaoui F. Elastomeric chain force decay in artificial saliva: an in vitro study. *Int Orthod*. 2013;**11**(1):60-70. doi: 10.1016/j.ortho.2012.12.007. [PubMed: 23375920].
- Kumar K, Shetty S, Krithika MJ, Cyriac B. Effect of commonly used beverage, soft drink, and mouthwash on force delivered by elastomeric chain: a comparative in vitro study. *J Int Oral Health*. 2014;**6**(3):7-10. [PubMed: 25083025].
- Omidkhoda M, Rashed R, Khodarahmi N. Evaluation of the effects of three different mouthwashes on the force decay of orthodontic chains. *Dent Res J (Isfahan)*. 2015;**12**(4):348-52. doi: 10.4103/1735-3327.161453. [PubMed: 26288625].
- Balhoff DA, Shuldberg M, Hagan JL, Ballard RW, Armbruster PC. Force decay of elastomeric chains - a mechanical design and product comparison study. *J Orthod*. 2011;**38**(1):40-7. doi: 10.1179/14653121141227. [PubMed: 21367827].
- Dittmer MP, Demling AP, Borchers L, Stiesch M, Kohorst P, Schwestka-Polly R. Tensile properties of orthodontic elastomeric chains. *J Orofac Orthop*. 2010;**71**(5):330-8. doi: 10.1007/s00056-010-1020-x. [PubMed: 20963542].
- Weissheimer A, Locks A, de Menezes LM, Borgatto AF, Derech CD. In vitro evaluation of force degradation of elastomeric chains used in orthodontics. *Dental Press J Orthod*. 2013;**18**(1):55-62. [PubMed: 23876950].
- Kanuru RK, Azaneen M, Narayana V, Kolasani B, Indukuri RR, Babu PF. Comparison of canine retraction by in vivo method using four brands of elastomeric power chain. *J Int Soc Prev Community Dent*. 2014;**4**(Suppl 1):S32-7. doi: 10.4103/2231-0762.144586. [PubMed: 25452925].
- Kim KH, Chung CH, Choy K, Lee JS, Vanarsdall RL. Effects of prestretching on force degradation of synthetic elastomeric chains. *Am J Orthod Dentofacial Orthop*. 2005;**128**(4):477-82. doi: 10.1016/j.ajodo.2004.04.027. [PubMed: 16214630].
- Wang T, Zhou G, Tan X, Dong Y. Evaluation of force degradation characteristics of orthodontic latex elastics in vitro and in vivo. *Angle Orthod*. 2007;**77**(4):688-93. doi: 10.2319/022306-76. [PubMed: 17605476].
- Crawford NL, McCarthy C, Murphy TC, Benson PE. Physical properties of conventional and Super Slick elastomeric ligatures after intraoral use. *Angle Orthod*. 2010;**80**(1):175-81. doi: 10.2319/013009-63.1. [PubMed: 19852658].
- Baratieri C, Mattos CT, Alves MJ, Lau TC, Nojima LI, de Souza MM, et al. In situ evaluation of orthodontic elastomeric chains. *Braz Dent J*. 2012;**23**(4):394-8. [PubMed: 23207855].
- Rembowski Casaccia G, Gomes JC, Alviano DS, de Oliveira Ruellas AC, Sant'Anna EF. Microbiological evaluation of elastomeric chains. *Angle Orthod*. 2007;**77**(5):890-3. doi: 10.2319/091106-367. [PubMed: 17685763].
- Barker CS, Soro V, Dymock D, Sandy JR, Ireland AJ. Microbial contamination of "as received" and "clinic exposed" orthodontic materials. *Am J Orthod Dentofacial Orthop*. 2013;**143**(3):317-23. doi: 10.1016/j.ajodo.2012.09.020. [PubMed: 23452965].