Revista de Chimie
https://revistadechimie.ro
https://doi.org/10.37358/Rev.Chim.1949

Evaluation of the Biomechanical Properties of Austenitic Stainless Steel Fixed Retainers

SILVIA IZABELLA POP[1], ZAKARIAS SZABOLCS[2], DANA CRISTINA BRATU[3], MIRCEA DUDESCU[4], MARIANA PACURAR[1]*, LAURA ROXANA CONTAC[5]

[1]University of Medicine, Pharmacy, Science and Technology ”George Emil Palade”, Faculty of Dental Medicine, Orthodontics Department, 38 Gh. Marinescu Str., 540139, Mures, Romania
[2] Private practice, DentEsthic, 3 Vörösmarty Mihály Str., 530130, Miercurea Ciuc, Romania
[3]University of Medicine and Pharmacy "Victor Babes", Faculty of Dental Medicine, Orthodontic Department, 9 Revolutiei 1989 Blvd., 300070, Timisoara, Romania
[4]Technical University of Cluj-Napoca, Department of Mechanical Engineering, 28 Memorandumului Str., 400114, Cluj-Napoca, Romania
[5]University of Medicine, Pharmacy, Science and Technology ”George Emil Palade”, Faculty of Dental Medicine, Paedodontics Department, 38 Gh. Marinescu Str., 540139, Mures, Romania

Abstract. *The insertion of the fixed retention is an important stage of the orthodontic treatment after fixed appliances. The fixed retainers used in orthodontic treatments must be passive towards teeth, without developing any stress. This characteristic is challenging to achieve due to the mechanical properties (bending properties, stiffness) of the materials the retainers are manufactured from. Residual stress might be generated because of their flexibility and because the chemical composition of the stainless steel wires.This study aims to determine the mechanical properties of different austenitic stainlees steel wires used in retention. Also, we have compared the mechanical properties of wires with different sizes, as well as wires with the same size, new and intra-orally used. The results confirm that the mechanical parameters of the two types of wires used in fixed retention (3 braided round wires and 6 braided Flat wires) present statistically insignificant differences. The study also reflects that the mechanical properties of the intra-orally used wires showed decreased values of the parameters.*

Keywords*: fixed retainers, mechanical properties, bending properties, stiffness*

1.Introduction

Stability is the main objective of the orthodontic treatment, therefore reducing the chances of relapse is required by: achieving adequate occlusion relationship between the two dental arches, establishing a normal balance of the muscular function, determining the relative position of the apical base respectively [4].

The retainer (bonded or removable) is used precisely to this purpose. The necessity to apply it and the duration depend on various factors (number of teeth involved, amount of tooth movement, occlusion, patient’s age, duration of orthodontic treatment, cuspid length, general state and health of the tissues involved, the relationship between plans, muscular forces and cellular metabolism) [5].

The most frequently used bonded orthodontic retainer material is stainless steel wire, with different stiffness and configuration [6- 8]. Lingual retainers can be fabricated from relatively thick flat or round wires (0.030 - 0.032 inch) or from thinner multistrand wires (0.0195 - 0.0215 inch) [6, 7, 9]. The stainless steel alloys used for retainers are of the ”18-8” auste nitic type, containing approximately 18 % Cr an 8% Ni. Approximately 12-13 % Cr is needed to impart the necessary corrosion resistance to these alloys [7]. The wires are bonded to each six anterior teeth in the maxilla and mandible. Clinical reports to date are more in favor of multistrand (5-stranded 0.0215-inch wire) wires compared to single or multistrand wires containing 3 or less strands that should be bonded to all anterior teeth in a segment [1,2].

*email:marianapac@yahoo.com

Moreover, the use of multistrand wires decreases wire breakage due to fatigue as a consequence of increased wire flexibility and reduces the individual mobility of the bonded teeth while maintaining physiologic mobility [10,11]. Several previous studies stressed the shortcomings of the use of stainless steel wires such as debonding, wire breakage, torque differences in the bonded teeth yielding to positional changes of the teeth, metal allergy and aesthetic concerns [12, 13]. The stability of the mechanical properties after several years of intraoral use is also an important factor.

Corrosion resistance of the SS wire is determined by the formation of Cr oxide during the passivation and repassivation (passive film on the alloy surface). The chemical reaction is:

$$Cr+O = CrO_2 \quad (1)$$

This study aims to determine the mechanical properties (load at maximum compressive extension, maximum compressive load, compressive extension at maximum compressive load) of the different austenitic stainlees steel metallic wires used in retention. Also, we have compared the mechanical properties for different sized wires, as well as wires with same size, both new and intra-orally used.

2. Materials and methods

In this study we have observed new austenitic stainless steel wires, 3 braided wires with a circular cross-cut (round) diameter of 0.175" (Ortho Technology, USA) and rectangular (flat) cross-cut six braided flat wires of 0.017" x 0.25" (Ortho Technology, USA), as well as same size wires, removed from patient’s oral cavity, after a mean period of use of 2 years and 3 months (27 months). Retrieval protocol of the used wires included: rinsing with distilled water to remove any precipitations and placing the wires in a self-closed plastic bag. The bags were labelled, recording the date of placement and retrieval, name of patient and type of wire.

The wires have been divided in 4 groups of 8 samples each: round and new, round and intra-orally used, flat and new and flat and intra-orally used austenitic stainless steel wires.

An Instron Universal Testing Machine type 3366, 10kN was used to perform the tests. The measured values were recorded for each specimen by the testing machine software InstronBluehill 2. The collected data was exported in spreadsheet file format (Microsoft Excel). In order to determine the mechanical characteristics of the wires, each specimen was subject to a three-point bend (Figure 1). The specimens were ligated with elastomeric ligatures in the slots of four edgewise brackets (3B STD Edgeweise). These brackets were glued to an aluminum base, attached to the lower jaw of the machine. A metal blade, with a curvature of 1 mm of its extremity, was fixed to the upper jaw of the machine, to deflect the mid portion of each sample. Each wire was deflected 2 mm, at a deflection speed of 1mm/min and then returned to its starting point at the same speed.

The following parameters have been recorded using the Instron Bluehill 2 software: load at maximum compressive extension, maximum compressive load, compressive extension at maximum compressive load. All the data obtained from the 2 tests described above were statistically analyzed. Descriptive analysis was made to determine the mean and standard deviation values.

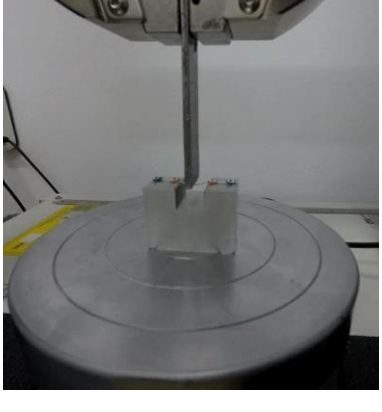

Figure 1. Fixed wire in Instron Universal Bending Machine

Revista de Chimie
https://revistadechimie.ro
https://doi.org/10.37358/Rev.Chim.1949

Student t test was performed in order to compare the results. Statistically significant differences (p<.05) were evaluated for all measurements.

During the bending test, the software recorded the values for each wire tested in a separate table, resulting in a comparative diagram of the tested wires (Figure 2 and 3).

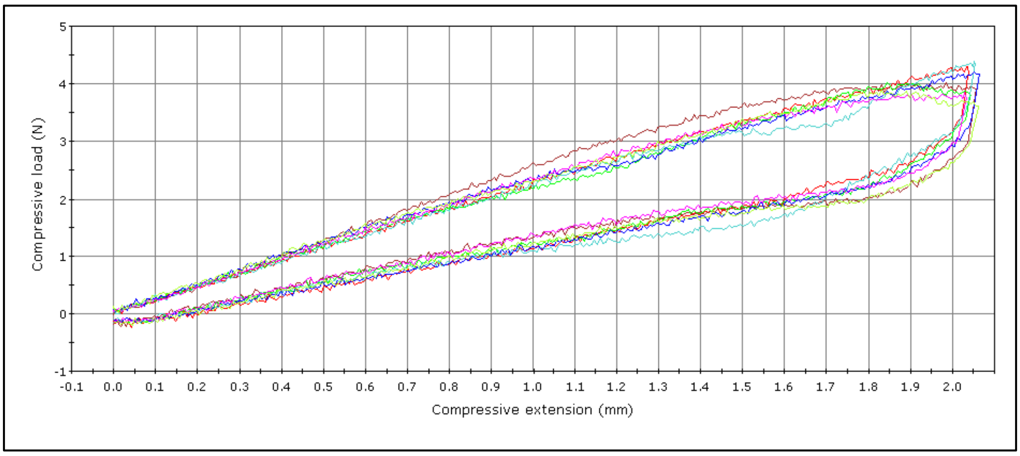

Figure 2. Bending test for round wires diagram

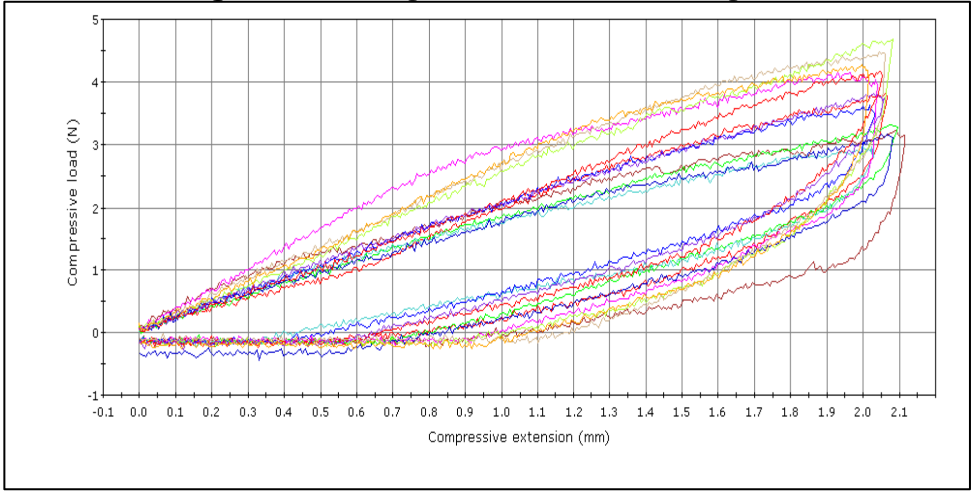

Figure 3. Bending test for flat wires diagram

3. Results and discussions

Table 1 presents the statistical data resulted for the new round and flat wires, as well as the *p* value after the statistical analysis. Comparing the values resulted for the 4 parameters observed, indicate that in the case of the new wires, the values are higher for the flat/rectangular wires. However the differences are not statistically significant.

Table 1. Mean value, standard deviation, confidence interval, *p*-value –new wires

	Circular New			Rectangular New			
	mean	± standard deviation	Confidence interval (95%)	mean	± standard deviation	Confidence interval (95%)	Comparison with the Student-t test (p < 0.05)
Maximum Compressive extension (mm)	2	0	0.0001	2	0	0	**0.9138**
Compressive load at Maximum Compressive extension (N)	3.95	0.224	0.166	4.127	0.273	0.2672	**0.2721**
Load at Maximum Compressive extension (N)	-3.95	0.224	0.166	-4.127	0.273	0.2672	**0.2721**
Extension at Maximum Compressive extension (mm)	-2.229	0.079	0.0586	-2.2	0.078	0.0764	**0.5678**
Maximum Compressive load (N)	4.056	0.171	0.1269	4.139	0.281	0.2758	**0.553**
Compressive extension at Maximum Compressive load (mm)	1.947	0.075	0.0557	1.986	0.027	0.0269	**0.3598**
Extension at Maximum Compressive load (mm)	-2.177	0.125	0.0926	-2.186	0.099	0.0973	**0.9041**
Load at Maximum Compressive load (N)	-4.056	0.171	0.1269	-4.139	0.281	0.2758	**0.553**

Table 2 presents the statistical data resulted in the case of flat wires, both new and used.

Table 2. Mean value, standard deviation, confidence interval, *p*-value new and used flat wires

	Rectangular New			Rectangular Used			
	mean	± standard deviation	Confidence interval (95%)	mean	± standard deviation	Confidence interval (95%)	Comparison with the Student-t test (p < 0.05)
Maximum Compressive extension (mm)	2	0	0	2	0	0	**0.2743**
Compressive load at Maximum Compressive extension (N)	4.127	0.273	0.2672	3.522	0.59	0.409	**0.0846**
Load at Maximum Compressive extension (N)	-4.127	0.273	0.2672	-3.522	0.59	0.409	**0.0846**
Extension at Maximum Compressive extension (mm)	-2.2	0.078	0.0764	-2.232	0.107	0.0744	**0.6117**
Maximum Compressive load (N)	4.139	0.281	0.2758	3.55	0.591	0.4095	**0.0929**
Compressive extension at Maximum Compressive load (mm)	1.986	0.027	0.0269	1.986	0.025	0.0176	**0.9782**
Extension at Maximum Compressive load (mm)	-2.186	0.099	0.0973	-2.218	0.126	0.0871	**0.6643**
Load at Maximum Compressive load (N)	-4.139	0.281	0.2758	-3.55	0.591	0.4095	**0.0929**

In the case of intra-orally used wires, both round and flat, it was observed a decrease in the parameter values, however this difference was not statistically significant.

There are several factors that influence the biomechanical properties of the braided metal wires used in orthodontic retainers. In this case the measurements of the maximum compressive load (stiffness) determine the wires resistance to torque that stress against them. In order for the device to be functional, the retainer must withstand the torque applied by the occlusion traits and other physiological buccal-lingual movements [11, 14].

Although the literature asserts that fixed retainers posse most problems regarding passiveness, it is important to mention wire breakage and composite detachments as further issues. This is due to unsatisfactory insertion of the retainers, as well as their undesired mechanical properties caused by the oral effects after a certain period of time [15, 16].

Stiffness of fixed retainers is highly influenced by the chemical composition of the wires. The chromium, carbon and nickel atoms are incorporated into the solid solution formed by the iron atoms. Variation in the Cr and Ni levels in the alloy might affect the biomechanical properties of the retainers [13].

Based on Parisa Selahi's measurements results, mean values of stiffness are 3.8 N for the 0.0195" diameter wire, which can be considered close to 4.1 N (flat wires) and 3.95 N (round wires), our resulted values. However, the values are greater than our values for the wires used (3.52 N) [17].

Dario T. Arnold and collaborators have investigated the degree to which the mechanical resistance of the materials used in different fixed retainers are different against the torques in the buccal cavity. In his study, different wires have been observed, rectangular (flat) (0.016" x 0.022" cross-cut size) and round (0.0175" cross-cut size). The flat wires presented better resistance due to their stiffness, opposed to the round wires [9].

4. Conclusions

Based on the observed results, it can be asserted that the mechanical parameters of the two type of austenitic stainless steel retainer wires (3 braided round wires and 6 braided Flat wires) presented differences, but they are not statistically significant.

It was observed that the mechanical properties of the braided wire used in the orthodontic retainers modify during use, decreasing the measured values.

References

1.ZACHRISSON BU, BUYUKYILMAZ T., Bonded retainers. In: Graber LW, Vanarsdall RL, Vig KW, editors. *Orthodontics: Current principles and techniques*. 5th ed. Philadelphia: Elsevier Mosby; 2012. p. 756-784.

2. TANER T., AKSU M. - A prospective clinical evaluation of mandibular lingual retainer survival, *European Journal of Orthodontics*, 2011, 34: 470-474.

3. TACKEN M. P. E., COSYN P., De WILDE, et al. - Glass fiber reinforced versus multistranded bonded orthodontic retainers: a 2 year prospective multi-centred study, *European Journal of Orthodontics*, 2010, 32: 117-123.
4.FÁBIÁN G., GÁBRIS K., TARJÁN I., Gyermekfogászat, Fogszabályozás és Állcsont-ortopédia, *Semmelweis Kiadó, Magyarország*, 2015, 461-465.
5.LITTLEWOOD SJ, MILLET DT, DOUBLEDAY B, BEARN DR, WORHINGTON H.V., Retention procedures for stabilising tooth position after treatment with orthodontic braces. *Cochrane Database of Systematic Reviews*. 2016; 29: CD002283.
6. ZACHRISSON BU. Multistranded wire bonded retainers: From start to success, *Am J Orthod Dentofacial Orthop* 2015; 148:724-727.
7.GRABER T. M., VANARSDALL R. L.- *Orthodontics - Current principles and techniques,* Mosby, Inc., Missouri, *USA*, 2000, 1005-1010.
8.ABUDIAK H., SHELTON A., SPENCER R.J., et al. - A Complication with Orthodontic Fixed Retainers: A Case Report, *Orthodontic Update*, 2011, 4: 112-117.
9.ARNOLD D.T., DALSTRA M., VERNA C.,D.T.- Torque resistance of different stainless steel wires commonly used for fixed retainers in orthodontics, *Journal of Orthodontics*, 2016, 43: 90-91.
10.SABOUTI F., RAKHSHAN V., SARAVI M.G. et al - Two-year survival analysis of twisted wire fixed retainer versus spiral wire and fiber-reinforced composite retainers: a preliminary explorative single-blind randomized clinical trial, *Korean Journal of Orthodontics*, 2016, 46: 104-110.
11.SALIH Y.A., AL-JANABI M. F. - Tensile force measurement by using different lingual retainer wires, bonding materials types and thickness (A comparative in-vitro study), *J Bagh College Dentistry*, 2014, 26: 167-172.
12.PARSHAN M., JAIN R.K. - A Review on Flexible Spiral Wire Retainer, *IOSR Journal of Dental and Medical Sciences*, 2014, 13: 24-26.
13.HYO-WON A., HYE-RYUN H., HO-NAM L., et al - Effects of aging procedures on the molecular, biochemical, morphological, and mechanical properties of vacuum-formed retainers, *Journal of the Mechanical Behavior of Biomedical Materials*, 2015, 51: 356-366.
14.SIFAKAKIS I., MAKOU M., PANDIS N., et al - In-vitro assessment of the forces generated by lingual fixed retainers, *American Journal of Orthodontics and Dentofacial Orthopedics*, 2011, 139: 44-48.
15.PAZELA P., FUDALEJ P, KATSAROS C., et al. - Severe complication of a bonded mandibular lingual retainer - *American Journal of Orthodontics and Dentofacial Orthopedics*, 2012, 142: 406-409.
16.SIFAKAKIS I., ELIADES T., BOURAUEL C. - Residual stress analysis of fixed retainer wires after in vitro loading: can mastication-induced stresses produce an unfavorable effect? , *De Gruyter*, 2015, 60: 617-622.
17.SALEHI P., NAJAFI H.Z., ROEINPEIKAR S.M. - Comparison of survival time between two types of orthodontic fixed retainer: a prospective randomized clinical trial, *Progress in Orthodontics*, 2013, 14: 25-29.

Manuscript received: 17.04.2020