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Original Article

Comparing the Impact of Titanium and Stainless Steel Retainers on Lower Incisor Stability, Periodontal Health, and Retainer Survival: A Preliminary Study

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Main Points

- Titanium and stainless steel retainer wires were successful in maintaining lower incisor stability.
- Titanium and stainless steel retainer wires gave similar periodontal results.
- No retainer failure was observed in either group.

ABSTRACT

Objective: This study aims to compare the impact of titanium and stainless steel (SS) retainer wires on lower incisor stability and periodontal health.

Methods: Fifty patients between the ages of 14.1 and 29.5 years were recruited for the study. The impact of 0.027x0.011-inch rectangular titanium dead-soft wire retainers was compared with that of 0.0215-inch six-stranded SS wire retainers. The retainers were bonded to the mandibular arch, and 3D models were evaluated after completion of the orthodontic treatment (T1), at the third month (T2), and at the sixth month (T3). Little's irregularity index (LII), the intercanine width, the pocket depth, the plaque index, bleeding on probing, and retainer survival were analyzed. The generalized linear model method was used to compare scores on LII, the intercanine width, the pocket depth, and plaque index values. Cochran's Q test was used to compare intragroup bleeding.

Results: A significant increase was found in the irregularity index parameter according to time (p=0.004) but no statistically significant difference was found between groups in terms of the LII according to material and time (p=0.826). No significant difference was found in intercanine width parameters between the groups according to material and time (p=0.977). No statistically significant difference was found between the groups in terms of pocket depth and plaque index scores, according to material and time. No retainer failure was observed in either group.

Conclusion: Both retainer wires offer successful results in terms of stability parameters and periodontal parameters after six months.

Keywords: Fixed orthodontic retention, orthodontic stability, orthodontic splint, titanium retainer, stainless steel retainer, periodontal health

INTRODUCTION

"Retention" is defined as maintaining the ideal functional and aesthetic tooth positions achieved by orthodontic treatment[1] and has been described by Oppenheim[2] as a major problem in orthodontic treatment. Orthodontically treated cases may be exposed to dynamic and changing situations, especially in the third and fourth decades of

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life, and relapse has been observed in a significant percentage of cases of mandibular anterior teeth alignment.[3,4] However, dental changes in mandibular arches can be observed even in individuals who have never had orthodontic treatment.[5] After orthodontic treatment, fixed and removable retention appliances can be used to prevent relapse.[6] While various orthodontic retention protocols are available, emerging evidence suggests that fixed retention is superior to removable options in long-term follow-ups.[7-9] The advantages of fixed retention appliances are that they do not rely on patient cooperation and do not adversely affect smile aesthetics.

Zachrisson[10] recommended the routine use of 0.0215-inch six-stranded, flexible stainless steel (SS) wire for fixed retention as the gold standard and has claimed that the material allows for physiological tooth movement and gives successful results in terms of stability as long as it is passively adapted to the tooth surfaces. In an in vitro study,[11] comparing multistranded SS and dead-soft wire, more deformation was observed in the dead-soft wire group compared to the SS wire group. As a result of the forces of chewing and the use of dental floss, the interdental wire will be subjected to repeated deformation, and wire breakage may occur.[11] In recent years, other materials have been introduced, such as polyethylene[12] and glass fibers,[13] but metallic retainers offer lower costs and demonstrate equal or better clinical performance. Nickel-titanium wire produced using computer-aided design (CAD)/computer-aided manufacturing (CAM) technology is one of the latest fixed retention materials used today.[14] Although fixed retainers are a preferred method after the treatment of specific orthodontic malocclusions (e.g., generalized spacing, rotated teeth) and for patients who do not want to wear removable appliances, some problems may be encountered depending on the materials used.

Periodontal problems, metal allergy due to the nickel composition, and breakage are some of the disadvantages of fixed retainers. Additionally, evidence has been published that metallic orthodontic braces and SS lingual retainers cause artifacts and distortions due to their ferromagnetic properties and may decrease the diagnostic value of the magnetic resonance images (MRIs).[15-17] Studies have shown that this image artifact extends beyond the boundaries of the oral cavity in cases where SS retainers are used.[15,17] As a result, SS retainers are incompatible with dental MRI and may also interfere with head or neck landmarks beyond the retainer area. In cases where SS retention wires are used, orthodontists are asked to remove these wires when MRI is required. This creates a handicap both in terms of cost and the fact that repeated processes can damage teeth. Research indicates that artifacts from titanium and gold retainers are minimal and do not impact *in vivo* MRI quality, even when positioned directly next to retainer wires. Titanium and gold retainers are fully compatible with both head and neck MRI, as well as dental MRI.[18]

Although the necessary duration of retention is unclear, the suggested strategy for maintaining lower incisor stability after orthodontic treatment is to implement long-term or life-long retention.[19] While the literature includes many studies on the success of multistranded SS retainers, there are a limited number of studies on titanium lingual retainers.[20] This study aimed to compare 0.027x0.011-inch rectangular titanium dead-soft wire and 0.0215-inch six-stranded SS retainer wire used for fixed retention in terms of their success in preventing relapse and their effects on periodontal health. The null hypothesis of the study is that there would be no significant difference between the two types of retainers regarding stability and periodontal effects.

METHODS

The study protocol was approved by the Trakya University Faculty of Medicine Scientific Research Ethics Committee (approval no.: 17/08, date: 14.10.2019). Written informed consent was obtained from participants or their parents.

Sample Size Calculation

The sample size of the study was calculated using the G*Power 3.1.9.7 software. Based on a previous study,[21] to detect a 1 mm difference on Little's Irregularity Index (LII), the study sample size was calculated as 25 for each group (with a power of 90%, and a margin of error of 5%).

Study Sample

In this retrospective study, 50 patients who had completed their orthodontic treatment at the Trakya University Faculty of Dentistry, Department of Orthodontics were selected. A random selection was made among 65 individuals who met the inclusion criteria and had control records in the archive for the periods of the end of treatment (T1), the third month (T2), and the sixth month (T3). Individuals with complete orthodontic model records and periodontal examinations were included in our study.

Inclusion Criteria

The inclusion criteria were:

- Moderate crowding in the lower arch;
- Non-extraction fixed orthodontic treatment; and
- No periodontal disease before orthodontic treatment.

Exclusion Criteria

Cases with missing or restored teeth and lower incisors with morphological anomalies were not included in the study.

Fixed Retention Protocol

The study compared 0.027x0.011-inch rectangular titanium dead-soft wire (Retainium, Reliance Orthodontic Products, Itasca, USA) and 0.0215-inch six-stranded SS retainer wire (G&H Orthodontics, Franklin, USA) (Figure 1). The routine bonding protocol was as follows: retainer wires were bonded to all teeth in the lower jaw between canines.[21] Wires were bent on the plaster model by a single clinician (MSY) using a bird beak #139 plier (Rocky Mountain Orthodontics, Illkirch, France). The lingual surfaces of the lower teeth were cleaned with fluoride-free prophylaxis paste before the bonding. Enamel surfaces

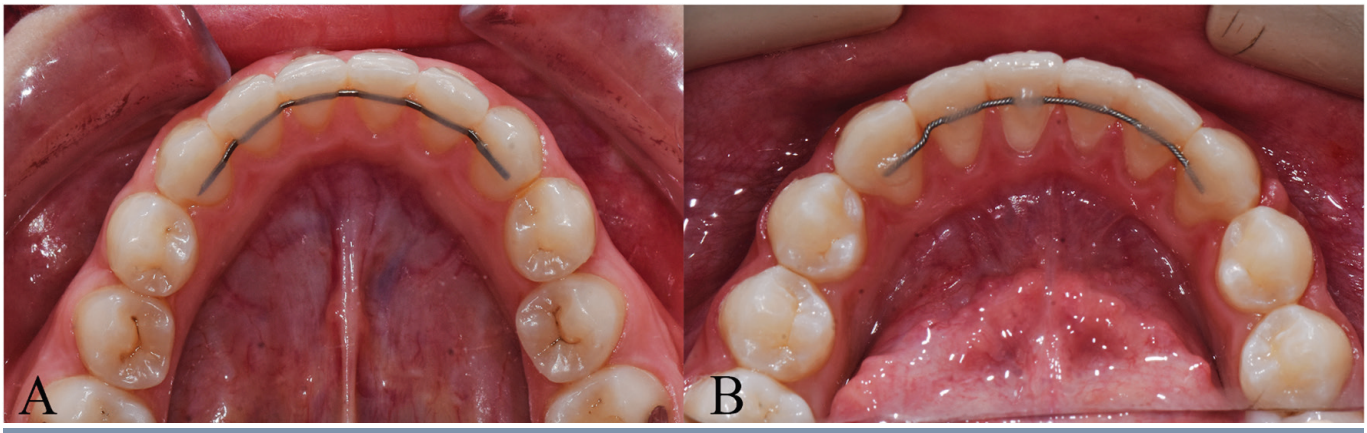

Figure 1. A) Titanium retainer, B) Stainless steel retainer

were etched with 37% orthophosphoric acid (Jade, Dharma Research, Miami, USA) for 30 seconds, washed with water and dried. A primer (Assure Plus, Reliance Orthodontic Products, Itasca, USA) was applied to the roughened enamel surfaces, slightly air-dried and cured on each tooth for 20 seconds using a 1200 mW/cm^2 LED light source (VALO Cordless Curing Light, Ultradent Products, South Jordan, USA). The retention wires were fixed passively and bonded to the tooth surface with a flowable composite (Flow Tain, Reliance Orthodontic Products, Itasca, USA). The adhesive was polymerized for 20 seconds with a 1200 mW/cm^2 LED light source on each tooth. All retainers were bonded by the same researcher (MSY). Advice on the brushing technique was given after the retainer was bonded, and patients were motivated at each control. No additional removable retention appliance was applied to either arch.

Orthodontic and Periodontal Records

For orthodontic records, alginate impressions (Zetalgin, Zhermack Group, Italy) were taken from the lower teeth of the patients immediately after the retainer wire was bonded (T1), at the third month (T2), and at the sixth month (T3), and a plaster model was obtained using a type IV plaster (Elite Rock, Zhermack, Italy). A digital model was obtained by scanning the plaster models with a 3D scanner (Maestro, AGE Solutions, Pisa, Italy). Little's Irregularity Index (LII) and intercanine width measurements were taken using reverse engineering OrthoModel software (OrthoModel V1.01, Istanbul, Turkey) on 3D models. The software allows for measurements in millimeters on scanned plaster models. For periodontal evaluation, pocket depth, plaque index, and bleeding on probing were measured at 0 months (T1), three months (T2), and six months (T3). During these appointments, the integrity of the wire and adhesive was also assessed for any potential failures.

Model Measurements

LII and Intercanine Width Measurements

Measurements in millimeters were taken at five contact points from the lower right canine tooth to the left canine. Scoring was based on measuring the linear displacement between the anatomical contact points of each mandibular incisor and its adjacent tooth; the sum of these five displacements indicates the degree of irregularity.[22] This procedure was performed on a total of 150 models from the 50 individuals included in the study. For the intercanine width measurements, the distance between the cusp tip of the lower canines in each model was measured in millimeters.[21] In the study, all values were obtained from the orthodontic models taken at the T1, T2, and T3 time points. All measurements were performed on 3D digital models by a single researcher (MSY).

Error of the Method

To determine the intraclass correlation coefficient (ICC), the LII and intercanine width measurements were repeated on 40 randomly selected digital models two weeks after the first measurements were taken.

Periodontal Measurements

Pocket Depth

To determine the pocket depth of the lower anterior six teeth, measurements in millimeters were taken using a Williams probe at three regions (the mesial, median, and distal) on the lingual surface.[23] To obtain the mean pocket depth value for a tooth, the arithmetic mean of the values recorded at three regions was taken and this measurement was repeated at 0 months (T1), three months (T2), and six months (T3).

Plaque Index

The Löe and Silness[24] plaque index was used to measure the presence of plaque on the lower anterior six teeth after the retainer wire was applied. Measurements were performed on the lingual side of the lower anterior six teeth at three different regions (the mesial, median, distal) using a scoring range from 0 to 3. To obtain the plaque index value of a tooth, the arithmetic mean of the values recorded at three regions was taken, and this process was repeated at 0 months (T1), three months (T2), and six months (T3).

Bleeding on Probing

Bleeding on probing was measured by recording the presence and absence of bleeding after probing the gingival sulcus on the

lingual surfaces of the related teeth using the Williams probe.[23] The measurements were repeated at 0 months (T1), three months (T2), and six months (T3). Due to the dynamic nature of periodontal tissues, repeating periodontal measurements to test intra-examiner reliability was not possible.

Retainer Survival

After the retainer wire was bonded, the presence of breakage on the wire-adhesive surface, the debond on the adhesive-tooth surface, and the deformation or breakage of the wire were evaluated as failures. The observation of failures was repeated at all time points.

Statistical Analysis

Data analysis was conducted using IBM SPSS V23 (IBM Company, Chicago, IL, USA). The Shapiro-Wilk test assessed conformity to a normal distribution. The chi-square test compared categorical variables between groups, while an independent two-sample t-test was used for normally distributed data, and the Mann-Whitney U test for non-normally distributed data. The generalized linear models method was used to compare scores on LII, the intercanine distance, the pocket depth, and plaque index values according to material and time. Cochran's Q test was used to compare intragroup bleeding according to time. The ICC was used to examine the agreement between measurements. Analysis results were presented as frequency (percentage) for categorical data, as mean ± standard deviation, and median (minimum–maximum) for quantitative data. The significance level was taken as $p<0.05$.

RESULTS

Statistically significant, very good agreement was found between the first and second measurement values on LII [ICC=0.999 (0.998-0.999)] and for the intercanine width [ICC=0.996 (0.992-0.998); $p<0.001$].

No statistically significant difference was found between the groups in terms of age (titanium: mean of 18.4 years, multistranded SS: mean of 19 years) ($p=0.404$) or gender (titanium: 17 females and 8 males, SS: 19 females and 6 males) ($p=0.529$). The LII (titanium: 6.9±2.1; multistranded SS: 7.0±2.2) and intercanine width (titanium: 25.8±2 mm; multistranded SS: 25.9±1.9 mm) values at the T0 time point (before the orthodontic treatment) were similar for both groups ($p>0.05$). No statistically significant difference was found between the groups in terms of posttreatment and pretreatment (T1-T0) intercanine width measurements (titanium: 0.2±1.8, multistranded SS: 0.2±1.6; $p=0.259$).

Stability Parameters

The descriptive statistics and comparison of stability parameters are presented in Tables 1 and 2. The main effect of time on LII was statistically significant ($p=0.004$). The mean LII scores obtained at the T1 time point were lower than the values obtained at the T3 time point. The main effect of material (retainer type) on intercanine width was statistically significant ($p=0.003$). While the mean of the T1, T2, and T3 values of the intercanine width in the titanium group was 25.4 mm, the mean of the T1, T2, and T3 values in the SS group was found to be 26.1 mm. The main effect of the material and time interaction was not statistically significant for the LII and intercanine width measurements ($p>0.05$).

Periodontal Parameters

The descriptive statistics and comparison of pocket depth and plaque index are presented in Tables 3 and 4. The main effect of time on pocket depth for teeth 43, 42, 41, 31, 32, and 33 was statistically significant ($p<0.05$). The mean pocket depth measurements obtained at the T1 time point were lower than the values obtained at other time points.

The main effect of material (retainer type) on pocket depth for teeth 32 and 33 was statistically significant ($p<0.05$). The mean of the T1, T2, and T3 values of the pocket depth was 1.5 mm in the titanium group and 1.7 mm in the SS group for tooth 32. The mean of the T1, T2, and T3 values of the pocket depth was 1.7 mm in the titanium group and 1.9 mm in the SS group for tooth 33.

The main effect of the material and time interaction was not statistically significant for pocket depth and plaque index ($p>0.05$).

A comparison of the T3-T1 difference in terms of pocket depth and plaque index for each tooth according to the groups is presented in Table 5. There was no significant difference between the groups in terms of the T3-T1 difference in pocket depth and plaque index ($p>0.05$).

A comparison of intra-group and inter-group bleeding on probing scores is presented in Table 6. The intra-group comparison shows that no significant difference was found in terms of bleeding scores on probing at the T1, T2, and T3 time points. While there was a significant difference between the groups at the T2 time point, there was no difference between the groups in terms of bleeding on probing at the T3 time point ($p>0.05$). This difference at the T2 time point was due to the higher percentage of bleeding in individuals in the titanium group.

No breakage, detachment, or retainer loss was observed in either group during the observation period.

DISCUSSION

Long-term stability is one of the most challenging topics in orthodontics. Riedel[25] has suggested that teeth undergoing orthodontic treatment should be held in position to reorganize the periodontal and gingival fibers, allow neuromuscular adaptation, and to minimize changes that may occur with growth. The principle finding of this study is that when the interaction between material and time for LII and intercanine width is examined, no significant differences were observed between the groups.

Table 1. Descriptive statistics of little irregularity index and intercanine width according to material and time

Stability parameters	Time	Material		Total
		Titanium	Multistranded SS	
Little's irregularity index	T1	1.87±0.38	1.75±0.32	1.81±0.35[a]
	T2	1.97±0.46	1.95±0.37	1.96±0.41[a,b]
	T3	2.10±0.47	2.04±0.36	2.07±0.41[b]
	Total	1.98±0.44	1.91±0.37	1.95±0.41
Intercanine width	T1	25.52±1.17	26.20±1.35	25.86±1.30
	T2	25.48±1.20	26.07±1.38	25.77±1.31
	T3	25.45±1.24	26.04±1.38	25.74±1.33
	Total	25.48±1.19	26.10±1.36	25.79±1.31

[a,b]There is no difference between time points with the same letter in terms of irregularity index. T1: After the application of fixed retainer, T2: 3rd month, T3: 6th month)
SS, stainless steel

Table 2. Comparison of little irregularity index and intercanine width according to material and time

Stability parameters		Test statistics*	df	p-value
Little's irregularity index	Material	1.053	1	0.305
	Time	10.907	2	**0.004#**
	Material*Time	0.383	2	0.826
Intercanine width	Material	9.064	1	**0.003#**
	Time	0.219	2	0.896
	Material*Time	0.046	2	0.977

*Wald chi-square test, df: degree of freedom, #p<0.05
The statistical significance level was p<0.05

According to a randomized controlled study, most relapses occur during the six months of retention.[26] Therefore, we investigated relapse in the first six months. Gunay and Oz[21] compared 0.0175-inch six-stranded SS retainer wire with 0.0195-inch dead-soft wire. Their results indicated that the increase in the LII values in the dead-soft wire group was significantly higher. This is explained by the possibility that the dead-soft wire is more prone to deformation and could not be passively placed during the application because it was bent and applied in the patient's mouth.

In our study, the lack of a significant increase in LII values in both groups may be related to the thicker cross-section of the six-stranded SS wire (0.0215") and the titanium dead-soft wire used, compared to the wires in the previous study. Additionally, the retainers were bent on plaster models in our study.

Artun et al.[27] measured LII on plaster models and reported that 0.0205-inch flexible multistranded spiral wire bonded to all teeth completely prevented any change in LII at a three-year follow-up: the change was 0. Although this finding supports the success of preventing incisor crowding of the SS wire used in our study, we think that the 0.29 mm increase seen in our study is due to the fact that we made precise measurements on the 3D digital model.

Different types of dead-soft wires are used for orthodontic retention. The results of a study comparing four different wires over a one year[28] period showed that LII changes were statistically significantly fewer in the SS and NiTi groups than in the other groups. However, a significantly higher relapse was observed in the dead-soft wire group over a six-month retention period. This result contradicts our findings; this discrepancy may be due to the different designs of the dead-soft wires used. The fact that the dead-soft wire used in the above-mentioned study is braided and the dead-soft wire used in our study is a ribbon arch structure may result in differences in the deformation resistance. However, the study concluded that relapse was not clinically significant in any group after one year. Alrawas et al.[29] compared the CAD/CAM-supported NiTi wire, 0.017-inch multistranded SS wire, 0.027x0.011-inch rectangular titanium wire, and a vacuum-formed retainer (VFR) appliance in terms of relapse prevention success and periodontal effects in the short term. They found that the increase in LII scores was not significant between and within the groups. The findings were similar to the LII increase observed as 0.29 mm in the SS wire group and 0.23 mm in the titanium wire group at six-month follow-up in our study.

No statistically significant difference was found in our study between the intra-group and the inter-group values for intercanine width in terms of the material and time interaction. From T3 to T1, the intercanine width decrease was 0.07 mm in the titanium group and 0.16 mm in the SS wire group, which was not statistically significant in either intra-group or inter-group comparisons. Our findings are consistent with those of Alrawas et al.[29] However, according to Adanur-Atmaca et al.,[28] the six-month change in the intercanine distance showed a decrease of 0.32 mm in the dead-soft wire group, which is higher than our findings. This may be due to the different dead-soft wires used in the studies. The decrease in intercanine distance in the SS wire group is similar to the SS group value in our study.

In the current study, no breakage, debonding from the tooth, or deformation was observed in the retainer wires at the six-

Table 3. Descriptive statistics of pocket depth and plaque index according to material and time

Tooth	Time	Pocket depth			Plaque index		
		Material		Total	Material		Total
		Titanium	Multistranded SS		Titanium	Multistranded SS	
43	T1	1.74±0.36	1.85±0.37	1.80±0.36[a]	0.47±0.52	0.34±0.47	0.41±0.49
	T2	1.89±0.28	1.88±0.31	1.88±0.29[a,b]	0.70±0.64	0.45±0.60	0.57±0.63
	T3	1.92±0.41	2.09±0.39	2.00±0.40[b]	0.61±0.71	0.74±0.69	0.68±0.70
	Total	1.85±0.36	1.94±0.37	1.89±0.36	0.60±0.62	0.51±0.61	0.55±0.62
42	T1	1.58±0.42	1.62±0.32	1.60±0.37[a]	0.39±0.51	0.39±0.45	0.39±0.48
	T2	1.73±0.28	1.76±0.22	1.74±0.25[b]	0.70±0.60	0.37±0.53	0.53±0.59
	T3	1.85±0.36	1.84±0.237	1.84±0.30[b]	0.62±0.66	0.61±0.69	0.61±0.67
	Total	1.72±0.37	1.74±0.277	1.73±0.32	0.57±0.60	0.46±0.57	0.51±0.59
41	T1	1.50±0.33	1.54±0.38	1.52±0.35[a]	1.74±6.53	0.33±0.45	1.03±4.63
	T2	1.69±0.33	1.65±0.28	1.67±0.30[b]	0.67±0.65	0.35±0.54	0.51±0.61
	T3	1.77±0.43	1.78±0.30	1.78±0.37[b]	0.62±0.66	0.61±0.69	0.61±0.67
	Total	1.65±0.38	1.66±0.33	1.66±0.36	1.01±3.79	0.43±0.58	0.72±2.72
31	T1	1.52±0.30	1.56±0.31	1.54±0.30[a]	0.38±0.54	0.34±0.44	0.36±0.49
	T2	1.64±0.21	1.72±0.26	1.68±0.24[b]	0.65±0.65	0.35±0.54	0.50±0.61
	T3	1.73±0.37	1.77±0.32	1.75±0.34[b]	0.62±0.66	0.58±0.70	0.60±0.67
	Total	1.63±0.31	1.68±0.31	1.65±0.31	0.55±0.62	0.43±0.57	0.49±0.60
32	T1	1.48±0.36	1.64±0.34	1.56±0.36[a]	0.42±0.53	0.33±0.45	0.37±0.49
	T2	1.57±0.26	1.68±0.29	1.62±0.28[a]	0.66±0.62	0.38±0.53	0.52±0.59
	T3	1.72±0.40	1.82±0.34	1.77±0.37[b]	0.57±0.69	0.58±0.70	0.57±0.69
	Total	1.59±0.35	1.71±0.33	1.65±0.35	0.55±0.61	0.43±0.57	0.49±0.59
33	T1	1.66±0.39	1.89±0.20	1.78±0.33[a]	0.42±0.54	0.34±0.48	0.38±0.51
	T2	1.82±0.32	1.88±0.23	1.85±0.27[a,b]	0.62±0.65	0.43±0.60	0.53±0.63
	T3	1.88±0.44	2.04±0.43	1.96±0.44[b]	0.57±0.71	0.65±0.74	0.61±0.72
	Total	1.79±0.39	1.93±0.31	1.86±0.36	0.54±0.63	0.47±0.62	0.51±0.63

Values are presented as mean ± standard deviation
[a,b]There is no significant difference between time points with the same letter in terms of pocket depth and plaque index. T1: After the application of fixed retainer, T2: 3rd month, T3: 6th month
SS, stainless steel

month follow-up. In a study comparing the success rates of 0.0175-inch SS wire and 0.027x0.011-inch rectangular titanium wire, the failure rate was 8.9% for the titanium wire and 18.1% for the SS wire.[20] Although the success of the titanium wire was found to be higher, unlike in our study, the breakage and debonding of the wire may be due to the longer follow-up period (24 months).

In both groups, a significant increase was observed in the pocket depth parameter from time point T1 to T3, but this increase was not clinically significant. When the material and time interaction was evaluated, no statistically significant difference was observed in pocket depths both intra and inter groups. In healthy individuals, the depth of the anatomical gingival sulcus can vary between 0.25 mm and 3 mm.[30] In this study, the mean pocket depth of a tooth varied between 1.72 mm and 2.09 mm over the six months. This reveals that neither material formed pathological pockets over the six months.

In a study comparing the periodontal status of individuals whose fixed orthodontic treatment was completed four years prior, it was revealed that the mean pocket depth of the incisors of the fixed retainer group was 1.85 mm, while the pocket depth of the incisors in the control group was 1.7 mm.[31] These values are similar to the pocket depths in our study and support the view that fixed retainer wire will not cause a periodontal pocket. In a study comparing the periodontal effects of 0.0215-inch three-stranded SS wire and 0.027x0.011-inch eight-stranded wire, it was shown that there was no significant difference between the two materials in terms of pocket depth measurements.[32] There was no significant increase in pocket depths at the 24-month follow-up in either group. In our study, similar materials were used in terms of thickness, and our results are consistent.

When the plaque index results of our study were examined, no statistically significant difference was found in the interaction of material and time in any of the mandibular anterior teeth. Gökçe and Kaya[33] found that there was only a minor alteration

in plaque index scores but no difference between the groups (0.0215" vs 0.0175" SS) in terms of periodontal health. Pandis et al.[34] found no significant difference in plaque index between short- and long-term follow-up periods when using a 0.0195" SS wire. Our results are in agreement with the literature.[28,29,32]

No significant intragroup difference was found between the T1, T2, and T3 time points in terms of the presence of bleeding on probing in both groups. When the presence of bleeding on probing was compared between the groups, a significant difference was found between the two groups in tooth 43 at the T1 time point. This difference is due to the fact that 76% of the individuals in the titanium group and 48% of those in the SS group had bleeding in tooth 43. This difference may be due to insufficient brushing of the right canine tooth region at the beginning of the retention period by the individuals in the titanium group. In the literature, there is evidence that right-handed individuals brush less effectively in their right quadrants.[35,36] Additionally, there was no significant difference in the other teeth at the beginning of the retention period and the difference in tooth 43 may be due to the fact that right-handed users were in the majority in the titanium group. In addition, the fact that the canine teeth are at the corner of the dental arch can make effective brushing difficult. However, we do not have any information on which hand the individuals in our study used for brushing.

A significant difference was found between the groups in terms of the rates of bleeding on probing at the T2 time point. This was attributed to the higher rate of bleeding in the titanium group. The difference between the groups disappeared at the T3 time point, with a reduction in bleeding in the titanium group and slightly increased bleeding in the SS group, resulting in no significant difference between the two groups. In the presence of retainers, an increase in periodontal parameters can be observed due to a lack of oral hygiene. Storey et al.[37] found a slight increase in periodontal parameters at one-year follow-up in their study using a thinner (0.0195 inch) SS wire. Rody et al.[38] found an increase in gingival crevicular fluid biomarker levels and gingivitis in teeth with fixed retainers. Studies on whether the placement of the retainer close to the gingiva or incisal affects gingival health show that the vertical position of the retainer does not influence periodontal health.[39,40] The reason may be that bleeding increased due to loss of oral hygiene motivation in the early stage in the titanium group, and rates

Table 4. Comparison of pocket depth and plaque index according to material and time

		Pocket depth			Plaque index		
Tooth		Wald χ^2	df	p-value	Wald χ^2	df	p-value
43	Material	2.418	1	0.120	0.745	1	0.388
	Time	8.697	2	**0.013#**	5.02	2	0.081
	Material*Time	1.829	2	0.401	2.699	2	0.259
42	Material	0.139	1	0.709	1.521	1	0.218
	Time	15.087	2	**0.001#**	3.778	2	0.151
	Material*Time	0.203	2	0.903	2.707	2	0.258
41	Material	0.007	1	0.932	1.787	1	0.181
	Time	13.822	2	**0.001#**	1.067	2	0.586
	Material*Time	0.358	2	0.836	1.901	2	0.387
31	Material	1.223	1	0.269	1.696	1	0.193
	Time	13.129	2	0.001	4.217	2	0.121
	Material*Time	0.146	2	0.929	1.54	2	0.463
32	Material	5.274	1	**0.022#**	1.598	1	0.206
	Time	10.749	2	**0.005#**	3.149	2	0.207
	Material*Time	0.213	2	0.899	1.617	2	0.445
33	Material	6.895	1	**0.009#**	0.38	1	0.538
	Time	6.955	2	**0.031#**	3.466	2	0.177
	Material*Time	1.63	2	0.443	1.178	2	0.555

#The statistical significance level was p<0.05, df, degrees of freedom

Table 5. Comparison of the T3-T1 difference in terms of pocket depth and plaque index according to materials

	Tooth	Titanium	Multistranded SS	Total	Test statistics	p-value
Pocket depth	43	0.17±0.42	0.24±0.41	0.21±0.41	t=-0.58	0.565
	42	0.27±0.47	0.21±0.34	0.24±0.41	t=0.462	0.646
	41	0.27±0.57	0.24±0.47	0.25±0.52	t=0.179	0.859
	31	0.21±0.46	0.21±0.49	0.21±0.47	t=0.006	0.995
	32	0.24±0.49	0.19±0.51	0.21±0.49	t=0.38	0.705
	33	0.21±0.43	0.15±0.48	0.18±0.45	t=0.515	0.609
	Tooth	**Titanium**	**Multistranded SS**	**Total**	**Test statistics**	**p-value**
Plaque index	43	0.13±0.63	0.40±0.73	0.26±0.69	t=-1.377	0.175
	42	0.22±0.63	0.21±0.77	0.22±0.70	t=0.07	0.945
	41	-1.12±6.60	0.28±0.74	-0.42±4.70	U=288.5	0.637
	31	0.24±0.65	0.24±0.72	0.24±0.68	t=-0.004	0.997
	32	0.14±0.68	0.25±0.72	0.20±0.70	t=-0.537	0.594
	33	0.14±0.62	0.30±0.74	0.22±0.68	t=-0.823	0.415

SS, stainless steel; t, independent samples t-test/Values are mean ± standard deviation. U, Mann-Whitney U test; T3-T1, difference between 0-6 months; The statistical significance level was p<0.05

Table 6. Comparison of intra-group and inter-group bleeding on probing

Tooth	Time	Bleeding on probing	Titanium (%)	Multistranded SS (%)	Total (%)	Test statistics	p-value
43	T1	Bleeding (-)	6 (24)	13 (52)	19 (38)	χ^2=4.16	0.041#
		Bleeding (+)	19 (76)	12 (48)	31 (62)		
	T2	Bleeding (-)	5 (20)	13 (52)	18 (36)	χ^2=5.556	0.018#
		Bleeding (+)	20 (80)	12 (48)	32 (64)		
	T3	Bleeding (-)	10 (40)	7 (28)	17 (34)	χ^2=0.802	0.37
		Bleeding (+)	15 (60)	18 (72)	33 (66)		
		Test statistics	Q=3.500	Q=6.00			
		p-value	0.174	0.051			
42	T1	Bleeding (-)	8 (32)	9 (36)	17 (34)	χ^2=0.089	0.765
		Bleeding (+)	17 (68)	16 (64)	33 (66)		
	T2	Bleeding (-)	4 (16)	13 (52)	17 (34)	χ^2=7.219	0.007#
		Bleeding (+)	21 (84)	12 (48)	33 (66)		
	T3	Bleeding (-)	8 (32)	10 (40)	18 (36)	χ^2=0.347	0.556
		Bleeding (+)	17 (68)	15 (60)	32 (64)		
		Test statistics	Q=2.462	Q=1.625			
		p-value	0.292	0.444			
41	T1	Bleeding (-)	9 (36)	10 (40)	19 (38)	χ^2=0.085	0.771
		Bleeding (+)	16 (64)	15 (60)	31 (62)		
	T2	Bleeding (-)	5 (20)	13 (52)	18 (36)	χ^2=5.556	0.018#
		Bleeding (+)	20 (80)	12 (48)	32 (64)		
	T3	Bleeding (-)	7 (28)	10 (40)	17 (34)	χ^2=0.802	0.37
		Bleeding (+)	18 (72)	15 (60)	33 (66)		
		Test statistics	Q=1.714	Q=1.059			
		p-value	0.424	0.589			
31	T1	Bleeding (-)	11 (44)	9 (36)	20 (40)	χ^2=0.333	0.564
		Bleeding (+)	14 (56)	16 (64)	30 (60)		
	T2	Bleeding (-)	7 (28)	14 (56)	21 (42)	χ^2=4.023	0.045#
		Bleeding (+)	18 (72)	11 (44)	29 (58)		
	T3	Bleeding (-)	7 (28)	9 (36)	16 (32)	χ^2=0.368	0.544
		Bleeding (+)	18 (72)	16 (64)	34 (68)		
		Test statistics	Q=2.286	Q=3.571			
		p-value	0.319	0.168			
32	T1	Bleeding (-)	10 (40)	9 (36)	19 (38)	χ^2=0.085	0.771
		Bleeding (+)	15 (60)	16 (64)	31 (62)		
	T2	Bleeding (-)	6 (24)	13 (52)	19 (38)	χ^2=4.16	0.041#
		Bleeding (+)	19 (76)	12 (48)	31 (62)		
	T3	Bleeding (-)	10 (40)	9 (36)	19 (38)	χ^2=0.085	0.771
		Bleeding (+)	15 (60)	16 (64)	31 (62)		
		Test statistics	Q=2.909	Q=2.667			
		p-value	0.234	0.264			
33	T1	Bleeding (-)	9 (36)	11 (44)	20 (40)	χ^2=0.333	0.564
		Bleeding (+)	16 (64)	14 (56)	30 (60)		
	T2	Bleeding (-)	7 (28)	14 (56)	21 (42)	χ^2=4.023	0.045#
		Bleeding (+)	18 (72)	11 (44)	29 (58)		
	T3	Bleeding (-)	12 (48)	11 (44)	23 (46)	χ^2=0.023	0.879
		Bleeding (+)	13 (52)	14 (56)	27 (54)		
		Test statistics	Q=3.167	Q=1.800			
		p-value	0.205	0.407			

χ^2 chi-square test; Q, Cochran's Q test; T1, after the bonding of fixed retainer; T2, 3rd month; T3, 6th month, (-), no bleeding; (+), bleeding; SS, stainless steel, #p<0.05

decreased when individuals were motivated during the control sessions. Although thicker wires were used in our study, the results were consistent with the literature.[29]

The results of a recent systematic review indicate that vacuum-formed retainers (VFRs) are associated with more discomfort and soreness when compared with fixed lingual retainers, but oral hygiene maintenance is better in the VFR group.[41] Results of the one-year follow-up study on bonded retainers and VFR are similar.[37] Bonded retainers are associated with greater plaque and calculus deposition than VFRs, but this does not appear to produce clinically significant, adverse periodontal problems. In the current study, both retainers produced similar results at the end of the six months and did not lead to a deterioration in periodontal status.

Furthermore, recent studies have shown that certain newly introduced compounds significantly impact the oral environment. The application of lysates[42] and postbiotics[43] can alter clinical and microbiological parameters in periodontal patients, suggesting that these products should also be evaluated in future clinical trials as adjuvants for long-term assessment of fixed retention.

Study Limitations

Some of the limitations of our study are that only the effects of lingual retainers on mandibular teeth were examined and only results over six months were analyzed. Another limitation of our study is its retrospective design. In this respect, prospective randomized studies are needed. The results of the findings obtained in this study indicated no difference between the two fixed retainer wires in terms of the success of preventing relapse and their effects on periodontal tissues in the short term. Both materials were effective in preventing relapse in the lower arch and did not have a negative effect on the periodontium. Thus, our study fails to reject the null hypothesis.

CONCLUSION

According to the data obtained from the study results, both retainer wires were successful in maintaining the stability of the mandibular incisors. Both retainer wires produced similar periodontal results. No retainer failure was observed in either group.

Ethics

Ethics Committee Approval: The study protocol was approved by the Trakya University Faculty of Medicine Scientific Research Ethics Committee (approval no.: 17/08, date: 14.10.2019).

Informed Consent: Written informed consent was obtained from participants or their parents.

Footnotes

Author Contributions: Surgical and Medical Practices - M.S.Y., P.M.; Concept - M.S.Y., P.M.; Design - M.S.Y., P.M.; Data Collection and/or Processing - M.S.Y., P.M.; Analysis and/or Interpretation - M.S.Y., P.M.; Literature Search - M.S.Y., P.M.; Writing - M.S.Y., P.M.

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