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ORIGINAL ARTICLE

Comparative evaluation of periodontal effects and survival rates of Memotain and five-stranded bonded retainers

A prospective short-term study

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Abstract

Purpose To prospectively compare the short-term periodontal effects and survival rates of mandibular lingual canine-to-canine Memotain (CA-Digital, Mettmann, Germany) and five-stranded bonded retainers.

Methods In all, 52 patients requiring retention after orthodontic treatment were assigned to 2 study groups ($n = 26$ in each group). Retention was provided by Memotain retainers which were fabricated digitally using CAD-CAM (computer-aided design and computer-aided manufacturing) technology in the first group and by five-stranded retainers which were fabricated manually using a conventional bending method in the second group. The patients were examined at the following time points: 1 week, 1 month, 3 months and 6 months. Plaque index, gingival index, probing depth, marginal recession, bleeding on probing, failure rate per tooth, and survival rate of retainer wires were analyzed by Mann–Whitney U, Friedman, Wilcoxon signed-rank, and χ^2 tests.

Results The differences between the groups were nonsignificant for plaque index, gingival index, probing depth, marginal recession, bleeding on probing, failure rate per tooth and survival rate of retainer wires. Significant differences were observed within the groups throughout the follow-up period for plaque index and probing depth. The survival rates of retainer wires were 77% for the Memotain retainers and 73% for the five-stranded retainers for the 6-month follow-up period.

Conclusions Periodontal outcomes and survival rates of Memotain and five-stranded mandibular lingual bonded retainers were similar. Furthermore, periodontal health was maintained and considerably high survival rates were achieved with both retainer types.

Keywords Orthodontic retainers · Periodontal health · Orthodontic treatment · CAD-CAM · Multistranded retainer

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Vergleichende Evaluierung der parodontalen Effekte und Überlebensraten von Memotain und fünfsträngigen geklebten Retainern

Eine prospektive Kurzzeitstudie

Zusammenfassung

Zielsetzung Prospektiver Vergleich der kurzfristigen parodontalen Effekte und Überlebensraten von Memotain (CA-Digital, Mettmann, Deutschland) und fünfsträngigen geklebten Eckzahn-zu-Eckzahn-Retainern im Unterkiefer.

Methoden Insgesamt wurden 52 Patienten, die nach kieferorthopädischer Behandlung eine Retention brauchten, in 2 Studiengruppen eingeteilt ($n=26$). Die Retention erfolgte in der ersten Gruppe durch Memotain-Retainer, die digital mit CAD-CAM(„computer-aided design and computer-aided manufacturing“)-Technologie hergestellt wurden, in der zweiten Gruppe durch fünfsträngige Retainer, die manuell mit einer konventionellen Biegemethode hergestellt wurden. Die Patienten wurden zu den folgenden Zeitpunkten untersucht: 1 Woche, 1 Monat sowie 3 und 6 Monate. Plaqueindex, Gingivaindex, Sondierungstiefe, marginale Rezession, Blutung bei Sondierung, Ausfallrate pro Zahn und Überlebensrate der Retainerdrähte wurden analysiert (Mann-Whitney-U-, Friedman-, Wilcoxon-Signed-Rank- und χ^2-Test).

Ergebnisse Die Intergruppen-Unterschiede waren für den Plaqueindex, den Gingivaindex, die Sondierungstiefe, die marginale Rezession, die Blutung bei Sondierung, die Ausfallrate pro Zahn und die Überlebensrate der Retainerdrähte nicht signifikant. Während der gesamten Nachbeobachtungszeit wurden innerhalb der Gruppen signifikante Unterschiede beim Plaqueindex und bei der Sondierungstiefe beobachtet. Während der 6-monatigen Nachbeobachtungszeit betrugen die Überlebensraten 77% für die Memotain- und 73% für die fünfsträngigen Retainer.

Schlussfolgerungen Die parodontalen Ergebnisse und die Überlebensraten für Memotain- und fünfsträngige lingual geklebte Retainer im Unterkiefer waren ähnlich. Darüber hinaus blieb die parodontale Gesundheit erhalten und es wurden mit beiden Retainer-Typen erheblich hohe Überlebensraten erzielt.

Schlüsselwörter Kieferorthopädische Retainer · Parodontale Gesundheit · Kieferorthopädische Behandlung · CAD-CAM · Mehrsträngiger Retainer

Introduction

The most important challenge in orthodontic treatment is the retention of treatment results after removal of orthodontic appliances [14]. Relapse of crowding is usually observed in the long term without use of retention devices, whereby maintenance of mandibular incisor alignment is a particular problem which requires long-term retention to prevent relapse [1, 5]. It is reported that 40–90% of orthodontically treated patients present alignment problems of anterior teeth 10 years postretention and only 10% of them have acceptable mandibular alignment 20 years postretention [9, 27]. As a result, application of retention appliances for sustaining stability after orthodontic treatment is essential particularly in the mandibular anterior region [11].

Different types of retention appliances have been introduced including banded fixed retainers, removable retainers, and bonded fixed retainers [4]. Bonded fixed retainers have gained increasing popularity since they were introduced in 1970s, having the advantages of requiring less patient compliance and being invisible from the front, while providing permanent retention that is safe, efficient, and predictable [20, 27, 29]. At present, bonded fixed retainers are routinely placed at the end of orthodontic treatment [30]. Nevertheless, some drawbacks related with them are reported such as their time consuming and sensitivity requiring placement technique, possible adverse effects on periodontal tissues, potential for causing tooth movement due to wire distortion and frequently observed bonding failures [15, 17, 21, 25, 27]. Contradictory results involving increase in plaque and calculus accumulation in addition to failure rates ranging from 5.9–53% have been reported for bonded mandibular retainers [2, 3, 7, 17, 19, 22, 24]. To eliminate these disadvantages, new bonded retainer types which are manufactured using digital technologies have been recently introduced [16, 17, 28].

Numerous studies examining the periodontal effects or survival rates of bonded retainers are available in the current literature [1–16, 18–27, 29, 30]. However, a comprehensive and prospective evaluation of conventional multistranded bonded retainers in comparison with the newly introduced bonded retainers fabricated using computer-aided design and computer-aided manufacturing (CAD-CAM) technology is not available in the literature. Therefore, the primary aim was to prospectively study the periodontal effects and survival rates of mandibular lingual bonded retainers fabricated digitally using CAD-CAM technology and compare the results with the retainers fabricated manually using the conventional bending method. The H_0 hypothesis was that the periodontal effects and survival rates of these two bonded retainers are similar with each other, and the H_1

hypothesis is that the periodontal effects and survival rates of these two bonded retainers are different from each other.

Materials and methods

This clinical study was organized prospectively with a parallel group design and 1:1 allocation ratio. The sample size required for the study was calculated prior to the start of the study with a power analysis by using data obtained from the literature [21]. The power analysis revealed that a total sample size of 52 ($n = 26$ per group) was required to distinguish significant differences between the two groups with a power of 81% at $\alpha = 0.05$ significance level with an effect size of 0.8 and 95% confidence interval (95% CI). Sample size estimation was performed by using PASS software (NCSS LLC, Version 2000, Kaysville, UT, USA). The study was approved by Baskent University Institutional Review Board and Ethics Committee (project number D-KA17/09).

Patients who had completed orthodontic treatment from July–December 2017 in the postgraduate orthodontic clinic of Baskent University, Ankara, Turkey with fixed appliances and who required mandibular lingual bonded retainers were included in the study. A total of 52 patients who agreed to take part in the study were randomly assigned to the study groups, by picking one of the opaque, sealed envelopes, which were prepared before the trial and each contained a card indicating the allocated group number. The inclusion criteria consisted of

- Presence of 6 mandibular anterior teeth involving 4 incisors and 2 canines
- No caries, restorations, fractures, periodontal disease of mandibular anterior teeth
- Adequate oral hygiene and treatment compliance.

Supragingival debridement was performed and dental impressions were taken following completion of orthodontic treatment in both groups. In the first group, Memotain retainers (CA-Digital, Mettmann, Germany) which were fabricated digitally using CAD-CAM technology and made of $0.014 \times 0.014''$ rectangular nickel–titanium wires were applied. Plaster dental casts obtained from dental impressions were scanned and sent to the manufacturer. Then, the Memotain retainers were digitally designed and manufactured by cutting from nickel–titanium sheets. The custom made Memotain retainer wires and silicone putty transfer trays were mailed to the researchers after approximately 3 weeks (Fig. 1). In the second group, $0.0215''$ five-stranded retainers (GC Orthodontics Inc., Alsip, IL, USA) which were fabricated manually from stainless steel coaxial wires using conventional bending method were applied. The $0.0215''$ five-stranded retainer wires were passively adapted to the lingual surfaces of the mandibular anterior teeth and transfer trays made of transparent silicone (Memosil, Heraeus Kulzer, Wehrheim, Germany) were prepared on plaster dental casts by the same laboratory technician (Fig. 2).

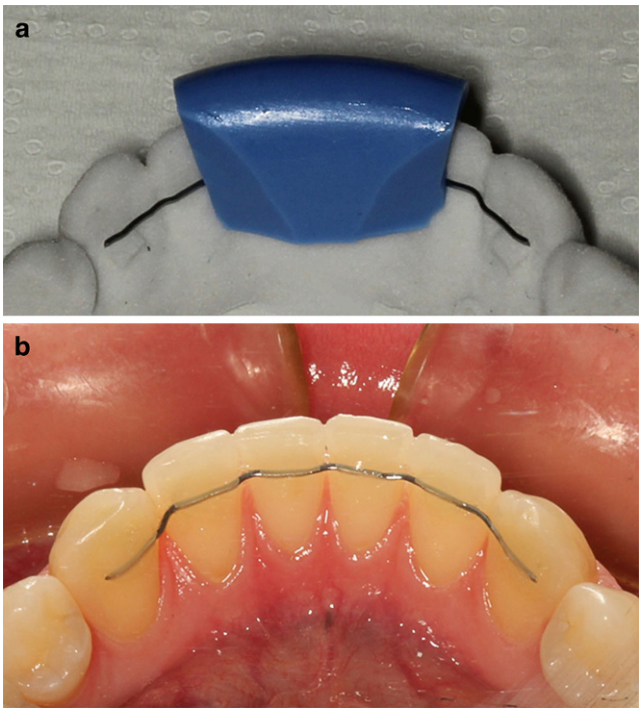

Fig. 1 Memotain retainer fabricated from $0.014 \times 0.014''$ rectangular nickel–titanium wire using CAD-CAM (computer-aided design and computer-aided manufacturing) technology. **a** Silicone putty transfer tray on plaster dental cast. **b** Memotain retainer wire bonded to mandibular anterior teeth

Abb. 1 Memotain-Retainer, hergestellt aus $0{,}014 \times 0{,}014''$ rechteckigem Nickel-Titan-Draht unter Verwendung der CAD-CAM(„computer-aided design and computer-aided manufacturing“)-Technologie. **a** Silikon-Übertragungsschlüssel auf Gipsabdruck. **b** Auf Unterkieferfrontzähne geklebter Memotain-Retainerdraht

In the clinic, both digitally fabricated Memotain retainers and manually fabricated five-stranded retainers were bonded using the same direct technique procedures. Lingual surfaces of mandibular anterior teeth were pumiced, rinsed with water, dried, and then etched with 37% phosphoric acid (Etch-Royale, Pulpdent, Watertown, MA, USA) for 30 s. The etched surfaces were rinsed thoroughly again, dried, and bonding adhesive primer was applied on mandibular canine teeth (Transbond XT primer, 3M Unitek, Monrovia, CA, USA). The transfer trays were positioned on the mandibular incisor teeth with a slight pressure for securing the retainer wires. The retainer wires were bonded to the lingual surfaces of mandibular canine teeth first, and then to the incisor teeth after removal of the transfer trays using light-cured adhesive resin (Transbond LR, 3M Unitek, Monrovia, CA, USA). Light curing was performed for 10 s per tooth using an LED device (Elipar S10, 3M ESPE, Monrovia, CA, USA).

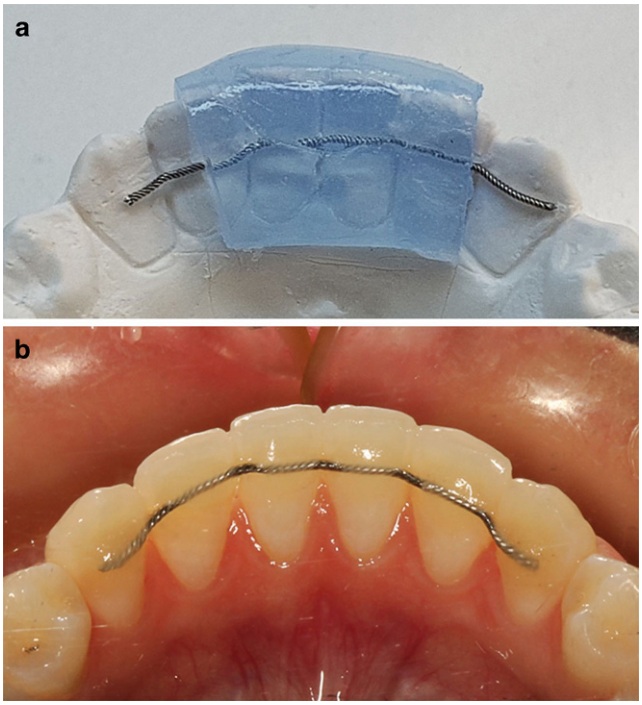

Fig. 2 Five-stranded retainer fabricated from 0.0215″ coaxial stainless steel wire using conventional bending method. **a** Transparent silicone transfer tray on plaster dental cast. **b** Five-stranded retainer wire bonded to mandibular anterior teeth

Abb. 2 Fünfsträngiger Retainer, hergestellt aus 0,0215″ koaxialem Edelstahldraht mit konventioneller Biegemethode. **a** Transparenter Silikon-Übertragungsschlüssel auf einem Gipsmodell. b Auf Unterkieferfrontzähnen geklebter fünfsträngiger Retainerdraht

All retainers were applied, oral hygiene and retainer usage instructions to the patients were given, and examinations were made by the same clinician (YK) to ensure the integrity and accuracy of the assessment procedures. Blinding of the clinician was not possible due to the nature of this study. The following clinical variables were assessed at the beginning of retention procedures and at the 1-week, 1-month, 3-month, and 6-month follow-up appointments:

- Plaque index was assessed on the lingual surfaces for each tooth using a probe [21]. The average for 6 mandibular anterior teeth was calculated and analyzed. Plaque accumulation was categorized with the following scale:
  - 0: No plaque formation
  - 1: Plaque detectable with a probe along gingival margin
  - 2: Visible plaque formation
  - 3: Abundant amount of plaque
- Gingival index was assessed on the mesial, lingual, and distal surfaces for each tooth [21]. The average for 6 mandibular anterior teeth was calculated and analyzed according to the following scale:
  - 0: No inflammation
  - 1: Mild inflammation, slight discoloration, minor edema, no bleeding on probing
  - 2: Moderate inflammation, glazing, redness, edema, bleeding on probing
  - 3: Severe inflammation, marked redness, hypertrophy, spontaneous bleeding
- Probing depth was measured with a periodontal probe in millimeters at three locations (mesiolingual, lingual, distolingual) for each tooth as the distance from gingival margin to the most apical part of the sulcus. The average for 6 mandibular anterior teeth was calculated and analyzed.
- Marginal recession was measured with a periodontal probe in millimeters at three locations (mesiolingual, lingual, distolingual) for each tooth as the distance from the cementoenamel junction to the gingival margin. Scores were recorded when the cementoenamel junction was visible due to recession. The average for 6 mandibular anterior teeth was calculated and analyzed.
- Bleeding on probing was examined at three locations (mesiolingual, lingual, distolingual) for each tooth and recorded either positive (bleeding observed) or negative (bleeding not observed). The average number of mandibular anterior teeth with positive recordings was calculated and analyzed.
- The failure rate per tooth was assessed by examining debonding of adhesive resin. The average number of adhesive resin detachment per tooth was calculated and analyzed.
- Total success rate of the retainer wire was assessed by examining survival or failure of the retainer wires. Absence of adhesive resin detachment or retainer wire breakage throughout the 6-month follow-up period was defined as survival, whereas presence of any of these events at any time was defined as failure. Adhesive remnants were removed and rebonding was undertaken at the chair-side, when detachments occurred.

Statistical analysis

Data analysis was performed using SPSS for Windows (IBM Corp, version 22, Armonk, NY, USA). Descriptive statistics were presented as a number and percentage for categorical variables such as gender and survival rate for the retainer wire, whereas they were presented as the mean and standard deviation (SD) for continuous variables such as age, plaque index, gingival index, probing depth, marginal recession, bleeding on probing, and failure rate per tooth. Furthermore, P values less than 0.05 were considered statistically significant. The Shapiro–Wilk test was used to determine the normality of variable distribution. The dif-

ferences between the study groups were analyzed using the Mann–Whitney U test for continuous variables which did not show normal distribution and using χ^2 test for categorical variables with frequencies. Differences within the study groups were analyzed using the Friedman test. The Wilcoxon signed rank test was used to distinguish those measurements where statistically significant differences were observed if the Friedman test revealed a significant difference.

Results

All of the 52 patients who were found to be eligible and included in the study completed the 6-month follow-up period. Comparisons of the groups according to gender and age are presented in Table 1. The differences between the groups were not statistically significant for gender, but significant for age.

The comparison of the plaque index scores between the groups is displayed in Table 2 and Fig. 3. No significant difference was observed for plaque index scores between the groups for any evaluated time interval. On the other hand, significant differences were observed within both groups for plaque index scores obtained at different appointments during the 6-month follow-up period.

The comparison of the gingival index scores between the groups is reported in Table 2 and Fig. 4. No significant difference was observed for gingival index scores between the groups for any evaluated time interval.

The comparison of the probing depth scores between the groups is shown in Table 2 and Fig. 5. No significant difference was observed for probing depth scores between the groups for any evaluated time interval. On the other hand, significant differences were observed within both groups for probing depth scores obtained at different appointments during the 6-month follow-up period.

The comparison of the marginal recession scores between the groups is presented in Table 2 and Fig. 6. No significant difference was observed for marginal recession scores between the groups for any evaluated time interval.

The comparison of bleeding on probing scores between the groups is displayed in Table 2 and Fig. 7. No significant difference was observed for bleeding on probing scores between the groups for any evaluated time interval.

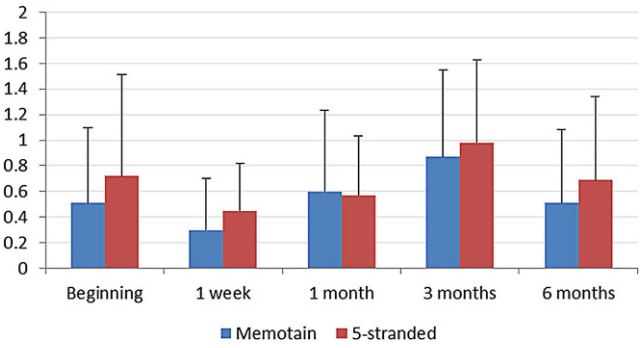

Fig. 3 Plaque index scores throughout the follow-up period
Abb. 3 Plaqueindex-Werte während der gesamten Nachbeobachtungsphase

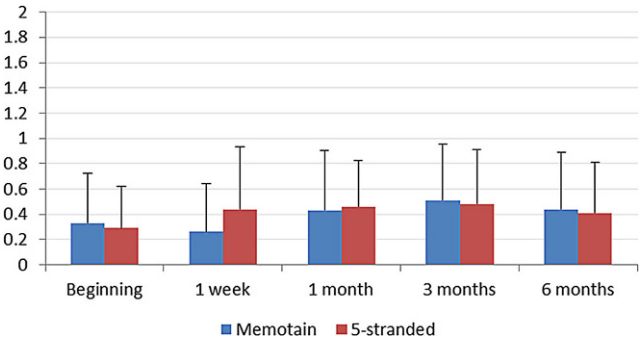

Fig. 4 Gingival index scores throughout the follow-up period
Abb. 4 Gingivaindex-Werte während der gesamten Nachbeobachtungsphase

Table 3 reveals the comparison of failure rate per tooth (average number of detachment per tooth) between the groups. All failures occurred due to debonding at the adhesive–enamel interface and none of the retainer wires were completely detached, deformed or broken. No significant difference was observed for failure rate per tooth scores between the groups for any evaluated time interval.

Total success rates of retainer wires for the 6-month follow-up period is reported in Table 4. The survival rates of the retainer wires were 77% for the Memotain group and 73% for the five-stranded group. The difference between the groups for total success rates was not statistically significant.

Table 1 Comparison of gender and age between the groups by the χ^2 test and Mann–Whitney U test, respectively
Tab. 1 Vergleich von Geschlecht und Alter zwischen den Gruppen mit dem χ^2- bzw. dem Mann-Whitney U-Test

		Gender (*n*, %)		Age (years)	
	n	Female/Male	*P*-value	Mean ± SD	*P*-value
Memotain	26	13/13, 50/50%	0.087	15.65 ± 2.17	0.031*
5-stranded	26	19/7, 73/27%		18.42 ± 5.17	

n number, %: percentage, *SD* standard deviation, $p \geq 0.05$: nonsignificant, $p < 0.05$(*): significant

Table 2 Comparison of plaque index (PI), gingival index (GI), probing depth (PD), marginal recession (MR) and bleeding on probing (BOP) between the groups by the Mann–Whitney U test, and within the groups by the Friedman and Wilcoxon signed rank tests

Tab. 2 Vergleich von Plaque-index (PI), Gingivaindex (GI), Sondierungstiefe (PD), marginaler Rezession (MR) und Blutung bei Sondierung (BOP) zwischen den Gruppen mit dem Mann-Whitney-U-Test, innerhalb der Gruppen dagegen mit dem Friedman- und dem Wilcoxon-Vorzeichen-Rang-Test

Time	Memotain	5-stranded	*P*-value
PI, mean ± SD			
Beginning	0.51 ± 0.59 (α)	0.72 ± 0.79	0.502
1 week	0.30 ± 0.40 (θ β)	0.45 ± 0.37 (Ω)	0.083
1 month	0.60 ± 0.63 (θ Σ)	0.57 ± 0.46 (λ)	0.774
3 months	0.87 ± 0.68 (α β Σ ϒ)	0.98 ± 0.65 (Ω λ ψ)	0.479
6 months	0.51 ± 0.57 (ϒ)	0.69 ± 0.65 (ψ)	0.341
P-value	0.001*	0.027*	–
GI, mean ± SD			
Beginning	0.33 ± 0.39	0.29 ± 0.33	0.931
1 week	0.26 ± 0.38	0.44 ± 0.49	0.142
1 month	0.43 ± 0.47	0.46 ± 0.36	0.609
3 months	0.51 ± 0.44	0.48 ± 0.43	0.802
6 months	0.44 ± 0.45	0.41 ± 0.40	0.963
P-value	0.067	0.198	–
PD, mean ± SD			
Beginning	1.32 ± 0.26 (α)	1.38 ± 0.25 (Ω λ ψ μ)	0.354
1 week	1.21 ± 0.18 (θ)	1.22 ± 0.15 (Ω)	0.638
1 month	1.24 ± 0.19 (β)	1.20 ± 0.19 (λ)	0.360
3 months	1.26 ± 0.19 (Σ)	1.22 ± 0.17 (ψ)	0.532
6 months	1.10 ± 0.11 (α θ β Σ)	1.17 ± 0.18 (μ)	0.223
P-value	0.001*	0.002*	–
MR, mean ± SD			
Beginning	0.00 ± 0.00	0.00 ± 0.00	1.000
1 week	0.02 ± 0.05	0.03 ± 0.08	0.654
1 month	0.05 ± 0.10	0.05 ± 0.13	0.837
3 months	0.10 ± 0.11	0.04 ± 0.07	0.058
6 months	0.03 ± 0.05	0.08 ± 0.15	0.371
P-value	0.058	0.099	–
BOP, mean ± SD			
Beginning	0.00 ± 0.00	0.00 ± 0.00	1.000
1 week	0.01 ± 0.06	0.04 ± 0.14	0.303
1 month	0.03 ± 0.13	0.00 ± 0.00	0.077
3 months	0.04 ± 0.14	0.02 ± 0.09	0.642
6 months	0.03 ± 0.09	0.00 ± 0.03	0.285
P-value	0.289	0.186	–

SD standard deviation, $p \geq 0.05$: not significant, $p < 0.05$(*): significant. Values indicated with the same symbols (*α, θ, β, Σ, ϒ, , λ, ψ, μ*) within each section show statistically significant difference

Discussion

Bonded lingual retainers are widely used to maintain stability and avoid relapse after orthodontic treatment. Hence, their impact on periodontal health, ability to sustain post-treatment stability, efficiency of different retainer wires, and factors affecting their survival rate has been inspected by numerous studies [1–3, 5, 6, 8–16, 18–27]. However, the performance of bonded retainers prepared digitally using CAD-CAM technology has not yet been examined comprehensively in the orthodontic literature. Therefore, the purpose of this prospective study was to evaluate the periodontal outcomes and survival rates of Memotain retainers which were fabricated using CAD-CAM technology in comparison with multistranded retainers which were fabricated using conventional bending method in a detailed manner. Memotain retainers are cut from nickel–titanium sheets (i.e., not bent), electropolished using electrolysis, have flat surfaces and are precisely adapted to patients' lingual tooth anatomy [17, 28]. Thus, their tendency for plaque accumulation and risk of wire fracture was expected to be less. Coaxial five-stranded 0.0215″ stainless steel wires were chosen for comparison with Memotain retainers, since they are the most frequently preferred retainer wires at present with proven long-term success [30].

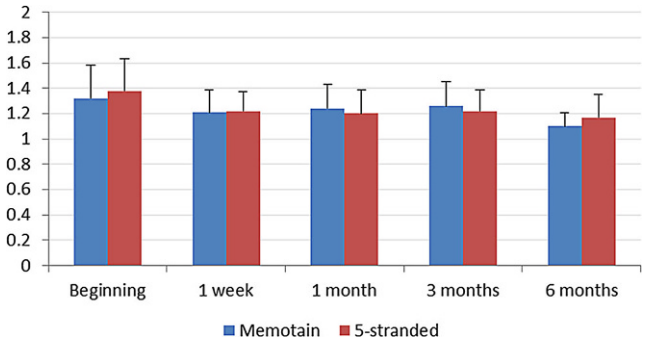

Fig. 5 Probing depth scores throughout the follow-up period
Abb. 5 Sondierungstiefe-Werte während der gesamten Nachbeobachtungsphase

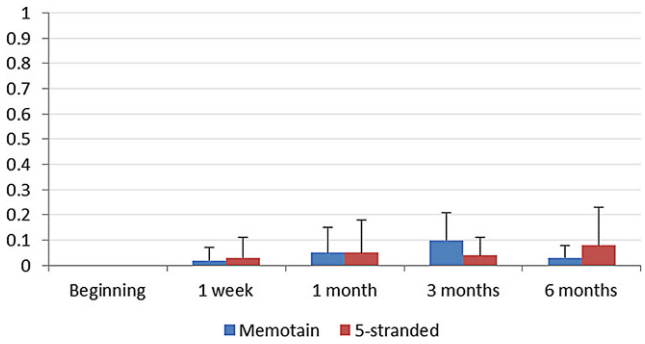

Fig. 6 Marginal recession scores throughout the follow-up period
Abb. 6 Marginale-Rezession-Werte während der gesamten Nachbeobachtungsphase

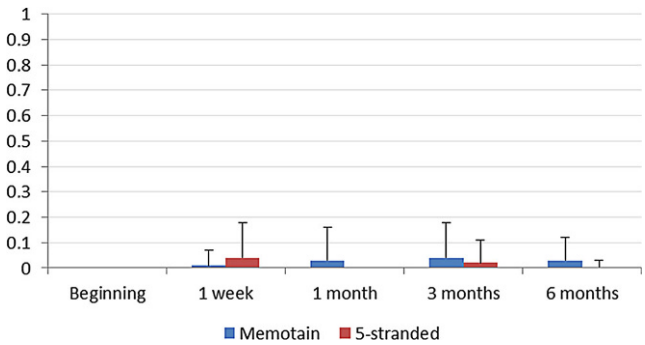

Fig. 7 Bleeding on probing scores throughout the follow-up period
Abb. 7 Blutung-bei-Sondierung-Werte während der gesamten Nachbeobachtungsphase

The adhesive primer and resin systems used in this study were the same in both bonded retainer groups to eliminate the influence of adhesive material differences on the parameters evaluated. In addition, all five-stranded retainer wires were bent by the same laboratory technician and all supragingival debridements were performed, retainers were bonded, instructions to the patients were given, and examinations were made by the same clinician to eliminate the influence of technician- and clinician-related factors.

Table 3 Comparison of failure rate per tooth (FR) between the groups by the Mann–Whitney U test
Tab. 3 Vergleich der Ausfallrate (FR) pro Zahn zwischen den Gruppen mit dem Mann-Whitney-U-Test

Time	Memotain	5-stranded	*P*-value
	Mean FR ± SD	Mean FR ± SD	
1 week	0.01 ± 0.06	0.01 ± 0.03	0.978
1 month	0.00 ± 0.00	0.03 ± 0.07	0.077
3 months	0.03 ± 0.10	0.02 ± 0.07	0.984
6 months	0.04 ± 0.11	0.01 ± 0.03	0.147

SD standard deviation, $p \geq 0.05$: non-significant

Table 4 Total success rates of retainer wires for the 6-month follow-up period
Tab. 4 Gesamterfolgsraten der Retainerdrähte über die 6-monatige Nachbeobachtungszeit

Group	Total	Survival		Failure		*P*-value
	n	*n*	%	*n*	%	
Memotain	26	20	77	6	23	0.749
5-stranded	26	19	73	7	27	

n number, % percentage, $p \geq 0.05$: non-significant. χ^2 test is used for analysis

The difference observed between the groups was statistically insignificant for gender, whereas it was significant for age. Nevertheless, both differences were clinically unimportant, with a maximum intergroup difference of 23% for gender and 2.77 years for age. Hence, the variation between the groups related with the demographic variables is not thought to have an influence on the study outcomes.

The plaque index assessment indicated that a small amount of plaque accumulation was detected along the gingival margin and oral hygiene was fairly good in the mandibular anterior lingual region during the 6-month retention phase in both study groups. The plaque index scores showed small decreases at the 1-week follow-up appointments, and later showed gradual increases until the 3-month follow-up appointments in both groups. The small but rapid decrease in plaque accumulation observed only after the first week can be attributed to the increased attention that patients show to their teeth just after debonding. On the other hand, the gradual increase in plaque accumulation which was observed only within the first 3 months can be explained with a delayed adaptation period of the patients that probably ended as a result of the ongoing instructions given to them at the follow-up appointments. No significant difference was observed for plaque index scores between the groups in any evaluated time interval. This result is comparable with the literature, but the plaque index scores observed in this study were slightly smaller and no other prospective study compared the outcomes of CAD-CAM fabricated retainers with conventionally fabricated multistranded retainers at regular multiple appointments during a 6-month follow-up period [1, 9, 10, 16, 21, 23].

Therefore, this result is unique for this study. The slightly smaller plaque index scores observed in this study may be attributed to the standardized detailed instructions given to the patients at the beginning of the retention phase by the same clinician.

The gingival index assessment indicated that gingival health conditions in the mandibular anterior lingual region did not change during the retention phase in the study groups. The gingival index scores remained approximately the same in both retainer groups during the 6-month follow-up period. No significant difference was observed for the gingival index scores between the groups during any evaluated time interval. This result suggests that bonded lingual retainers do not cause either positive or negative impacts on gingival health during the retention phase, and this is independent from the retainer wire material or fabrication technique. This finding is similar with the literature, but the gingival index scores observed in this study were considerably smaller and the outcomes of CAD-CAM fabricated retainers were not compared with conventionally fabricated multistranded retainers prospectively and at regular multiple appointments in other studies [1, 5, 9, 10, 16, 21, 23]. Thus, this finding is also unique for this study. The smaller gingival index scores observed in this study may also be attributed to the standardized instructions given to the patients at the beginning of the retention phase.

Assessment of probing depth and marginal recession indicated that probing depth remained within normal limits and no recession occurred at the gingival margin during the retention phase in the study groups. The probing depth scores showed slight decreases in both retainer groups, whereas the marginal recession scores did not show any change in either retainer group during the 6-month follow-up period. Therefore, no significant differences were observed in probing depth and marginal recession scores between the groups during any evaluated time interval. These results reveal that neither CAD-CAM fabricated flat surfaced bonded lingual retainers nor conventionally fabricated multistranded retainers cause detrimental effects on periodontal tissues that lead to increase in probing depth or marginal recession. This study investigated the changes that occurred in periodontal conditions due to usage of bonded lingual retainers only for short-term which was limited to 6 months. The probing depth and marginal recession results obtained in this study were compatible with the short-term results, but incompatible with the long-term results of other studies, as those studies observed an increase in probing depth and marginal recession within 3–11 years of retention [9, 10, 15, 16, 21]. Furthermore, comparison of CAD-CAM fabricated retainers with conventionally fabricated multistranded retainers was not of concern in long-term studies, while the examinations were realized retrospectively and only at nonstandardized single appointments in the short-term study, which also make these results unique for this study.

Assessment of bleeding on probing indicated that gingival bleeding was very rarely observed during the 6-month follow-up period in both study groups. No significant difference was observed for bleeding on probing scores between the groups during any evaluated time interval. This finding suggests that gingival conditions remained healthy with bonded lingual retainers in the mandibular anterior lingual region during the retention phase, independent from retainer wire material or fabrication technique. Bleeding on probing was less frequently observed in both groups of our study compared to other studies; however, those studies investigated the periodontal effects of retainer wires retrospectively and only at nonstandardized single appointments [9, 16]. Therefore, the results of this study related to bleeding on probing are also unique.

Average numbers of detachment per tooth were fairly small in the study groups during the 6-month follow-up period. This result reveals that debonding of adhesive resin was rarely observed with both retainers. No significant difference was observed for failure rate per tooth between the groups during any evaluated time interval. On the other hand, the survival rates of retainer wires were 77% for the Memotain group and 73% for the five-stranded group for the 6-month follow-up period. The difference between the groups was not statistically significant for the survival rates of the retainer wires. These findings are similar with the findings of some studies [5, 6, 24], whereby the survival rates of the bonded lingual retainers are higher in our study compared to various other studies [1, 3, 9, 11, 12, 18, 20, 25]. Nevertheless, the study methods, observation periods, bonding techniques and wire designs used in those studies are not comparable with this study. A study comparing the survival rate of CAD-CAM fabricated retainers with conventionally fabricated multistranded retainers is still not present in the literature and this is another unique finding of this study. The higher survival rates obtained in this study may again be attributed to the comprehensive instructions given to the patients at the beginning of the retention period.

The prospective design of this study allowed for more detailed assessment of time-related changes in periodontal conditions as well as failure frequencies and patterns compared to retrospective studies in which data are typically collected from patient files and are less detailed. Nonetheless, dropouts are one of the major challenges of prospective retention studies, since patients are usually reluctant to attend follow-up appointments as they consider the essential treatment is accomplished. However, no dropouts were observed during the 6-month follow-up period in this study, as all patients were reminded of the follow-up appointments in advance and either confirmed or re-scheduled. On the other hand, the 6-month follow-up period is one of the limitations

of this study, as it can reveal only short-term periodontal outcomes and survival rates of the examined bonded lingual retainers. Lack of blinding for the evaluator is another limitation of this study, since it can cause the evaluator to make measurements in favor of one of the methods assessed.

Conclusions

- The periodontal outcomes and survival rates of Memotain and five-stranded mandibular lingual bonded retainers were similar. Hence, the H_0 hypothesis is accepted.
- Gingival health was maintained and periodontal tissues remained sturdy in the mandibular anterior lingual region with both Memotain and five-stranded bonded retainers.
- The survival rates were 77% for the Memotain and 73% for the five-stranded mandibular lingual bonded retainers for a 6-month follow-up period.

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Compliance with ethical guidelines

Conflict of interest Y. Kartal, B. Kaya and Ö. Polat-Özsoy declare that they have no competing interests.

Ethical standards All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee (Baskent University Institutional Review Board and Ethics Committee, project number D-KA17/09) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study. This article does not contain any studies with animals performed by any of the authors.

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