RESEARCH

Post-treatment stability after insertion of CAD/CAM fabricated or Conventional fixed orthodontic retainers: a two-year follow-up

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Abstract

Objective Since relapse after orthodontic treatment and stability and failure of CAD/CAM fabricated and Conventional fixed retainers are widely discussed, this study investigated and compared two-year post-treatment stability after insertion of a CAD/CAM fabricated or Conventional fixed retainer in the lower jaw.

Materials and methods Digitized dental casts or intraoral scans of $n=60$ patients were used for data acquisition. The patients were divided into two groups according to the retention protocol: CAD/CAM fabricated fixed retainer ($n=30$, mean age 16.97 ± 5.74 years) and Conventional fixed retainer ($n=30$, mean age 15.70 ± 4.19 years). The evaluation included established procedures for dental measurements of the mandible (Intercanine Distance and Little´s Irregularity Index) before orthodontic treatment, at the end of orthodontic treatment, when the fixed retainer was inserted and two years after the insertion of the fixed retainer. All retainers were inserted by the same practitioner. Complications were recorded. Statistics included Shapiro-Wilk-, T- and Friedman-Tests. The level of significance was set at $p<0.05$.

Results In patients with Conventional fixed retainers the change of the Intercanine Distance between insertion of the fixed retainer and two years afterwards was significantly more pronounced than in patients with CAD/CAM fabricated fixed retainers (ICD: Δ CAD/CAM$_{t1-t2}$: -0.03 ± 0.22 mm; Δ Conventional$_{t1-t2}$: 0.12 ± 0.29 mm). Stability of Intercanine Distance was less in patients with Conventional fixed retainers. The change of Little´s Irregularity Index was not significant between the groups. In two patients with a Conventional fixed retainer a bonding surface was renewed within the first three months.

Conclusions Within two years, CAD/CAM fabricated fixed retainers showed less relapse of Intercanine Distance and fewer complications than Conventional fixed retainers.

Clinical relevance Considering the amount of relapse and the differences in complications, CAD/CAM fabricated fixed retainers and Conventional fixed retainers are useful appliances for stabilization of treatment results with favorable stability. Fabrication of CAD/CAM based fixed retainers is aside from that timesaving compared to Conventional fixed retainers.

Keywords CAD/CAM · Fixed retainers · Stability · Intercanine distance · Little´s irregularity index

Introduction

To prevent relapse after orthodontic tooth movement, the retention phase should be seen as an important part of treatment. Retention appliances and protocols are widely discussed [1, 10, 14, 23, 25, 31]. Fixed retainers are attached to the lingual surface of mainly canines and/or incisors. Removable retainers are acrylic plates or vacuum formed

splints [16, 17]. Since the 1970s, fixed retainers have gained fame increasing in recent years and been widely discussed [9, 30]. There were major concerns concerning plaque accumulation, but recent studies stated, that fixed retainers are not causing dental, gingival or periodontal diseases, but poor oral hygiene does [4, 5, 19]. Nonetheless, relapse after orthodontic treatment is complex and multifactorial [32]. Failure rate of fixed retainers and the risk of relapse due to tension in periodontal fibers cannot be predicted and are described with 3–90% in the lower arch [4, 6, 17, 30]. The final occlusion and the compliance of the patient can also affect stability [19]. Besides that, tooth movement after orthodontic treatment is seen as a normal change due to aging and occurs in patients without previous orthodontic

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treatment as well. Retainers are therefrom used to prevent relapse after orthodontic treatment or unwanted tooth movement due to aging [17]. Among orthodontists, different opinions concerning the need of retention, the type of the retainer and the time of the retention phase exist [3]. Materials and methods concerning retainers are evolving continuously and new alternatives are arising. However, standardized retention protocols are missing [3]. Computer-aided design and manufacturing (CAD/CAM) technology has been used for fixed orthodontic retainers using different materials [7]. CAD/CAM fabricated fixed retainers have been discussed as feasible alternatives to conventional, manually bent fixed retainers [28]. There are some studies comparing CAD/CAM fabricated and conventional fixed retainers six to twelve months after insertion [12, 18, 20, 21]. Fixed retainers may fail many years after orthodontic treatment [28]. Therefrom, it is important to evaluate their survival in longer terms. To our knowledge, the literature lacks studies that evaluate stability of orthodontic treatment results and fixed retainers in longer terms. This study adds value to the current literature by means of evaluating different materials and methodologies for fixed retainers in the lower jaw for at least two years, inserted by one clinician.

Aims of the study

The aims of this study were the evaluation and comparison of two-years post-treatment stability after the insertion of a CAD/CAM fabricated or Conventional fixed retainer in the lower jaw inserted by one clinician. The purpose was to evaluate dental changes. Feasible complications in conjunction with CAD/CAM fabricated or Conventional fixed retainers should be considered.

Materials and methods

Patients

Between July 2018 and December 2022, in $n=67$ patients fixed retainers were inserted in the mandible by the same practitioner. $N=7$ patients were excluded from the study, since they did not come back for a follow-up.

The remaining $n=60$ patients were divided into two groups (CAD/CAM fabricated fixed retainer or Conventional fixed retainer – Fig. 1), and compared to each other. The study was planned retrospectively. Digitized dental casts or intraoral scans by means of a TRIOS scanner (3Shape A/S, Copenhagen, Denmark) of the 60 non-syndromic patients (30 CAD/CAM fabricated fixed retainer, 30 Conventional fixed retainer) at the age of 16.97 ± 5.74 years (CAD/CAM fabricated fixed retainer) and 15.70 ± 4.19 years (Conventional fixed retainer) were identified and analyzed. Due to sample size, a gender division was not performed. All patients were diagnosed and treated exclusively at Saarland University Hospital. None of the patients needed extraction of premolars during treatment. The retainers were bonded on all six teeth from canine to canine in the mandible at the day of debonding. None of the patients received an additional, removable retention appliance.

Fig. 1 Overview of the mandibular fixed retainers on dental casts and in situ: CAD/CAM (left) and conventional (right)
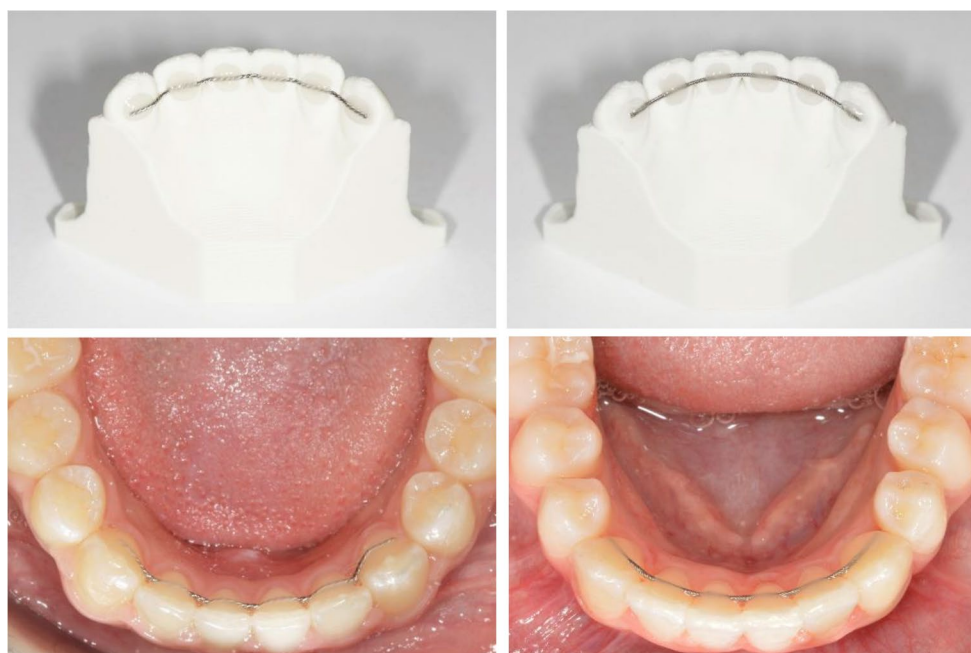
Inclusion/exclusion criteria

Inclusion criteria included completed orthodontic treatment with insertion of a fixed retainer at the end of treatment. All fixed retainers should have been inserted by the same practitioner. As a precondition, diagnostic data including dental casts or intraoral scans had to be present. Data were extracted from before the beginning (t_0) and the end of orthodontic treatment (t_1) and two years after insertion of a fixed retainer (t_2). Exclusion criteria included comorbid syndromes and genetic disorders.

Control group

All patients with CAD/CAM fabricated fixed retainers ($n=30$) were matched with patients with Conventional fixed retainers ($n=30$) regarding age and treatment protocol. Both groups received prior orthodontic treatment with brackets. Since many of our patients did not opt for fixed retainers due to financial reasons, Conventional fixed retainers were used in our clinic until 2020, and inclusion criteria was that the same practitioner inserted the fixed retainers, sample size determination was only partially possible. Against this background, we collected $n=30$ patients with Conventional fixed retainers between 2018 and 2020. Since we changed to CAD/CAM fabricated fixed retainers in 2020, the sample size of this group matching the inclusion criteria until 2022 was $n=37$ and $n=7$ patients were excluded from the study. The mean treatment duration of patients receiving a CAD/CAM fabricated fixed retainer was 34.47 ± 1.28 months. The mean treatment duration of patients receiving a Conventional fixed retainer was 40.93 ± 19.10 months.

CAD/CAM fabricated fixed retainer

Fixed retainers were custom-bent using multistranded Dentaflex wires (dentaflex®, ⌀ 0.50 mm, Dentaurum GmbH & Co., Ispringen, Germany) the in-office CAD/CAM system with the software FixR and the BenderI machine (YOAT Corp., Lynwood, USA) (Fig. 2). All patients presented themselves for a quarterly recall for two years after insertion of the retainer.

Fig. 2 Overview of the proceeding of a custom-bent fixed retainer using the in-office CAD/CAM system with the software FixR and the BenderI machine
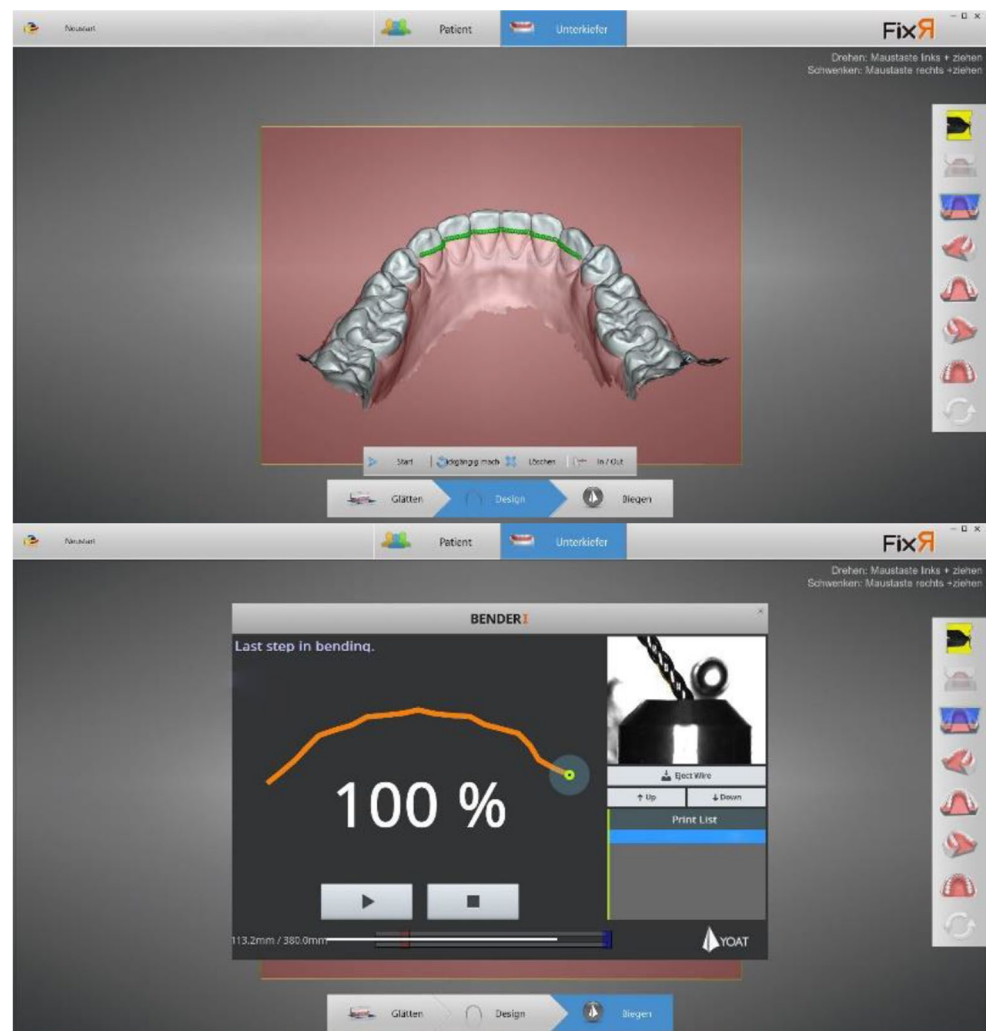
Conventional fixed retainer

Fixed retainers were bent manually by a dental technician by means of a dental cast of the lower jaw of the patient using preformed archwires (RESPOND® 0.0170, Ormco Corp., California, USA). All patients presented themselves for a quarterly recall for two years after insertion of the retainer.

Insertion technique of fixed retainers

CAD/CAM fabricated fixed retainers or Conventional fixed retainers were bonded on the lingual surfaces of the anterior teeth of the mandible. The proceeding was: cleaning of the teeth, application of 35% phosphoric acid (Reliance Orthodontic Products, Itasca, USA) and application of bonding agent (Transbond™ MIP, 3 M Germany GmbH, Neuss, Germany). The fixed retainers were placed secured with floss followed by application of light cure adhesive (Transbond LR, 3 M Germany GmbH, Neuss, Germany).

Dental casts/intraoral scans measurement

A total of 180 mandibular dental casts or intraoral scans were available. Since 2020, we are using a TRIOS scanner (TRIOS® 3, 3Shape A/S, Copenhagen, Denmark) for intraoral scans. Before 2020, the dental casts were digitized using a 3D-scanner orthoXScan (orthoX® - DENTAURUM GmbH & Co. KG Ispringen, Germany). For linear measurements (Intercanine Distance and Little's Irregularity Index) the software OnyxCeph® 3TM (Image Instruments GmbH, Chemnitz, Germany) was used.
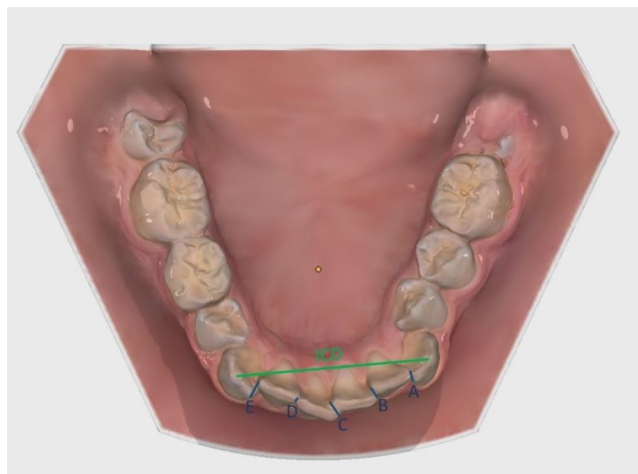

Fig. 3 Overview of the linear measurements in the mandible for ICD (green) and LII (blue)

Measuring technique

Intercanine Distance and Little's Irregularity Index [24] (Fig. 3)

The distance between the cuspids of the canines (Intercanine Distance, ICD) of the mandible was measured. Linear distances from anatomic contact points to adjacent contact points of both canines and the four incisors of the mandible were measured (Distance A, B, C, D, E). The sum of the five measured distances represents Little's Irregularity Index (LII) [24].

Statistical analysis

Statistical analysis was performed with the SPSS software version 28 (IBM, Armonk, NY, USA). Statistics included Shapiro-Wilk-, T- and Friedman-Tests. The level of significance was set at $p < 0.05$. The significance level was defined as follows: $p \geq 0.05$ not significant, $p < 0.05$ significant, $p < 0.01$ highly significant and $p < 0.001$ most highly significant. The effect sizes were tested using Cohen's criteria (for r): $0.1–0.3 =$ small effect size and low correlation, $0.3–0.5 =$ moderate effect size and correlation, $> 0.5 =$ large effect size and high correlation or Cohen's criteria (for d): $0.2 =$ small effect size and low correlation, $0.5 =$ moderate effect size and correlation, $0.8 =$ large effect size and high correlation. For testing the interrater reliability the evaluation process was repeated by a second examiner two months after the first investigation to evaluate the impact of landmarking errors, which involved removing and replacing the markings. The differences were statistically analyzed using Pearson correlation test. The correlation r in the present study was > 0.7 for all measurements. Intrarater reliability was not tested, since a single examiner conducted the investigation and the degree of subjectivity existing despite time-shift should be minimized. According to power analysis using the software G*Power version 3.1.9 (HHU, Düsseldorf, Germany), with an effect size of 0.50 and an alpha level of 0.05 the actual power was 60.6%. An effect size of 0.5 was selected to verify moderate or large differences.

Results

Dental measurements

CAD/CAM fabricated fixed retainers (Table 1)

In this group the Intercanine Distance increased between t_0 and t_1 and t_0 and t_2 (ICD: t_0: 26.46 ± 1.49 mm; t_1: 26.72 ± 1.53 mm; t_2: 26.69 ± 1.57 mm; $p_{t0–t1}$: 0.246;

Table 1 CAD/CAM fabricated fixed retainers ($n=30$) – measurements: distances [mm]. t_0: pretreatment visit; t_1: posttreatment visit, insertion of the fixed retainer, t_2: two years after t_1; M mean, SD standard deviation, [a]T-test within group between t_0-t_2

T	t_0	t_1	t_2	P value[a] t_0-t_1	P value[a] t_0-t_2	P value[a] t_1-t_2
	M ± SD	M ± SD	M ± SD			
ICD	26.46 ± 1.49	26.72 ± 1.53	26.69 ± 1.57	0.246	0.289	0.458
LII	6.82 ± 2.93	1.89 ± 0.79	1.93 ± 0.75	<0.001	<0.001	0.526

Table 2 Conventional fixed retainers ($n=30$) – measurements: distances [mm]. t_0: pretreatment visit; t_1: posttreatment visit, insertion of the fixed retainer, t_2: two years after t_1; M mean, SD standard deviation, [a]T- or Friedman-test within group between t_0-t_2

T	t_0	t_1	t_2	P value[a] t_0-t_1	P value[a] t_0-t_2	P value[a] t_1-t_2
	M ± SD	M ± SD	M ± SD			
ICD	26.42 ± 2.32	26.57 ± 1.47	26.69 ± 1.65	0.710	0.496	0.026
LII	7.25 ± 2.41	2.23 ± 1.71	2.27 ± 1.66	<0.001	<0.001	0.519

Table 3 CAD/CAM fabricated fixed retainers versus Conventional fixed retainers – measurements Δ: distances [mm]. t_0: pretreatment visit; t_1: posttreatment visit, insertion of the fixed retainer, t_2: two years after t_1; M mean, SD standard deviation, [a]T-test between the groups between t_0-t_2

Δ CAD/CAM fabricated fixed retainers

T	t_0-t_1	t_0-t_2	t_1-t_2
	M ± SD	M ± SD	M ± SD
ICD	0.26 ± 1.22	0.23 ± 1.18	-0.03 ± 0.22
LII	-4.94 ± 3.08	-4.90 ± 3.05	0.04 ± 0.34

Δ *Conventional fixed retainers*

T	t_0-t_1	t_0-t_2	t_1-t_2	P value[a] t_0-t_1	P value[a] t_0-t_2	P value[a] t_1-t_2
	M ± SD	M ± SD	M ± SD			
ICD	0.15 ± 2.18	0.27 ± 2.17	0.12 ± 0.29	0.805	0.930	0.024
LII	-5.02 ± 2.71	-4.98 ± 2.66	0.04 ± 0.22	0.912	0.911	1.000

Table 4 CAD/CAM fabricated fixed retainers versus Conventional fixed retainers – measurements: distances [mm]. t_1: posttreatment visit, insertion of the fixed retainer; M mean, SD standard deviation, [a]T-test between the groups at t_1

ICD

T	CAD/CAM t_1	Conventional t_1	P value[a] t_1
	M ± SD	M ± SD	
	26.72 ± 1.53	26.57 ± 1.47	0.724

LII

T	CAD/CAM t_1	Conventional t_1	P value[a] t_1
	M ± SD	M ± SD	
	1.89 ± 0.79	2.23 ± 1.71	0.325

p_{t0-t2}: 0.289) and decreased between t_1 and t_2 (ICD: t_1: 26.72 ± 1.53 mm; t_2: 26.69 ± 1.57 mm; p_{t1-t2}: 0.458).

Little´s Irregularity Index decreased between t_0 and t_1 and t_0 and t_2 (LII: t_0: 6.82 ± 2.93 mm; t_1: 1.89 ± 0.79 mm; t_2: 1.93 ± 0.75 mm; p_{t0-t1}: <0.001, d_{t0-t1}: 1.603; p_{t0-t2}: <0.001, d_{t0-t2}: 1.607) and increased between t_1 and t_2 (LII: t_1: 1.89 ± 0.79 mm; t_2: 1.93 ± 0.75 mm; p_{t1-t2}: 0.526).

Conventional fixed retainers (Table 2)

In this group the Intercanine Distance increased between t_0 and t_1, t_0 and t_2 and t_1 and t_2 (ICD: t_0: 26.42 ± 2.32 mm; t_1: 26.57 ± 1.47 mm; t_2: 26.69 ± 1.65 mm; p_{t0-t1}: 0.710; p_{t0-t2}: 0.496; p_{t1-t2}: 0.026, d_{t1-t2}: 0.428).

Little´s Irregularity Index decreased between t_0 and t_1 and t_0 and t_2 (LII: t_0: 7.25 ± 2.41 mm; t_1: 2.23 ± 1.71 mm; t_2: 2.27 ± 1.66 mm; p_{t0-t1}: <0.001, r_{t0-t1}: 0.289; p_{t0-t2}: <0.001, r_{t0-t2}: 0.259) and increased between t_1 and t_2 (LII: t_1: 2.23 ± 1.71 mm; t_2: 2.27 ± 1.66 mm; p_{t1-t2}: 0.519).

CAD/CAM fabricated versus Conventional fixed retainers – main differences (Table 3) and comparison at t_1 (Table 4)

In patients with Conventional fixed retainers the change of Intercanine Distance between t_1 and t_2 was significantly more pronounced than in patients with CAD/CAM fabricated fixed retainers (ICD: Δ CAD/CAM$_{t1-t2}$: -0.03 ± 0.22 mm; Δ Conventional$_{t1-t2}$: 0.12 ± 0.29 mm; p_{t1-t2}: 0.024, d_{t1-t2}: 0.064). Stability of Intercanine Distance was less in patients with Conventional fixed retainers. The change of Little´s Irregularity Index was not significant between the groups. At t_1, the Intercanine Distance and the Little´s Irregularity Index were almost indistinguishable between the groups.

Fixed retainers complications

In one patient with a CAD/CAM fabricated fixed retainer, a change of the left mandibular canine was visible at t_2. The retainer was preventively removed and renewed. In two patients with Conventional fixed retainers each of them had loosening of one bonding surface within three months

after insertion of the retainer. The bonding surfaces could be renewed and were stable afterwards. Gingival recession or dental calculus were not present in any of the patients at t_2.

Discussion

Since the same practitioner should have inserted all fixed retainers of our study, the smaller number of 60 patients for this study was acceptable, especially regarding post-treatment stability evaluation after two years. Shortening of the two-year interval did not make sense, because stability should be assessed in longer terms. To our knowledge, this is the only study in existence covering a two-year follow up period concerning CAD/CAM fabricated fixed retainers compared to Conventional fixed retainers inserted by one clinician. Still, after division into different groups, necessary for comparison of different materials and methodologies of fixed retainers, the number of patients per group remained low. The different material, methodologies and insertion techniques of fixed retainers of different clinicians in existence did not allow the inclusion of casts or intraoral scans from other centers to increase numbers. However, especially CAD/CAM fabricated fixed retainers appear to be useful for stabilization of treatment outcomes. Alrawas et al. [2] compared 60 patients in their study for six months during retention phase with CAD/CAM NiTi, multi-stranded stainless steel, single stranded nickel-free titanium or vacuum-formed removable retainers in the lower jaw. The patients were approximately 20 years old at the beginning of the retention phase. They concluded that in all groups relapse was seen in anterior teeth, but regarding clinical failure rate, no differences were found between the groups. The results are comparable to our results in short-term. Furthermore, they observed less plaque accumulation and gingival inflammation in the CAD/CAM NiTi retainer group. Egli et al. [11] compared 64 patients with indirect or direct bonded fixed retainers in the lower jaw and described a failure rate of 40% within two years with 43% failure rate in the indirect bonding group and 37% in the direct bonding group occurring mainly during the first year. In our study, the failure rate was 3% in patients with CAD/CAM fabricated fixed orthodontic retainers and 6% in the patients with Conventional fixed retainers, but comparison of failure rates is difficult due to heterogeneity in bonding methods, dimensions and materials and differences in follow-up duration. Pulisaar et al. [27] evaluated 181 patients, 90 with CAD/CAM fabricated fixed retainers (Memotain®) and 91 with conventional multistranded fixed retainers of two centres 12 and 24 months after insertion of the retainers. They included maxillary retainers as well. Within 24 months, they described a failure rate of CAD/CAM fabricated fixed

retainers with 42% and of conventional multistranded fixed retainers with 40%. In groups of failure-free patients, differences in Little´s Irregularity Index and arch dimensions were not remarked.

Schmid-Herrmann et al. [29] analyzed the accuracy of 41 retainers including CAD/CAM and hand-bent retainers by means of superimposition. They described CAD/CAM retainers with a good positioning accuracy in the mandible and good retention properties regarding posttreatment changes.

Tran et al. [32] compared a total of 43 patients divided into three different groups: CAD/CAM group with multistranded stainless steel retainers, lab group with the same multistranded stainless steel retainers and a chairside group with stainless steel Ortho-FlexTech wires in the lower jaw. After two years, they reported a significantly less reduction of intercanine width in patients with CAD/CAM multistranded stainless steel retainers compared to the lab and chairside group and a lower failure rate (21.4%). The sample size per group was smaller than in our study but results regarding stability of intercanine distance was similar. They used Dentaflex wires as well in the CAD/CAM and in the lab group and described the Dentaflex wires as more rigid compared to the Ortho-FlexTech wires and as more stabilizing concerning intercanine witdth. In our study, the CAD/CAM fabricated fixed retainer was less flexible as the Conventional fixed retainer as well. Muhareb et al. [26] stated in their review that concerning intercanine distance, arch length and failure rate, differences between CAD/CAM and conventional retainers were not significant regardless of follow up time or retainer wire type. Plaque index was reduced with CAD/CAM retainers after six months. Regarding intercanine distance and failure rate, the results of our study were similar.

Baysal et al. [8] reported, that rigid stainless steel wires are less easily deformed due to mastication forces or cleaning. An explanation concerning the lower failure rate of CAD/CAM fabricated fixed retainers using a bending machine can be that the bending machine is able to bend more precisely following the lingual contours leading to better interproximal adaption [32]. Hu et al. [13] concluded in their study, that the CAD/CAM method in fabricating lingual retainers is more stable and saves much time. They reported, that fabricating a lingual retainer in the lower jaw using the CAD/CAM method takes only half of the time compared to fabricating a conventional one. Concerning failure rate, insertion technique of the clinician can also play an important role, especially because bonding failure is the main reason why fixed retainers fail [15, 22, 32]. To minimize different insertion techniques, all fixed retainers of our study were inserted by one clinician. Moreover, patients'

compliance during mastication is important, since too much power can lead to failure of the fixed retainer as well [19].

Limitations of the study

The number of patients of our study was acceptable. Nonetheless, a larger patient number could have been reached, but many patients could not defray the costs of fixed retainers or did not come back for a follow-up after insertion of the fixed retainer. Moreover, the retainers should be inserted by the same practitioner. Due to the smaller number of patients, a gender division was not performed during comparison of post-treatment stability. The recruitment duration was rather long, since only a few patients opt for fixed retainers. Some of our patients decided on removable retainers for financial reasons.

Clinical applicability of our study was limited due to the two-year follow-up, since retention needs to be seen as a long-term subject of decades.

Another limit of our study is the evaluation of Little´s Irregularity Index, since deviations of contact points were measured, but the Index does not consider inclination or vertical changes. At baseline, crowding was more in patients with Conventional fixed retainers, but the patients were randomly selected for the study.

Finally, post-treatment stability does not exclusively depend on final occlusion and duration of the retention phase, but also on the patient's compliance concerning appropriate handling of a fixed retainer.

Conclusion

Within two years, CAD/CAM fabricated fixed retainers showed less relapse of Intercanine Distance and fewer complications than Conventional fixed retainers. Nonetheless, considering clinical relevance, the actual amount of relapse and the difference in complications between CAD/CAM fabricated fixed retainers and Conventional fixed retainers are almost indistinguishable.

Fabrication of CAD/CAM based fixed retainers is aside from that timesaving compared to Conventional fixed retainers. Larger patient numbers and a longer follow-up examination, however, would have been favorable for a final assessment.

Declarations

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