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Success rate and efficiency of activator treatment

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SUMMARY In a retrospective multicentre study, the success rate and efficiency of activator treatment were analysed. All patients from two University clinics (Giessen, Germany and Berne, Switzerland) that fulfilled the selection criteria (Class II division 1 malocclusion, activator treatment, no aplasia, no extraction of permanent teeth, no syndromes, no previous orthodontic treatment except transverse maxillary expansion, full available records) were included in the study. The subject material amounted to 222 patients with a mean age of 10.6 years. Patient records, lateral head films, and dental casts were evaluated. Treatment was classified as successful if the molar relationship improved by at least half to three-fourths cusp width depending on whether or not the leeway space was used during treatment. Group comparisons were carried out using Wilcoxon two-sample and Kruskal–Wallis tests. For discrete data, chi-square analysis was used and Fisher's exact test when the sample size was small. Stepwise logistic regression was also employed.

The success rate was 64 per cent in Giessen and 66 per cent in Berne. The only factor that significantly ($P < 0.001$) influenced treatment success was the level of co-operation. In approximately 27 per cent of the patients at both centres, the post-treatment occlusion was an 'ideal' Class I. In an additional 38 per cent of the patients, marked improvements in occlusal relationships were found.

In subjects with Class II division 1 malocclusions, in which orthodontic treatment is performed by means of activators, a marked improvement of the Class II dental arch relationships can be expected in approximately 65 per cent of subjects. Activator treatment is more efficient in the late than in the early mixed dentition.

Introduction

The correction of a Class II division 1 malocclusion by means of functional appliances is a frequent treatment approach (O'Connor, 1993). Numerous studies have focused on the mode of action of the different types of removable functional appliances, evaluating their dental and skeletal effects. However, much is still unknown regarding the factors leading to success or failure of functional appliance treatment. Scientific studies performed on this topic are rare and have been undertaken in only small patient samples (Ahlgren, 1972; Ahlgren and Laurin, 1976; Bondevik, 1991, 1995; Weiland *et al.*, 1997).

The aim of the present, retrospective, multicentre investigation was, therefore, to evaluate the success rate and efficiency of activator treatment in a large number of Class II division 1 patients treated at two different University clinics. The following factors that may be associated with the treatment outcome were considered: age, gender, dental and skelettofacial morphology, the type of activator used, pre-treatment maxillary expansion, the level of co-operation, treatment length, and the centre where treatment was performed.

Material and methods

From all patients treated with activators at the Departments of Orthodontics of the Universities of Giessen, Germany, during the years 1985–2001, and Berne, Switzerland, during the years 1992–2002, those presenting with a Class II division 1 malocclusion with an overjet ≥ 5 mm and where full available records were selected.

If the patient was in the permanent dentition, the molar relationship had to be half or more cusp distal, and in the mixed dentition, with the second lower primary molar still present, the relationship had to be three-fourths or more cusp distal due to the expected spontaneous mesial drift of the molar as a result of the leeway space (Bishara *et al.*, 1988).

Patients presenting with agenesis, extraction of permanent teeth, syndromes, and previous orthodontic treatment, except for transverse maxillary expansion, were excluded from the study.

Dental casts from before (T0) and after (T1) activator treatment were used to measure the overjet and overbite, the sagittal molar relationship (in quarter cusp steps), and dental maturity (Björk *et al.*, 1964).

Using the lateral head films taken at T0, the sagittal jaw base position (SNA and SNB angles), the sagittal jaw base relationship (ANB angle), the vertical jaw base relationship (ML/NL angle), and the mandibular plane angle (ML/NSL) were measured. Furthermore, for the patients from Berne, skeletal maturity, using the cervical vertebrae maturation method (Hassel and Farman, 1995), was assessed.

All measurements were performed twice and the mean of the duplicate registrations was used in the final analysis of

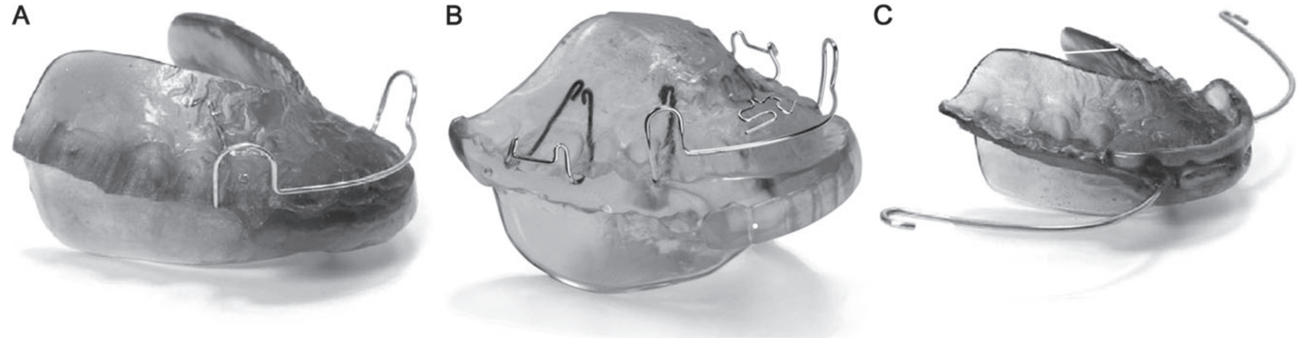

Figure 1 The three different types of activators used for the treatment of the 222 Class II division 1 patients: (A) Andresen, (B) Herren, and (C) van Beek.

the data. The registrations of the patients treated in Giessen and Berne were undertaken by independent investigators. No interexaminer error was assessed. However, for the assignment into the successful, marked improvement and failure groups (see below) agreement between the two investigators in Giessen (MG and HP) and Berne (CC and SR) had to be reached.

One hundred and eighteen patients fulfilled the selection criteria in Giessen (48 females, 70 males) and 104 in Berne (49 females, 55 males). Thus, in total, 222 patients (97 females, 125 males) could be analysed. The mean patient age at T0 was 10.0 years [standard deviation (SD) 1.38 years)] in Giessen and 11.2 years (SD 1.33 years) in Berne.

Three different types of activators (Figure 1) were used in the treatment of the patients: the Andresen activator (Andresen *et al.*, 1953), the activator according to Herren (Herren, 1959, 1980), and the van Beek activator (van Beek, 1982). The number of patients treated with each appliance amounted to 92 Andresen activators (Giessen 92, Berne 0), 72 Herren activators (Giessen 0, Berne 72), and 58 van Beek activators (Giessen 26, Berne 32). All treatments at both centres were performed by senior staff and postgraduate students.

By examining the patient records, indirect information about compliance: oral hygiene, missed appointments, and fitting accuracy of the appliance were derived. Using these data, the co-operation of the patients was categorized as good or bad. Bad co-operation was assumed if the patient's records showed several missed appointments, repeated notes on bad oral hygiene, reports on bad appliance fitting, or even appliance loss.

The length of activator treatment was defined as the time span from T0 to T1. The mean treatment time was 2.3 years in Giessen (SD 1.34 years) and 1.8 years in Berne (SD 1.03 years).

Treatment success

Activator treatment was considered successful if the following conditions were met bilaterally: treatment started in the permanent dentition: improvement in the sagittal molar relationship of half or more cusp; treatment started in the mixed dentition: improvement in the sagittal molar relationship of a half or more cusp. However, if the second lower primary molar was exfoliated during the treatment period, the improvement in occlusal relationships had to be three-quarters or more of a cusp.

In case of an asymmetric improvement on the right or left side, the smaller amount of cusp width improvement was used in the final evaluation.

For comparison between permanent and mixed dentition treatment, the net activator effect (= total molar relationship change minus quarter cusp for leeway space usage) was used in the final evaluation.

In order to assess the degree of efficiency of activator treatment, the successful group was further divided into two subgroups: (1) an 'ideal' occlusion group and (2) a marked improvement group. The following post-treatment criteria had to be fulfilled to be assigned to the ideal occlusion group: Class I molar relationship + 1 mm, overjet and overbite less than 4 mm, occlusal contact on all teeth, and crowding in the upper and lower anterior segments less than 2 mm.

Any patient from the successful group not fulfilling all of the ideal criteria was assigned to the marked improvement group.

Statistical analysis

For the biometric and cephalometric data, descriptive statistics were performed (mean, median, SD). Group comparisons were undertaken using non-parametric tests (Wilcoxon two-sample and Kruskal–Wallis). For discrete data, the chi-square analysis was used; where the sample size was low, Fisher's exact test was used. Stepwise logistic regression was employed to assess possible interrelationships between treatment success and the independent variables gender, co-operation, activator type, treatment length, transverse expansion, dental, and skeletal maturity. The statistical significance was determined at the 0.1, 1, and 5 per cent levels of confidence. A confidence level greater than 5 per cent was considered not statistically significant.

Table 1 Pre-treatment age, treatment duration, pre-treatment dental cast, and cephalometric data of 222 Class II division 1 activator patients.

	Giessen (n = 118)		Berne (n = 104)		Group difference mean	P-value
	Mean	SD	Mean	SD		
Age (years)	10.02	1.38	11.24	1.33	−1.22	***
Treatment duration (years)	2.27	1.34	1.81	1.03	0.46	***
Dental cast variables						
Overjet (mm)	7.08	1.66	7.42	2.04	−0.34	ns
Overbite (mm)	3.18	2.29	2.92	2.01	0.26	ns
Molar relationship right (cusp width)*	−0.84	0.27	−0.77	0.28	−0.07	ns
Molar relationship left (cusp width)*	−0.86	0.32	−0.76	0.31	−0.10	ns
Cephalometric variables						
SNA (°)	80.89	3.41	80.73	3.17	0.16	ns
SNB (°)	75.11	3.05	75.50	3.16	−0.39	ns
ANB (°)	5.78	2.05	5.22	1.70	0.56	ns
ML/NSL (°)	33.22	5.15	32.66	5.43	0.56	ns
ML/NL (°)	26.21	5.32	26.36	5.56	−0.15	ns

*A negative value implies a distal molar relationship.
***$P < 0.001$; ns, not significant.

Results

T0 data of the dental cast and cephalometric characteristics of the two activator groups are given in Table 1.

The patients in Giessen were, on average, younger (1.2 years, $P < 0.001$) at T0 and were treated for 0.5 years longer ($P < 0.001$) than those in Berne. Pre-treatment transverse maxillary expansion was performed twice as often in Giessen (71 per cent) as in Berne (31 per cent). The mean pre-treatment time during which transverse maxillary expansion was performed amounted to 0.8 years (SD 0.57 years) in Giessen and 0.9 years (SD 0.44 years) in Berne (not significant).

Applying the criteria for success (net improvement in sagittal molar relationship of at least half a cusp), the success rate amounted to 64 per cent in Giessen and 66 per cent in Berne (Figure 2). Correspondingly, the failure rate was 36 per cent and 34 per cent, respectively. The total amount of molar relationship improvement showed a large interindividual variation ranging form 0 to 1.5 cusp widths. For 4 per cent (n = 5) of the patients in Giessen and 8 per cent (n = 7) in Berne, no improvement at all in sagittal molar relationship was seen.

From the total patient material, 26 per cent attained an ideal occlusion in Giessen and 27 per cent in Berne. The remaining 38 per cent of successful patients achieved a marked improvement in the sagittal molar relationship during activator treatment at both centres.

As no statistically significant group differences (Giessen/Berne) existed for the T0 malocclusion severity (dental cast or cephalometric variables) or for the T1 dental cast characteristics (Table 2) and as the success rate as well as the treatment efficiency were almost identical at both centres, the patient material was pooled for further analysis.

Pre-treatment age, treatment length as well as dental cast and cephalometric characteristics of the successful and unsuccessful groups are given in Table 3. Except for treatment length, no statistically significant group differences were found for any of the variables analysed. Treatment length in the successful group was 0.6 years longer than in the failure group ($P < 0.001$).

The average improvement (net activator effect) in molar relationship was significantly larger ($P < 0.001$) in the successful (mean 0.7 cusp widths, SD 0.24 cusp widths) than in the unsuccessful group (mean 0.3 cusp widths, SD 0.27 cusp widths). These differences in reaction resulted in statistically significant ($P < 0.001$) differences in T1 dental cast characteristics between the groups (Table 4).

No significant differences between the success and failure groups were found when testing for nominal data such as gender, activator type used (Figure 3), location where the treatment was performed, dental maturity, skeletal maturity (available data from Berne only), or whether or not transverse maxillary expansion was performed before activator treatment. The only significant factor found to influence the success rate of activator treatment was the level of patient co-operation. While in the success group 75 per cent were classified as co-operating well, this was the case in only 29 per cent in the failure group ($P < 0.001$). Good patient co-operation was also the only predictive factor for treatment success identified by means of logistic regression ($P < 0.001$).

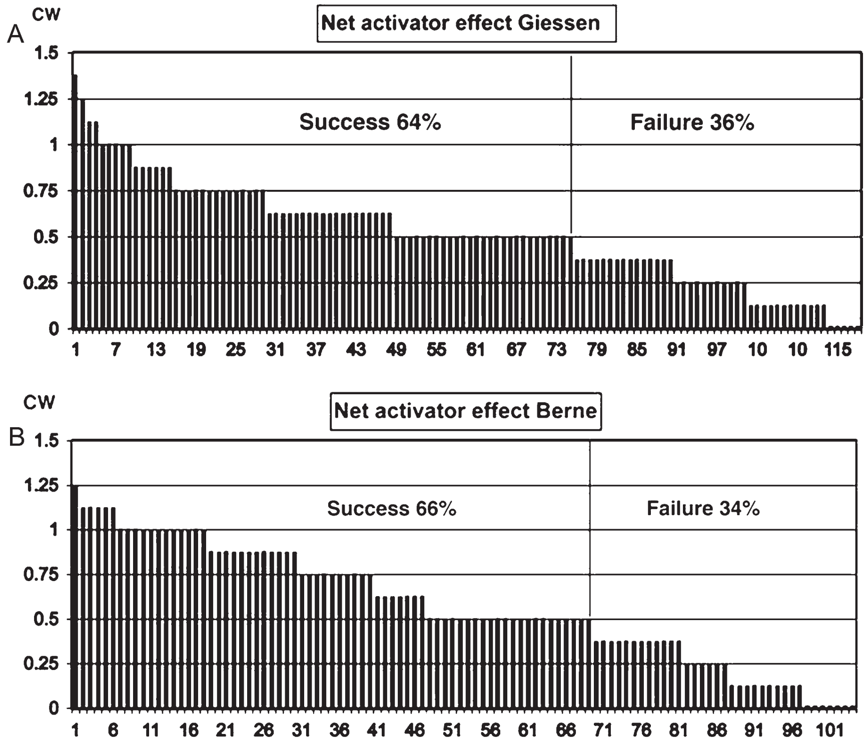

Figure 2 Individual improvement of sagittal molar relationship (net activator effect) expressed in cusp widths (CW) in 222 Class II division 1 patients treated with activators at the Universities of Giessen (A) and Berne (B).

Table 2 Post-treatment (TA) dental cast data of 222 Class II division 1 activator patients.

	Giessen (n = 118)		Berne (n = 104)		Group difference mean	P-value
	Mean	SD	Mean	SD		
Dental cast variables						
Overjet (mm)	3.46	1.80	3.60	1.66	−0.14	ns
Overbite (mm)	2.84	1.51	2.72	1.41	0.12	ns
Molar relationship right (cusp width)*	−0.15	0.37	−0.10	0.32	−0.05	ns
Molar relationship left (cusp width)*	−0.16	0.42	−0.13	0.30	−0.03	ns

ns, not significant.
*A negative value implies a distal molar relationship.

Although no statistically significant differences between the different activator types existed, there was a tendency for a larger cusp width improvement with the van Beek activator (median 0.63 cusp widths) when compared with the Andresen and Herren activators (median = 0.50 cusp widths).

Even if dental maturity had no influence on treatment success, it did significantly influence treatment length. Activator treatment started in the early mixed dentition resulted in a longer treatment period (mean 2.7 years, SD 1.3 years) than activator treatment started in the late mixed dentition (mean treatment length 1.7 years, SD 1.04 years; Figure 4).

After activator treatment, 40 per cent of the successful subjects required no further orthodontic treatment, 50 per cent were treated with fixed appliances, and 10 per cent had other types of therapy. In 21 per cent of the failure group, no further orthodontic treatment was performed because orthodontic therapy was discontinued due to lack of co-operation/motivation. After activator therapy, 49 per cent of

Table 3 Pre-treatment age, treatment duration, pre-treatment dental cast, and cephalometric data of 222 Class II division 1 patients treated successfully or unsuccessfully with activators.

	Success group (n = 145)		Failure group (n = 77)		Group difference mean	P-value
	Mean	SD	Mean	SD		
Age (years)	10.60	1.33	10.57	1.45	0.03	ns
Treatment duration (years)	2.25	1.25	1.69	0.92	0.56	***
Dental cast variables						
Overjet (mm)	7.24	1.85	7.00	1.84	0.24	ns
Overbite (mm)	3.06	2.16	3.32	1.97	−0.26	ns
Molar relationship right (cusp width)*	−0.81	0.26	−0.81	0.31	0	ns
Molar relationship left (cusp width)*	−0.83	0.31	−0.82	0.33	0	ns
Cephalometric variables						
SNA (°)	80.79	3.33	80.94	3.25	−0.15	ns
SNB (°)	75.39	3.17	75.02	2.85	0.37	ns
ANB (°)	5.40	1.87	5.92	1.93	−0.52	ns
ML/NSL (°)	33.02	5.57	32.72	5.82	0.30	ns
ML/NL (°)	26.54	5.61	25.55	5.23	0.99	ns

*A negative value implies distal molar relationship.
***$P < 0.001$; ns, not significant.

Table 4 Post-treatment dental cast data of 222 Class II division 1 patients treated successfully or unsuccessfully (n = 77) with activators.

	Success group (n = 145)		Failure group (n = 77)		Group difference mean	P-value
	Mean	SD	Mean	SD		
Dental cast variables						
Overjet (mm)	2.82	1.06	4.85	1.97	−2.03	***
Overbite (mm)	2.52	1.26	3.29	1.68	−0.77	***
Molar relationship right (cusp width)*	0.03	0.21	−0.41	0.39	0.44	***
Molar relationship left (cusp width)*	0.02	0.23	−0.45	0.39	0.47	***

*A negative value implies distal molar relationship.
***$P < 0.001$.

the failure group had fixed appliances, 20 per cent were treated with a Herbst appliance, and 10 per cent with other types of appliances.

Discussion

The present study is a retrospective case series implying that it ranks relatively low in the hierarchy of evidence because of the inherent risk for selection bias and the lack of a control group. Selection bias in this context would especially mean that the patient material included in this study is not representative of a normal population of patients with Class II division 1 malocclusions.

The patients included in this study had been treated at two University centres, where they had been referred for orthodontic care. Even though these treatments were performed in two different countries and within two different health care systems, which might have influenced patient selection at T0 or the treatment decision, neither their dental cast nor their cephalometric variables showed any statistically significant differences. Therefore, it seems likely that the patient material of the present study is representative of a normal adolescent Class II division 1 malocclusion population.

Treatment success was defined as an improvement in molar relationship of at least a half to three-quarters cusp width depending on whether or not the leeway space was used during treatment. Bishara *et al.* (1988) reported a spontaneous mesial drift of the lower molars on exfoliation of the second primary molars in approximately 60 per cent

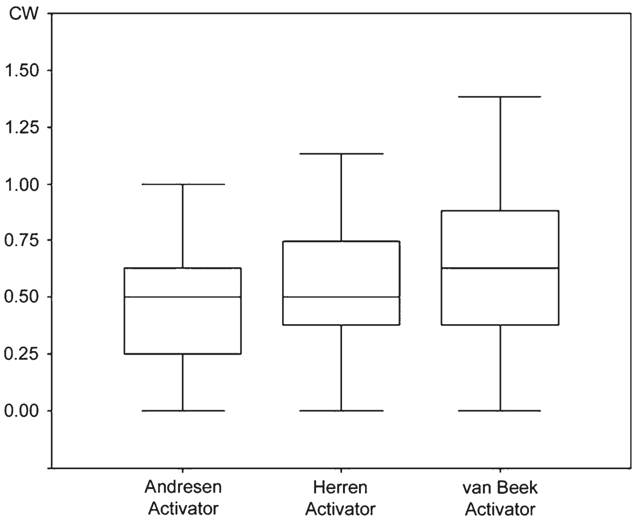

Figure 3 Influence of the activator type (Andresen, Herren, and van Beek) used for treatment in 222 Class II division 1 patients on the improvement in sagittal molar relationship (net activator effect) in cusp widths (CW). Note: the differences between the activator types were not statistically significant.

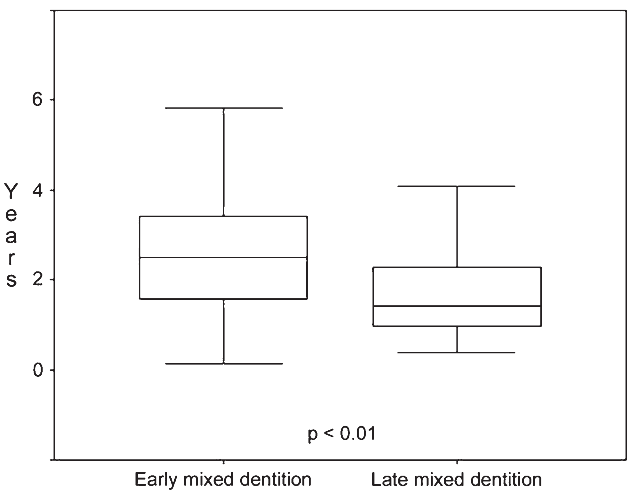

Figure 4 Influence of dental maturity (early mixed dentition, late mixed dentition) during which treatment was started on treatment length (years) in 222 Class II division 1 patients.

of untreated Class II occlusion subjects, depending on the quality of the interdigitation of the teeth. When an activator is worn, the occluding teeth are separated and the acrylic is trimmed to allow the molars to freely move mesially. Therefore, it was assumed that there would be a greater percentage of cases with molar drift than would spontaneously occur.

Such a spontaneous mesial drift of the molars (Bishara *et al.* 1988) could result in an improvement of the occlusal relationship even without any orthodontic intervention. Therefore, the severity of the malocclusion had to be a quarter cusp width more severe if the lower primary molar was still in place before treatment. Besides this molar drift, no spontaneous improvement in the Class II relationship, sagittal jaw base relationship, and overjet can be expected with age (Bishara, 1998). Therefore, even without an untreated control group, the present results should be transferrable to Class II division 1 patients in general.

The reason for considering a certain amount of sagittal molar relationship improvement as success criteria instead of, for example, the achievement of a Class I occlusion, was the independence of this method from the pre-treatment severity of the Class II occlusion.

The success rate of activator treatment was on average 65 per cent in the present study. A comparison with investigations is difficult as activator treatment success has not analysed in depth and the treatment objectives and analysing methods have differed. Ahlgren (1972) and Ahlgren and Laurin (1976) reported a success rate of 71 per cent in a sample of 37 patients treated with Andresen activators. However, their criteria for success were limited to an improvement of overjet and overbite. In a study by Weiland *et al.* (1997), 43 per cent of the Class II division 1 patients treated with Herren activators or with activator–headgear combinations attained a Class I occlusion. However, they only investigated the initial effects within the first 8 months and did not report on the pre-treatment malocclusion severity.

From the present total patient material, 27 per cent attained an ideal occlusion. This is similar to the results of Bondevik (1991) who reported that 18 per cent of his patients treated simultaneously with an Andresen activator and a headgear achieved satisfactory results (neutral occlusion ±1 mm, overjet and overbite less than 4 mm, no observable rotation of upper incisors, occlusal contacts on all teeth, crowding less than or equal to 1 mm). However, except for the inclusion criteria of a Class II division 1 malocclusion and the age of the patients, he did not report any details on pre-treatment malocclusion severity or the amount of treatment change, thus limiting comparability with the present results.

Most interestingly, the success and failure rates were nearly identical at both university centres. It must be noted that all treatments were planned and performed by independent teams of clinicians (postgraduate students, senior residents, and department heads at both locations). This strengthens the results, showing that success rates achieved are obviously realistic figures of what can be expected.

The only factor that significantly influenced treatment success in the present study was the level of co-operation; while in the success group 75 per cent were classified as co-operating well, this was the case in only 29 per cent in the failure group. This is in agreement with several other studies (Ahlgren, 1972; Ahlgren and Laurin, 1976, Bondevik, 1991; Cureton *et al.*, 1993; von Bremen and Pancherz, 2002; Wheeler *et al.*, 2002; Ruf *et al.*, 2007). But it remains open why, despite good co-operation, as judged from the patient's records, some individuals did not respond well and *vice versa*. The importance of a certain level of co-operation during orthodontic treatment is unquestionable. However, the degree of co-operation required and its relationship to the amount of treatment response is unknown. It might be argued that it would have been better to use more objective measures of co-operation such as timing devices or logs of hours of appliance wear. However, even in prospectively designed randomized clinical trials (Tulloch *et al.*, 1997), these measures of co-operation failed and the investigator had to rely on indirect measurements of co-operation such as those used in the present study.

It should be pointed out that there could be additional decisive factors for the outcome of activator treatment, such as a favourable dental reaction and/or growth pattern (Skieller *et al.*, 1984; Tulloch *et al.*, 1997; Bendeus *et al.*, 2002; Patel *et al.*, 2002; Ruf *et al.*, 2007). However, the pre-treatment sagittal and vertical skeletal morphology (lateral head film analysis), which should be indicative of the growth pattern, did not influence treatment success in the present study. It would, no doubt, have been desirable also to analyse post-treatment lateral head films of the subjects. These were, however, not consistently available.

The successful group was treated on average 0.6 years longer than the failure group. There are two possible explanations for this difference. The first is that in the failure group, treatment was stopped or altered earlier due to lack of co-operation or treatment reaction. The second possibility is a longer retention period in the successful group. The latter seems likely as in case of no further need for orthodontic treatment, the retention period was prolonged until the second molar had erupted. However, if further fixed appliance treatment was necessary, it was started as soon as premolar and canine eruption had finished.

Although dental maturity and treatment length had no influences on treatment success, there was a significant association between dental maturity and active treatment duration; with progressing dental development, the active treatment time decreased. A similar tendency has been described by others (Gianelly, 1995; Tulloch *et al.*, 1997, 1998, Firestone *et al.*, 1999; O'Brien *et al.*, 2003; Tulloch *et al.*, 2004). The relatively longer treatment time, when starting early, can be explained by the fact that activator treatment is generally continued until all permanent teeth (except for third molars) have erupted into occlusion.

In the present study, treatment of patients from Berne was on average 0.5 years shorter compared with Giessen. An explanation for this is that 80 per cent of the patients in Berne were more dentally advanced (late mixed dentition) at the start of activator treatment, whereas the distribution in Giessen was approximately even (48 per cent late mixed dentition, 52 per cent early mixed dentition). This explanation is also conclusive with the younger age (mean 1.2 years) of the patients in Giessen. The earlier treatment start in Germany compared with Switzerland might be attributed to the difference in health care systems. The majority of orthodontic treatments in Switzerland are private, while in Germany they are covered by the public health care system. Insurance coverage has been shown to lead to larger and earlier demand for medical care (Meer and Rosen, 2004), and thus possibly also for dental care.

The larger percentage of patients treated with transverse maxillary expansion prior to activator treatment in Giessen (71 per cent) compared with Berne (31 per cent) may be due to the fact that in Berne the Herren activator was the most frequently used appliance. A transverse expansion screw is generally incorporated into the Herren activator, thus permitting simultaneous transverse expansion and antero–posterior correction.

Based on these data, it can be assumed that activator treatment is more efficient when started in the late mixed dentition (compared with early mixed dentition cases). This is in agreement with Tulloch *et al.* (1997, 1998, 2004), von Bremen and Pancherz (2002), and O'Brien *et al.* (2003). It must, however, be considered that for individual cases with large psychosocial distress or high trauma potential, an early treatment start can be beneficial.

After activator treatment, fixed appliances were required in many of the cases (60 per cent success group, 70 per cent failure group) in order to improve tooth alignment and/or to continue with Class II correction. This leads to an important question: does activator therapy as a first phase of treatment result in a shorter and thus more efficient second phase of treatment? It can be supposed that the fixed appliance treatment time may only be reduced for the patients in the successful group. However, Tulloch *et al.* (1997, 1998, 2004) reported that two-phase Class II division 1 treatment started in the early mixed dentition might not be more effective than one-phase treatment started in the late mixed dentition. Those authors found no reduction in the average duration of fixed appliance treatment during the second stage of treatment and no decrease in the frequency of complex treatments involving extractions or orthognathic surgery. Only 2.4 per cent of their patients were judged not to require comprehensive orthodontic treatment after the first phase with either bionators or headgears. It remains debatable, why the success rate in the study of Tulloch *et al.* (2004) was so low compared with the 27 per cent of the total present patient material that did not require any fixed appliance treatment after activator therapy. Of course it might be argued that due to the retrospective design of the present study, some bias cannot be ruled out. However, patient selection in the present study was based on clearly defined inclusion and exclusion criteria as well as the availability of records. It seems unlikely that the availability of records should have been better for successful than for unsuccessful patients.

Conclusion

Activator treatment was effective in improving the sagittal molar relationship in about 65 per cent of the Class II division 1 patients. Therapy lead to an ideal occlusion in 27 per cent of the subjects. The level of co-operation was the only variable that could be significantly linked to a successful result. Activator treatment was more efficient when started in the late mixed dentition.

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