

# Factors affecting the duration of orthodontic treatment: a systematic review

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**SUMMARY** The aim of this study was to systematically investigate the literature for articles referring exclusively to the duration of orthodontic therapy and to explore the various factors that could affect this. A Medline search from 1990 to the first week of March 2005 was conducted, the Cochrane Database for Systematic Reviews was utilized, five orthodontic journals were hand searched, the abstracts of related articles were reviewed to search for any relevant studies that might have been missed, and the reference lists of the retrieved articles were hand assessed. Eligibility was determined by reading the reports identified by the search. The end result of this search provided 41 articles.

Although there is a need for more conclusive research, the present review revealed several conclusions concerning the duration of orthodontic treatment: (1) there are indications that extraction treatment lasts longer than the non-extraction therapy; (2) age does not seem to play a role provided the patients are in the permanent dentition; (3) when Class II division 1 malocclusions are considered, there is evidence that the earlier the orthodontic treatment begins the longer its duration; (4) there is conflicting information regarding treatment duration within public health systems; (5) combined orthodontic–surgical treatment duration is variable and appears to be operator sensitive; (6) various factors, such as the technique employed, the skill and number of operators involved, the compliance of the patients, and the severity of the initial malocclusion, all seem to play a role; and (7) impacted maxillary canines appear to prolong treatment.

## Introduction

When conducting an initial consultation, every clinician is called upon to answer questions regarding the duration of the treatment proposed. The answer to this question usually depends, among other factors, on the clinician's experience and this, in turn, might depend on his educational background, technical skills, and practice management methods. Success in orthodontic practice is influenced by an accurate prediction of treatment duration (Shia, 1986). In a 2003 orthodontic practice survey, finishing a case in the predicted time was considered an important practice building method (Keim *et al.*, 2004). Patients who are given accurate information also appear to be better consumers of dental services, with more reasonable expectations of treatment outcomes (Klein, 1988), and more greatly satisfied with their overall treatment (Cunningham *et al.*, 1996). The British Orthodontic Society recommends that patients should receive sufficient information about the proposed treatment, including a realistic estimate of the timescale involved and the retention phase of treatment (Warren, 1999).

Cost efficiency is an important concept in modern health care and prolonged treatment time may be detrimental to the 'profitability' of a practice or a national health care system (Turbill *et al.*, 2001). Shorter treatments are also desirable in view of the briefer exposure to possible

harmful side-effects (Graber *et al.*, 2004; Segal *et al.*, 2004; Fox, 2005).

Therefore, it is to the benefit of both the patient and the profession to present reliable information regarding the duration of treatment. The purpose of this study was to investigate the literature for articles referring exclusively to the duration of orthodontic therapy and to explore the various factors that may have an effect.

## Materials and methods

In order to consider studies for inclusion in the review, the duration of orthodontic treatment, or the factors affecting it, had to be a major component of the study and not a secondary outcome measure. Articles referring to craniofacial anomalies (e.g. clefts, syndromes, etc.) were excluded.

In order to find the relevant articles, a Medline search from 1990 to the first week of March 2005 was conducted by both authors; 1990 was chosen in order to acquire data from treatment techniques which are currently used since it is accepted that changes have occurred in the field of orthodontic materials and methods in the last 15 years. Papers published after the first week of March 2005 were not considered (Skidmore *et al.*, 2006). The Medline search was based upon the following key words: orthodontics,

treatment duration, treatment effectiveness, and treatment timing. The Cochrane Database for Systematic Reviews was also searched. Furthermore, five orthodontic journals (*The American Journal of Orthodontics and Dentofacial Orthopedics*, *European Journal of Orthodontics*, *Seminars in Orthodontics*, *Journal of Orthodontics*, and *Journal of Clinical Orthodontics*) were hand searched for the same time period. The abstracts of related articles were also studied to search for any relevant studies which may have been missed, and the reference lists of the retrieved articles were hand searched. Eligibility was determined by reading the reports identified by this search.

## Results

These search strategies produced a total of 128 papers, and after reading these papers thoroughly and following the hand searching of journals and abstracts, the final result of this search was 41 articles (Table 1, available online to subscribers).

### *Effect of extractions on the duration of orthodontic treatment*

Vig *et al.* (1990) reported a retrospective, cross-sectional, case-control study based on the records from five practices (438 patients) located in a specific US state. Selection criteria, other than those patients on the higher and lower percentiles on an extraction/non-extraction scale, were not mentioned in the paper. The mechanics were not described and all types of malocclusion were combined for analysis. The investigators used a stepwise regression analysis to investigate the association between duration of treatment and nine variables. The final equation, which included five explanatory variables, predicted only 33 per cent of the variability in duration of treatment. In a critical review of their results, the authors stated that 'the sampling method used to identify practices with high and low extraction rates and the pooling of data from all five practices tended to obscure differences in duration between extraction and non-extraction treatments by virtue of other important confounding variables that are not accounted for when patients are compared merely on the singular criterion of extraction'. The average duration time for the extraction group was estimated to be 31.3 months and for the non-extraction group 31.2 months, although within an individual practice, the mean difference between groups could be almost 7 months. The authors concluded that (1) differences in duration of treatment were apparent when extraction and non-extraction patients within each individual practice were compared and treatment with extractions was likely to take longer; (2) the duration of treatment may be affected not only by the extraction decision but also by variables such as whether one or both arches were treated and by the number of phases of treatment; and (3) considerable differences

exist in treatment practices with low extraction rates and those with high extraction rates.

Fink and Smith (1992) performed a retrospective comparative study on patient records from six private offices. Caucasian patients who had undergone a single course of fixed appliances treatment and who had complete records were included. All types of malocclusions and treatment approaches were included. The Salzmann index, ANB angle, mandibular plane angle, upper/lower face height ratio, and 15 additional variables concerning treatment and patient and clinician characteristics were also recorded. With regard to the malocclusion index, it should be noted that this lacks validity and also has poor reliability (Albino *et al.*, 1978). The number of subjects ( $n=118$ ) recruited in that project appears inadequate taking into account the number of statistical analyses undertaken. The average treatment duration was  $23.12 \pm 6.67$  months; however, there were great variations between offices. The mean duration of treatment within an office varied from a high of  $27.85 \pm 4.53$  months to a low of  $19.45 \pm 3.52$  months. Approximately 25 per cent of the variation in treatment duration was explained by a five-step regression equation. The authors stated that the explained variation was 50 per cent; however, the regression coefficient ( $R$ ) was only 0.499 so  $R$  increased to the second power ( $R^2$ ) equals only 0.249 or 24.9 per cent. One noticeable finding in that study was the longer treatment time that the extraction cases required and this was proportional to the number of teeth extracted. Non-extraction cases took, on average, 21.95 months, two premolar extraction cases 25 months, and four premolar extraction cases 26.18 months.

Vig *et al.* (1998) collected data from 567 Class II and 399 Class I patients treated at a university graduate clinic. The duration of treatment was  $24.6 \pm 11.6$  months for Class I and  $29.0 \pm 11.2$  months for Class II subjects. The Peer Assessment Rating (PAR) score before intervention was statistically different between the two groups, with the Class II cases presenting more severe malocclusions. However, the final results were similar in both groups, supporting the opinion that practitioners seek uniform treatment goals regardless of malocclusion type. When the two groups were combined and then re-divided on the basis of extraction ( $n=411$ ) and non-extraction ( $n=583$ ), the treatment duration was  $24.0 \pm 11.2$  and  $29.4 \pm 11.3$  months, respectively. This difference was significant ( $P < 0.05$ ).

### *Removable appliances and treatment duration*

Tang and Wei (1990) compared the effectiveness of removable and fixed orthodontic appliances by means of the occlusal index (Summers, 1971) by measuring the duration of treatment. This was a retrospective study based solely on study models from 147 patients who had completed orthodontic treatment in a dental hospital. Undergraduate students under supervision treated the removable appliance

cases ( $n=80$ ), and only those that were considered 'good teaching cases' were selected. Two postgraduate students under supervision had treated the fixed appliance cases ( $n=67$ ) by means of edgewise or Begg appliances, and only those with complete records were included in the study. Although statistical tests were mentioned as having been performed, they were not shown in the article. The average duration of treatment in the removable appliance group was  $13.4 \pm 10.3$  months and for the fixed appliances  $20.2 \pm 4.5$  months. According to the authors, this difference was statistically significant. The average duration of treatment with the Begg technique was  $21.5 \pm 2.9$  months and with the edgewise technique  $19.5 \pm 5.0$  months. The mean occlusal improvement, using the occlusal index, with the removable appliances was only 53 per cent of that produced with the fixed appliances.

A later study (Kerr *et al.*, 1994) examined the study casts of 150 consecutive patients who completed treatment by means of removable and/or fixed appliances at a dental hospital. Cases treated with upper removable and/or fixed appliances ( $n=103$ ) were pooled, as well as those treated with an activator-type appliance and/or headgear ( $n=43$ ), and two groups were formed. It was claimed that the rationale for this grouping was the different co-operation required by the second group. The mean treatment duration with one removable appliance was  $6.4 \pm 3.9$  months, with two appliances  $13.5 \pm 4.4$  months, and with three appliances  $19.8 \pm 6.7$  months. There were no data regarding the duration of treatment for the activator-type group. According to the authors, the regression equations derived from the statistical analysis of the data explained approximately 60 per cent of the variability in duration of treatment.

Taylor *et al.* (1996) evaluated the records of patients treated at a dental hospital by means of two-arch fixed appliances and by a combination of removable and 'mini-fixed' appliances. The PAR score and percentage reduction were also measured but not presented. A regression equation for two-arch fixed appliance treatment included the number of appointments, the pre-treatment PAR score, and the presence of an anterior crossbite. The authors presented an  $R^2$  value of 0.77 for this model. A similar model for the removable/mini-fixed appliances had an  $R^2$  value of 0.80. However, it must be noted that the sample exhibited bias and the statistical conclusions are also weak due to the small sample size ( $n=156$ ). The presence of an anterior crossbite had a negative correlation; this is almost certainly a reflection of the fact that an anterior crossbite is often related to malocclusions with skeletal discrepancies which are difficult to treat.

#### *Age effect on treatment duration*

Dyer *et al.* (1991) undertook a retrospective study based on the cephalometric records selected from a single private practice to investigate the differences between adolescents

and adult patients. Five selection criteria were used: (1) Class II sagittal molar relationship, (2) Class II division 1 incisors, (3) female patients, (4) availability of pre- and post-treatment records, and (5) full permanent dentition. The cases were selected regardless of treatment outcome. The mean age at the beginning of treatment was  $12.5 \pm 0.67$  years in the adolescent group and  $27.57 \pm 5.38$  years in the adult group, and mean treatment duration was  $2.46 \pm 0.36$  and  $2.56 \pm 0.35$  years, respectively, with no statistically significant difference between the two groups. There were, however, baseline differences between the two groups with respect to various cephalometric parameters.

Vayda *et al.* (1995) presented the results of a retrospective cross-sectional study based on the records of 995 patients with all types of malocclusions treated at a university clinic during the period 1977–1991. The patients were divided into a younger (age less than 15 years) and an older (age greater than or equal to 15 years) group. The duration of treatment was shorter for the older ( $24.2 \pm 9.1$  months) compared with the younger ( $27.1 \pm 12.1$  months) group. However, the occlusal results, as measured by the PAR index, were inferior for the older group and this was significant ( $P < 0.001$ ).

Another retrospective comparative study (Robb *et al.*, 1998) was based on consecutively completed cases within the previous 5 years from the private practices of three 'experienced practitioners'. The two groups consisted of 32 adults (mean age:  $31.3 \pm 7.7$  years) and 40 adolescents (mean age:  $12.9 \pm 1.3$  years), with the majority presenting with a Class I malocclusion treated by means of four premolar extractions. The mean duration of treatment was  $30.6 \pm 8.0$  months for the adult group and  $29.4 \pm 8.8$  months for the adolescent group. There was no significant difference ( $P > 0.05$ ) between the two groups and the percentage PAR reduction was similar. Multiple regression analysis revealed that the number of failed/cancelled appointments and appliance repairs explained 46 per cent of the variation in treatment duration. A different analysis showed that 'the orthodontic treatment of the buccal occlusion and overjet' explained 46 per cent of the variability in treatment duration. Of interest is that the authors had determined the sample size necessary to achieve a power of 0.80 at an  $\alpha$  level of 0.05 *a priori* and the required sample size was 21 patients in each group. Their final Class I sample was much larger than this, yet they still biased these groups by adding two Class II cases to each group.

Von Bremen and Panherz (2002) published a retrospective study based on the records of 204 patients with Class II division 1 malocclusions treated between 1990 and 1997 at a university orthodontic clinic. Fifty-four patients were treated in the early mixed dentition, 104 in the late mixed, and 46 in the permanent dentition. The appliances used during treatment were functional, functional/fixed combination, Herbst/fixed appliance combination, and fixed appliances alone. The mean treatment duration was 37

months and the duration decreased with dental development: patients in the early mixed dentition were treated for an average of 57 months, those in the late mixed dentition for 33 months, and in the permanent dentition for 21 months. Patients treated with Herbst/fixed appliances or fixed appliances alone had a shorter treatment period (19 and 24 months, respectively) than those treated with functionals or a combination of functional/fixed appliances (38 and 48 months, respectively).

#### *Duration of treatment in public health care environment*

Richmond and Andrews (1993) assessed orthodontic treatment standards in Norway. One hundred and twenty cases from six specialists' offices (20 consecutive cases each) and 100 cases from five practices visited by one of the authors were randomly chosen. The selection process suggests that allocation and selection limitations may have existed. The results indicated that there was a considerable reduction in PAR score (by 78 per cent). Treatment duration was 2.1 years on average (range: 0.2–7 years) and involved an average of 20 visits. No information was presented regarding the malocclusions treated, the appliances used, or the age of the patients included in the study.

In an attempt to assess the provision of orthodontic care in the general dental services, Richmond *et al.* (1993) assessed 1010 cases obtained from the English Dental Practice Board. The cases were said to have been collected systematically although no further description was provided, nor was any information regarding the types of malocclusions. The cases were treated with either fixed or multiple removable (55 per cent of cases) appliances. When the standard of treatment was evaluated by means of the reduction in PAR score, a substantial proportion of patients were 'worse off' after orthodontic treatment. The majority of orthodontic treatment was completed within 2 years and 15 per cent of the cases within 1 year. Only 25 per cent of treatments took longer than 2 years.

In another retrospective study (Turbill *et al.*, 2001), the records of 1527 orthodontic cases were used. These cases represented the English Dental Practice Board's routine systematic sampling of every 50th case submitted over an 8 month period during 1990–1991. Of these, 1506 cases with complete records regarding different characteristics of practitioners, malocclusions, treatment variables, and outcomes were evaluated. Data were submitted to multivariate analysis, with treatment duration as the dependent variable. The factors found to increase duration were the use of fixed appliances, multiple stages in treatments, premolar extractions, and correction of the buccal segment relationship. Age, buccal segment relationship, grade 5 IOTN DHC (dental health component of the index of orthodontic treatment need), and the orthodontic qualifications of practitioners were associated with slightly longer treatments. However, the regression

model explained only 41 per cent of the variance. The mean treatment time was  $13.05 \pm 1.92$  (range: 3–39) months. Mean treatment time for removable appliances was 10 months, and treatments including the use of dual arch fixed appliances had the longest mean duration at 19 months. One-stage treatments averaged 11 months and two-stage treatments 17 months. If the treatment plan included correction of the buccal segment relationship, duration was on average 6 months longer. Treatments without extraction of permanent teeth were shorter, averaging 9.5 months, and those involving four premolar extractions tended to be the longest at 18.6 months. Treatments started for patients younger than 11 years lasted on average 8 months, which was statistically different to the 11- to 16-year-old group at 14.7 months. Cases treated by orthodontically qualified practitioners averaged nearly 2 months longer than those of other practitioners. This research produced some findings regarding treatment duration which conflicted with other studies (Vig *et al.*, 1994; Robb *et al.*, 1998; Teh *et al.*, 2000; von Bremen and Pancherz, 2002; Tulloch *et al.*, 2004). When Teh *et al.* (2000) examined records from 128 patients with all types of malocclusions treated by specialists working in the Scottish dental service, their results indicated that the median duration was 15 (range: 2–41) months. Treatment duration had a positive correlation with the pre-treatment PAR score, extractions, mixed dentition stage, and appliance damage. However, the  $R^2$  value of this regression model was only 29.2.

#### *Duration of treatment for Classes I, II, and III malocclusion cases*

Colela *et al.* (1994) performed a retrospective study based on the records from the University of Pittsburgh. The sample comprised 311 Class II and 176 Class I patients who were between 11 and 14 years old at the start of treatment. The mean duration of treatment was  $28.7 \pm 0.62$  months for Class II and  $24.66 \pm 0.83$  months for Class I cases.

Another retrospective study based on the records from the Universities of Pittsburgh and Ohio State found that the duration of treatment for Class I cases was  $26 \pm 13.4$  months, for Class II  $29.9 \pm 12.2$  months, and for Class III  $28 \pm 17.0$  months (Wenger *et al.*, 1996).

Vig *et al.* (1994) studied variables that contributed to the duration of Class I and Class II treatments in a group of 311 Class II and 176 Class I patients aged 11–14 years, treated at the University of Pittsburgh. The results showed that the effect of broken appointments was twice as great as in the Class II group, the percentage improvement in PAR score increased Class I, but not Class II, treatment duration, and headgear use increased Class I, but not Class II, treatment duration.

These three studies were all presented as congress abstracts and no further details were available.

The effectiveness of Class II division 1 malocclusion treatment was evaluated in a retrospective study based on the records of 250 adolescent patients aged 11–14 years, treated at the University of Pittsburgh (O'Brien *et al.*, 1995). The sample was subdivided into extraction and non-extraction groups and then into one- and two-stage treatments. A baseline comparison revealed that there were significant differences in PAR scores between the extraction and non-extraction patients. The mean treatment duration for the extraction cases was  $30.6 \pm 10.4$  months and for the non-extraction cases  $24.8 \pm 9.2$  months; for one stage, treatment duration was  $27.1 \pm 9.8$  months and for two stages  $33.7 \pm 10.4$  months. A multiple regression analysis was used to define parameters affecting treatment duration and 49 per cent of the variation was explained by the pre-treatment PAR score, the number of treatment stages, the percentage of appointments attended, the number of appliance repairs, and whether or not the treatment involved extractions.

O'Brien *et al.* (2003) also conducted a multi-centre, randomized controlled trial in orthodontic departments in the United Kingdom and examined 215 patients who were randomized to receive treatment with either a Herbst ( $n=105$ ; age: 12.41 years) or a twin-block ( $n=110$ ; age: 12.74 years) appliance. Treatment with fixed appliances following the initial phase was mandatory for the Herbst group but optional for the twin-block group. There was an average decrease in PAR score of  $40 \pm 29.3$  per cent for the twin-block group and  $39 \pm 21.1$  per cent for the Herbst group. The time in treatment for the Herbst group was 20.84 months and for the twin-block group 21.99 months. There were no differences in treatment time between the appliances, although phase I treatment was more rapid with the Herbst appliance. Table 1 (available online to subscribers) indicates that the numbers of the individuals participating in the study were 56 in the twin-block and 70 in the Herbst appliance groups (available online to subscribers). However, the study was based on the premise that to achieve an 80 per cent power with an  $\alpha$  level of 0.5, and in order to detect a clinically meaningful difference in PAR score of 15 per cent, the number of patients in each group should be 80. This may have influenced the findings of the study.

A clinical trial published by Tulloch *et al.* (2004) monitored randomized Class II children to three groups: (1) observation only, (2) headgear, or (3) functional appliance (modified bionator). Of the 166 patients who completed this first phase of the trial, 147 continued to a second phase of treatment. The children were then randomized within their phase 1 treatment group to one of four orthodontists for comprehensive orthodontic treatment by means of edgewise appliances. Due to various reasons, only 137 of the children who entered phase 2 completed treatment and entered the final analysis. Treatment outcomes of the study were addressed by means of 11 cephalometric measurements describing skeletal jaw and dentoalveolar relationships.

Additional outcomes addressed alignment and occlusion (assessed by the PAR index), duration, and complexity of treatment. The median treatment time for phase 2 (including interim treatment time) of the control group was 34.5 months, for the functional appliance group 25.5 months, and for the headgear group 30.1 months. When interim treatment time was excluded, the respective times were 26.7, 23.5, and 28.5 months. The difference in treatment time, including interim appliances, between the groups approached significance at  $P=0.03$ . When the time in fixed appliances, excluding interim treatment, was compared, the mean treatment duration was almost identical for the three groups. It appeared that there were significant differences between the four orthodontists with respect to duration of treatment (median duration ranged from 37 to 52 months). The authors of this investigation recognized the limitations of their sample since it did not include all types of Class II malocclusions; therefore, their conclusions are valid for Class II malocclusions with normal face height, but not for those with combined anteroposterior and vertical problems or those with skeletal asymmetries.

A recent retrospective study utilized records of 237 active retention patients divided into Class I non-extraction and Class II division 1 extraction and non-extraction cases (Popowich *et al.*, 2005). Treatment duration was  $20.25 \pm 5.96$  months for Class I,  $25.7 \pm 6.78$  months for Class II non-extraction, and  $24.97 \pm 5.48$  months for Class II extraction cases. A regression analysis identified the following factors as being significantly associated with treatment duration: (1) type of Class II correction appliance (Herbst appliance required on average 9.09 months longer compared with headgear), (2) duration of wear of the Class II correction appliance, (3) duration of wear of interarch elastics, (4) whether or not maxillary expansion was undertaken (2.64 months longer treatment on average), (5) frequency of bond failures, and (6) average time interval between appointments.

#### *Duration of orthodontic–surgical treatment*

A retrospective cross-sectional comparative study, based on the records of 57 patients treated in a university faculty practice, 96 treated in a university graduate clinic, and 193 treated by private practitioners, collected data concerning pre-surgical, post-surgical, and total treatment times (Proffit and Miguel, 1995). The median duration of surgical orthodontics was 28 months in total (range: 4–92 months) for the patients treated outside the university clinic, 24 (range: 10–51) months for those treated by residents, and 18 (range: 7–57) months for those treated by faculty members. The pre-surgical times were 17, 15, and 11 months, respectively. There was a significant difference ( $P < 0.001$ ) for the pre- and post-treatment times between private practice and faculty treatments and also for total treatment time between the three groups ( $P < 0.001$ ).

Dowling *et al.* (1999) performed a similar study in which either orthodontic specialists or postgraduate students had carried out the orthodontic procedures. The median total treatment time for all patients was 21.9 (range: 6.5–96.9) months. The pre-surgical treatment had a median duration of 15.4 (range: 2.6–91.6) months and the post-surgical treatment a median of 5.9 (range: 0.9–32.2) months. There were no statistically significant differences between treatments of Class II and Class III malocclusions. Median values for treatments involving extractions were approximately 5 months longer than non-extraction cases (21.2 compared with 25.6 months total time) and treatment time was reduced by almost 4 months (23.2 compared with 19.4 months) when the orthodontist had treated 10 or more patients during that period. Treatments performed at the university showed small (2 months) but significant differences ( $P < 0.01$ ) in pre-surgical duration compared with those by private practitioners. However, the total treatment time was similar.

Another study, by Luther *et al.* (2003), was based on the records collected from three consultant orthodontists and one senior specialist registrar over a 5 year period. The median duration of pre-surgical treatment was 17 (range: 7–47) months and there were no differences in duration for the different malocclusions or for extraction versus non-extraction cases. Only the treating orthodontist appeared to affect duration.

In a retrospective study, Breuning *et al.* (2005) assessed surgical-orthodontic treatment in Class II malocclusions by analysing three groups. They included 10 subjects (mean age: 10.11 years; range: 9.1–13.9 years at the beginning of treatment) who were treated with a headgear activator, fixed appliances, and intraoral osteodistraction of the mandible; 19 subjects (mean age: 12.3 years; range: 9.6–16.1 years) treated with fixed appliances and intraoral distraction; and 13 subjects (mean age: 27.3 years; range: 12.11–40.7 years) treated with fixed appliances and a bilateral sagittal split osteotomy. All were treated by the same clinician and surgery was carried out by the same surgeon. The mean treatment times were 44.2 (range: 29–63), 28.6 (range: 16–40), and 34.7 (range: 19–55) months for the three groups, respectively. Significant differences ( $P < 0.05$ ) were found between the groups. As the second and third groups were comparable at the beginning of treatment regarding their morphological characteristics, this difference in treatment duration may be attributed to the difference in the surgical technique used.

#### *Various other parameters affecting treatment duration*

A comparative study of Class I malocclusion non-extraction patients was undertaken in order to assess differences between two treatment techniques used by a certified practitioner (Shelton *et al.*, 1994). The two groups were historically different since the first 25 cases completed their treatment using the Tip-Edge appliance (between 1987 and

1991) and were compared with 28 similar cases treated earlier by means of the Begg technique (between 1980 and 1987). The authors compared several characteristics to ensure pre-treatment similarity. The average treatment time was significantly shorter in the Tip-Edge group when compared with the Begg subjects [12.8 (range: 7–25) and 20.9 (range: 8–35) months, respectively].

A cross-sectional comparative study on treatment duration before and after 1984 was based on the records from two US university orthodontic clinics (Rinaldi *et al.*, 1996). In this study, all malocclusions were combined. The results indicated that the duration of treatment during the first decade was significantly ( $P < 0.001$ ) longer than during the second decade in both clinics. However, it was interesting that the PAR reduction did not change. This study was published as a research abstract and thus further details are not available.

The influence of operator changes on treatment time in a teaching environment was approached in a retrospective comparative study (McGuinness and McDonald, 1998). All patients were treated using the same type of edgewise appliance in both arches and two groups of patients were identified: those whose treatment was started and finished by the same operator (group A) and those whose treatment was begun by one operator, but finished by another (group B). The average treatment time for the patients treated by one operator was  $17.67 \pm 4.15$  months, while for those treated by two operators  $26.1 \pm 6.78$  months ( $P < 0.001$ ).

In an attempt to identify and quantify factors that affect duration, Beckwith *et al.* (1999) collected data from 140 consecutively completed patients in five orthodontic offices and found that average treatment time was 28.6 (range: 23.4–33.4) months. Almost half of the variation (46.9 per cent) in treatment duration was explained by a five-step multiple regression analysis where the number of missed appointments, replaced brackets/bands, treatment phases, negative chart entries regarding oral hygiene, and the prescription of headgear during treatment were taken into consideration. The number of missed appointments explained 17.6 per cent of the variation in treatment duration. Each failed appointment was associated with a little over 1 month of additional treatment time. An additional 6.7 per cent of the variance was also explained by variation among the five offices. It should be noted, however, that the regression analysis employed a small number of cases considering the large number of independent variables examined.

The differences between 20 patients treated by serial extractions and 20 treated using premolar extractions were investigated in a retrospective comparison study (Wagner and Berg, 2000). The total treatment time for the first group was, on average, 6 years, while for the second group 3.6 years. However, the time in fixed appliances was only 1.4 years for the first group and 2.3 years for the second ( $P < 0.001$ ). In both groups, the severity of malocclusion was significantly reduced ( $P < 0.05$ ). PAR score did not

appear to be significantly correlated with total treatment time, duration of active treatment, duration of fixed appliance therapy, or the number of appointments.

Amditis and Smith (2000) retrospectively compared 32 patients treated using a 0.018 inch slot and 32 using a 0.022 inch slot; all patients were treated by the same clinician. The mean treatment duration was 20.2 (range: 13–25) months for the 0.018 inch slot group and 21.7 (range: 16–29) months for the 0.022 inch slot group ( $P < 0.05$ ). The cases were separated according to malocclusion type and the data for the subgroups were presented. The mean duration for the extraction cases was significantly different between the 0.018 and 0.022 inch slot groups ( $20.5 \pm 2.2$  and  $22.6 \pm 4.5$  months, respectively;  $P < 0.05$ ).

In an attempt to explore the factors affecting two-arch fixed appliance treatments, Chew and Sandham (2000) retrospectively studied a group of 177 patients divided according to age, gender, extractions, and headgear use. The mean treatment duration was  $24.9 \pm 9.3$  months. The use of headgear significantly increased the treatment time from 24.2 to 32.2 months ( $P < 0.05$ ). Also with extractions, the treatment duration was increased significantly from 20.0 to 25.8 months ( $P < 0.05$ ). The frequency of office visits explained 40 per cent of the variation in treatment duration, while the pre-treatment PAR score, extractions, and the use of headgear added only another 9 per cent to the variability. One explanation could be that the stratification of the group produced subgroups with inadequate numbers of individuals for the types and numbers of statistical calculations executed. Interestingly, the authors quote different values in the text to those presented in the tables.

Another study compared differences in treatment provided by orthodontists in private practice with that of graduate orthodontic residents (Mascarenhas and Vig, 2002). Cohorts of patients under 25 years of age receiving treatment from five private orthodontic offices (143 cases) and in a graduate orthodontic programme (165 cases) in the United States of America since 1997 were followed. The duration of treatment was  $27.5 \pm 11.8$  months for the students and  $33 \pm 18.5$  months for the private practitioners; this difference was statistically significant, even after controlling for confounding factors such as age, gender, race, starting malocclusion, and number of treatment stages.

Andria *et al.* (2004) published a retrospective study which examined the correlation between the cranial base angle and its components and treatment time in 99 Class II and Class I patients. It was concluded that the linear and proportional lengths of the cranial base had a small significant negative correlation with treatment time.

Factors affecting treatment duration were also examined in a retrospective study based on the records of 93 Class I and Class II division 1 patients treated during the period 1983–1994 by five orthodontists in a health centre (Järvinen *et al.*, 2004). The children were divided into three age

groups (7–9, 10–11, and 12–13 years) and the mean treatment times were  $3.6 \pm 0.9$ ,  $3.1 \pm 1.4$ , and  $1.9 \pm 0.8$  years, respectively. For non-extraction cases, the mean treatment time was  $2.9 \pm 1.3$  years and for extraction cases  $3 \pm 1.4$  years. Class II division 1 cases required longer treatment ( $3.4 \pm 1.3$  years) than Class I cases ( $2.5 \pm 1.2$  years). According to the authors, a regression analysis indicated that 42.8 per cent of variation in treatment time could be explained by malocclusion type, patient's age at the start of treatment, type of appliances used, number of appliances used, number of missed appointments, and main additional diagnosis at the start of treatment (namely, anterior crossbite). However, the results of this equation were not presented in the paper.

Haralabakis and Tsiliagkou (2004) published a retrospective study to identify the main factors affecting the duration of fixed appliance and single-phase treatment. They utilized the records of 360 patients from the first author's office and additional selection criteria included treatment in the permanent dentition (age: greater than 11 years) with the presence of second molars, patients with no more than two missed or cancelled appointments, no changes in the treatment plan, and no more than five broken, loose, or lost appliances. The mean treatment time was  $19.92 \pm 6.2$  (range: 9–41) months. A regression model with age, molar relationship, number of extracted teeth, and pre-treatment PAR score as the explanatory variables explained 46.33 per cent of the variation in treatment duration. However, scrutiny of the tables referring to this analysis showed that four of the seven parameters had a value that was not significant ( $P > 0.05$ ).

Marketing and commercial promotion of self-ligating brackets have claimed a significant reduction in treatment time with this type of appliance. Two reports regarding the efficiency of brackets were those found in the search.

In the first retrospective study, 30 consecutively finished cases treated using Damon self-ligating brackets were compared with 30 cases treated with conventional pre-adjusted brackets (Harradine, 2001). There was an attempt to match cases according to incisor relationship, age, initial PAR score, extraction patterns (12 extraction cases), and surgical involvement. Treatment times were  $19.4 \pm 3.2$  months for the Damon group and  $23.5 \pm 5.16$  months for the conventional group, this difference was significant ( $P = 0.007$ ). Patients in the Damon group required an average of four visits less with complete active treatment in comparison with the conventional appliances group (12.7 versus 16.5 visits, respectively).

The second retrospective study, in this category, utilized records collected from two private practices and the archives of a dental school (Eberting *et al.*, 2001). All patients were treated by means of Damon self-ligating brackets (108 patients) or conventionally ligated brackets (107 patients). An even distribution of extraction and non-extraction cases was maintained between the two groups. The mean treatment

time in the Damon group was  $24.54 \pm 6.45$  months and in the conventional brackets group  $30.87 \pm 7.85$  months ( $P < 0.001$ ). The cases treated with the Damon brackets required on average seven appointments less than the conventionally ligated cases.

#### *Impacted canines and treatment duration*

Iramaneerat *et al.* (1998) performed a retrospective cephalometric study based on the records of 11- to 16-year-old patients who received orthodontic treatment for palatally impacted permanent canines in a dental hospital. The canine position was defined using a customized analysis and only those that were evaluated as positioned with the crown tip between 0 and 10 mm from the A-perpendicular plane and between 5 and 10 mm above the occlusal plane were included. Twenty-five canines were subjected to simple exposure and packing of the area prior to placing an attachment at a later visit. Another 25 had attachments with gold chains bonded at the time of surgery, followed by replacement of the flap. The mean treatment duration, from exposure to debonding, was 28.8 months for both groups. The treatment duration until the canine was in the line of the arch was 17.7 months in the simple exposure group and 19.3 months in the bonded chain group. An attempt to correlate treatment duration with canine position was not successful.

Another retrospective study utilized the complete records of 47 patients from three private practices in order to explore factors that related to treatment duration for palatally impacted canines (Stewart *et al.*, 2001). A matching control group without impactions was used for comparison. Treatment duration was selected as the dependent variable against which many independent variables were regressed. The average treatment duration for the impacted canine group was 28.3 (range: 13–50) months. The group with unilateral impactions required, on average, 25.8 (range: 13–40) months of treatment and those with bilateral impactions, 32.3 (range: 23–50) months. The control group showed an average treatment time of 22.4 (range: 10–41) months. This difference was significant at  $P < 0.001$ . Age and the amount of mandibular crowding contributed to an  $R^2$  value capable of explaining 30 per cent of the variability in treatment duration. The younger the patient and the greater the crowding, the longer the treatment duration. If the canine was impacted less than 14 mm away from the occlusal plane, treatment duration averaged 23.9 months. If the canine was impacted more than 14 mm away from the occlusal plane, treatment averaged 31.1 months.

Becker and Chaushu (2003) utilized the records of 19 adult patients (mean age:  $28.8 \pm 8.6$  years) and 19 younger patients (mean age:  $13.7 \pm 1.3$  years) who were matched according to the position of the impacted tooth. In that study, the duration of treatment and success of outcome were assessed. Treatment was defined as successful if it was completed to full alignment

of the canine in the arch, partially successful if the canine could not be fully aligned, and failed if the canine could not be moved (ankylosis). The treatment duration was  $23.3 \pm 12.5$  months for the adult group and  $19.7 \pm 7.6$  months for the younger group. The groups were probably too small to detect any statistical differences; however, one interesting finding of the study was that the success rate in the adult group was only 69.5 per cent compared with 100 per cent in the adolescent group. It also took only 6.9 appointments on average to align the canine in the adolescent cases compared with 15.3 appointments in the adult group.

#### **Discussion**

The literature for articles referring exclusively to the duration of orthodontic therapy was the aim in this study and the various factors that could affect it were explored. These factors included the age of the patients; the types of malocclusion; presence/absence of extractions; use of removable or fixed appliances; techniques applied by means of fixed appliances; the method of ligation; one- or two-phase treatment; provision of orthodontic services in a private office, public clinics, or university faculty, postgraduate and undergraduate health care environments; the involvement of surgery for the management of dentofacial deformities; criteria for assessing post-treatment results; and presence or absence of impacted teeth. Obviously, this type of study cannot be all-inclusive.

No evidenced-based information concerning treatment duration is currently available for some of the relatively new orthodontic modalities (such as the Invisalign technique and orthodontic mini-implants; Djeu *et al.*, 2005). In addition, there is insufficient scientific evidence to assess treatment time in cases in which non-conventional adjunctive methods are implemented (Iseri *et al.*, 2005).

Forty-one articles were found to comply with the search criteria; therefore, more conclusive research is needed to evaluate the duration of various types of orthodontic treatment. As described, several of the reports also present methodological deficiencies, biased conclusions, and inconclusive outcomes. Prospective investigations are in a minority and are clearly more difficult to undertake but may prevent some of these problems in future research.

Nevertheless, this systematic review revealed the following conclusions:

1. It seems that extraction treatments take longer than the non-extraction cases. The duration of the treatment also appears to be associated with the number of extracted teeth.
2. Valid conclusions regarding the duration of treatment with removable appliances cannot be drawn.
3. Age differences do not seem to play a role in the duration of the treatment, provided that patients are in the permanent dentition.



4. When Class II division 1 malocclusions are considered, there is strong evidence that the earlier the orthodontic treatment begins the longer it lasts.
5. There is little evidence regarding the differences in treatment duration between malocclusions.
6. The literature contains contradictory information regarding the treatment duration within public health systems.
7. The duration of combined orthodontic–surgical treatment is variable and seems to be operator sensitive. Operators undertaking a large number of surgical cases seem to complete them in shorter time.
8. Various factors such as the technique employed, the skill and number of operators involved, the compliance of the patients, and the severity of the initial malocclusion all seem to play a role in the duration of treatment. However, the contribution of each factor remains unknown and is an area which needs to be explored.
9. There is limited evidence that self-ligation might lead to shorter treatment times.
10. Impacted maxillary canines prolong treatment. The severity of impaction, as well as the age of the patient, may be correlated with treatment duration.
11. New studies with robust research techniques are required before precise answers can be given.

### Supplementary data

Supplementary material mentioned in the text is available on *European Journal of Orthodontics* online.

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