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Factors Influencing Duration of Orthodontic Treatment: A 12-Year Retrospective Study

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ABSTRACT

Introduction. This is a cross-sectional, 12-year study in an orthodontic clinic to identify factors that influence orthodontic treatment time. *Methods*. The sample consisted of all patients from 1999 to 2010 treated with fixed appliances and who were debonded in the clinic, excluding cleft and craniofacial syndrome patients and those solely treated with removable and functional appliances. Four categories of data (demographic characteristics, malocclusion type, treatment methods and patient cooperation) were collected from patient records. Treatment time was defined as 'the time when the first orthodontic appliance or component was fitted to the time treatment was completed and all appliances were removed'. *Result.* The sample comprised 872 patients; 283 males and 589 females (mean age 16.7 years; S.D.4.5). The majority of malocclusions were Class II Division 1 (52.4%) followed by Class I (28.2%), Class III (14.8%) and Class II Division 2 (4.6%). The mean treatment time was 44.5 ± 22.2 months with a wide range from 7.6 to 156.8 months. Patient characteristics which had significant influence on treatment duration were age (p<.002), ethnic group (p<.0001), malocclusion type (p<.008), impacted teeth (p<.0001), pre-treatment dentition (p<.0001). Clinical decisions which influenced treatment time were treatment modality (p<.0001), number and type of extractions (p<.0001) and alignment of impacted teeth (p<.0001). Patient and clinic factors which contributed to treatment duration were number of operator change (p<.0001), interappointments longer than 6 months (p<.0001), appointment changes (p<.0001), rebonds/repairs (p<.0001) and number of clinic visits (p<.0001). *Conclusion*. Orthodontic treatment time is influenced by a number of clinical decisions and patient factors. Change in operators and appointments, inter-appointment duration longer than 6 months, extractions, rebonds, alignment of impacted tooth, starting treatment during mixed dentition stage and treatment type were factors which influenced treatment time although they contributed to only 57.3% of possible causes.

Key Words: Orthodontics, Treatment duration, Fixed appliance, Factors, Retrospective

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INTRODUCTION

Every potential orthodontic patient is keen to know the total duration of the treatment proposed as it involves commitment, compliance, financial and logistic implications on the patient and family. The answer to this question depends on many factors; the type and complexity of treatment agreed, the clinician's experience and skill and practice management methods. Generally, a rough estimate can be given according to the treatment type and complexity. However this prediction may be complicated by patient's poor compliance and behavior; oral hygiene problems, associated dental problems during treatment, non-attendance or frequent change of appointments, appliance breakages, patient transfer and change of operators within the clinic.[1]

It is important that reliable and fairly accurate prediction of the treatment time in the proposed treatment be outlined to the patient and family from the start. Patients who are given more accurate information on treatment duration may have an easier task to decide or agree to the treatment plans proposed and may be more compliant and have expectations of more reasonable treatment outcomes than an ill-informed patient. The British Orthodontic Society

recommends that patients receive sufficient information about the proposed treatment, including a realistic estimate of the length of time involved.[2]

The ability to accurately predict treatment duration is an essential practice management skill for all orthodontists as this may influence success in orthodontic practice.[3,4] Timely completion of treatment satisfies patient and parents and allows more precise prediction of required clinic visits.[4,5,6] This may indirectly give a more accurate prediction of calculated overhead costs.[7] Turbill et al.(2001)[7] asserted that cost efficiency is an important concept in modern health care and long treatment duration may lead to unfavorable profitability in practice or national health system.

Prolonged treatment time can cause potentially harmful side-effects to the patient. It is also not beneficial to the health care system in terms of cost efficiency and efficacious service to the public. Cellular and genotoxicity to DNA and oral mucosal cells from corrosion of Nickel and titanium in orthodontic wires and brackets is a concern when treatment is unduly long.[8,9,10] Although localized genotoxic effects have been reported, these changes revert and cells recovered after the appliances were removed.[10]

A multitude of factors may influence the duration of orthodontic treatment. Generally, these factors may be divided into four main categories, namely; sociodemographic characteristics, diagnostic characteristics, treatment modalities and patient behavior. Some factors are related to the orthodontist, such as when to start and whether to extract, whereas others are related to patient behavior, such as compliance to appliance care and keeping to appointments. In the private sector orthodontic patients are normally treated from start to finish by the same orthodontist. However, in the public sector when orthodontists are transferred, resign or when patients move from place to place, their treatment is continued with the next attending orthodontist in the same clinic or different clinic.

In our clinic, it was observed that treatment time appeared very variable between patients for apparently similar malocclusions and certain operator and patient characteristics during treatment appear to be associated with prolonged treatment time. Thus, this retrospective study aims to elucidate factors that may influence treatment duration in our orthodontic patients.

METHODOLOGY

Study design

This is a cross-sectional study of all patients who have completed orthodontic treatment with fixed appliances within the last 12 years in the Klang Orthodontic specialist clinic from 1999 to 2010.

Sample

All patients with complete treatment records and who had fixed appliance treatment completed and debonded in the Klang orthodontic clinic within the last 12 years were included in our sampling. These included those treated with a combination of fixed and removable / functional appliances / additional surgical treatment and orthognathic surgery. Patients with incomplete records, craniofacial syndromes, cleft lip and palate or treated with only removable or functional appliances were excluded.

Data collection

The Orthodontic treatment card was the main source of data and was supplemented by study models and radiographs. Variables recorded included patient demographics, total treatment time and factors which may influence treatment time such as different treatment modalities, type of malocclusion, number of clinic visits including additional visits for oral hygiene purposes, frequency of rebonds and repairs of appliances, frequency of appointment changes by the clinic or patient, number of operator changes and treatment started in the mixed or permanent dentition. Data recording, entry and cleansing was done before being analysed in the SPSS (version 16.0) program.

Statistical analysis 11

Analysis of treatment time with gender, ethnic group and malocclusion types were carried out with One-way ANOVA test if the variable was normally distributed and there was homogeneity of variances. Post Hoc tests were run to determine significant differences between the various groups. If the variable was not normally distributed and there was significant difference in variances, non-parametric tests were carried out. The Mann-Whitney U Test was done if there were two groups

or Kruskal-Wallis test if there were three or more groups. Statistical significance was set at p<.05.

Correlation tests with treatment time were carried out with quantitative variables like 'age at start', number of extractions, number of rebonds/repairs, number of appointment change, number of oral hygiene visits, number of operators and number of clinic visits. Pearson's correlation test was carried out if the variable was normally distributed. Non-parametric Spearman's correlation was done if the variable was not normally distributed.

If the categorical explanatory variable was binary or dichotomous, then a numerical code (0,1) is chosen for the two responses as in gender, mixed or permanent dentition, absence/presence of dental anomalies, inter-appointment <6 months/ more than 6 months. When the explanatory variable is qualitative and has more than two categories, the variable was regrouped into 2 groups with numerical codes as in non extraction/extraction (0,1), no impacted teeth & impacted teeth not aligned / impacted teeth aligned, (0,1). Treatment type was regrouped into fixed only versus fixed plus other appliances or surgery (0,1).Generally, fixed appliance treatment which required additional appliances are more complex cases and require longer treatment time.

Variables which had statistical significance with treatment time were run in multiple linear regression using stepwise selection. Variables which showed non-statistical significance were removed from the model. The adjusted R square (R2) value (coefficient of determination) is used to assess the effect of each of the explanatory variables on treatment time. The predictive model was obtained by running the statistically significant explanatory variables which were independent in a stepwise regression and removal of extreme values of outliers until the residuals were normally distributed and linear. A reasonable number of variables were included for the best 'goodness-of-fit' model.

Definition of terms

Total treatment time

Total Treatment Time (months) was defined as treatment duration from the 'Start of orthodontic treatment' (when the first orthodontic appliance or component was fitted in the patient whether it is a removable or functional appliance, orthodontic bands, brackets, transpalatal arches, quadhelix or headgears) to 'End of Active treatment' (when the fixed appliance was debonded).

Total number of clinic visits

These included all regular visits, rebond of broken or dislodged brackets/bands, repair/redo/refit of appliances, oral hygiene and emergencies. Visits for extractions or separator placement were excluded.

Number of visits for Rebond/repair/reconstruction of appliance

The number of visits where orthodontic brackets / bands / archwires were fixed again (rebond) to teeth or appliances were repaired or redone. This was recorded as one visit irrespective of the actual number of breakages rebonded during that visit.

Number of extra visits for oral hygiene purposes

These were extra visits solely for the purpose of improving oral hygiene apart from the routine oral hygiene instructions and care during regular orthodontic appointments. These extra visits included scaling and polishing, oral hygiene reinforcement and monitoring and referrals to the periodontist.

Number of operator changes

An operator change was recorded if the treatment of the patient was transferred to another orthodontist for continuation. This included transfers by operators within the clinic or by an orthodontist from another clinic.

Number of appointment changes

This included appointments changed by the clinic or by the patient. It is not recorded as an appointment change if the patient failed to attend at the given appointment until a new appointment is rescheduled.

Number of extractions

Permanent teeth including those extracted previously before pre-treatment were included. Primary teeth or supernumerary teeth were excluded.

Inter-appointment duration

If the interval between any consecutive appointments was more than 6 months, this was recorded only once irrespective of the number of times this occurred during the whole treatment.

Table 1. Demographics of patient gender, ethnicity and malocclusion

Variable	No. of patients (%)	Mean treatment time (S.D.) in months	Range (months)	Significance p<0.05
Gender				
Male	283 (32.5)	47.7 (25.1)	7.6-156.8	.041*
Female	589 (67.5)	43.0 (20.5)	8.8-136.8	
Ethnic group				
Malay	350 (40.1)	44.9 (20.5)	10.7-107.3	.0001*
Chinese	275 (31.5)	39.3 (18.2)	8.8-118.5	
Indian	247 (28.3)	49.7 (26.8)	7.6-156.8	
Age at start				
Age group				
<12 yrs	98 (11.2)	53.0 (26.3)	15-0-136.8	.002*
13-19 yrs	618 (70.9)	43.8 (21.9)	7.6-156.8	
20> yrs	156 (17.9)	41.9 (19.1)	8.8-103.7	

*Kruskal-Wallis Test

Table 2. Patient pre-treatment characteristics and treatment time

Variable	No. of patients (%)	Mean treatment time (S.D.) in months	Range (months)	Significance p<0.05
Dental anomalies				NS#
Absent	806 (92.4)	44.5 (22.0)	7.6-156.8	
Present	66 (7.6)	44.9 (24.3)	11.1-118.5	
Malocclusion				.008*
Class I	246 (28.2)	37.6 (19.3)	7.6-107.5	
Class II Div1	457 (52.4)	48.5 (23.1)	10.6-156.8	
Class II Div2	40 (4.6)	50.2 (23.9)	12.7-114.3	
Class III	129 (14.8)	41.9 (19.6)	11.1-107.3	
Impacted teeth				.0001*
No impactions	807 (92.5)	43.8 (21.9)	8.8-156.8	
Impacted teeth aligned	30 (3.4)	64.7 (20.9)	29.4-99.9	
Impacted teeth not aligned	35 (4.0)	42.2 (21.5)	7.6-107.3	
Pre-treatment dentition				.0001*
Mixed	50 (5.7)	61.4 (26.3)	18.1-137.7	
Permanent	822 (94.3)	43.5 (21.5)	7.6-156.8	

NS# = not significant *Kruskal-Wallis test

Associated dental anomalies

Supernumeraries, hypodontia and transposition of teeth were included.

Impacted teeth

Impacted teeth included incisors, canines and premolars other than third molars which may require surgical removal or surgical exposure and/or orthodontic alignment as part of the treatment.

Additional minor surgery

This included surgical exposure of unerupted permanent teeth, periodontal surgery or frenectomy.

RESULTS

There were a total of 872 cases which satisfied the criteria in our sampling. There were 283 males and 589 females comprising 40.1% Malays/Bumiputras, 31.5% Chinese and 28.3% Indians (Table 1). The

majority of malocclusions were Class II Division 1 (52.4%) followed by Class I (28.2%), Class III (14.8%) and the least Class II Division 2 (4.6%). The mean treatment time was 44.5 ± 22.2 months with a wide range from 7.6 to 156.8 months. A small number of cases (7.6%) had associated dental anomalies which had no significance influence on treatment time.

Since there were many variables evaluated in this study, they were grouped into 4 main categories for better comprehension (Table 2-4). Table 2 shows patient demographics and Table 3 shows patient pre-treatment characteristics in association with treatment time. Table 4 shows clinical factors and Table 5 shows variables due to patient cooperation during the course of the treatment.

Table 3. Clinical factors and treatment time

Variable	No. of patients (%)	Mean treatment time (S.D.) in months	Range (months)	Significance p<0.05
Treatment type				
Fix only	687 (78.8)	41.3 (20.5)	7.6-137.7	.0001*
Fix + URA	74 (8.5)	51.5 (20.3)	18.1-107.3	
Fix + functional	71 (8.1)	58.7 (27.4)	18.2-156.8	
Fix + jaw surgery	10 (1.1)	52.8 (19.7)	32.2-90.8	
Fix + other surgery	30 (3.4)	62.7 (25.6)	14.3-118.5	
Extraction pattern				
Non-extraction	228 (26.1)	38.0 (20.1)	7.6-126.1	.0001#
Extraction exclude molars	610 (70.0)	46.4 (22.6)	12.8-156.8	
Extraction include molars	34 (3.9)	54.0 (17.9)	27.1-91.4	
No. of extractions				
None	228 (26.1)	38.0 (20.1)	7.6-126.1	.0001*
1	24 (2.8)	42.6 (19.4)	18.1-82.1	
2	79 (9.1)	47.7 (24.2)	13.2-120.4	
3	36 (4.1)	56.0 (28.8)	13.9-156.8	
≥4	505 (57.9)	46.2 (21.7)	12.8-137.7	
Impacted teeth				
Impacted teeth aligned	30 (46.2)	64.7 (20.9)	29.4-99.9	.0001#
Impacted teeth not aligned	35 (53.8)	42.2 (21.5)	7.6-107.3	
No. of operators				
1	497 (57.0)	42.3 (19.4)	8.8-111.6	.0001*
2	332 (38.1)	43.8 (21.7)	7.6-137.7	
3	41 (4.7)	72.7 (30.7)	16.2-156.8	
4	2 (0.2)	120.5 (23.0)	104.2-136-8	

#one-way ANOVA *Kruskal-Wallis test

Factors influencing treatment duration:

Age and gender

Gender was not a factor in treatment duration (Table 2). There was significant difference in treatment duration with age at start of treatment and between the 3 different age groups of adolescents, teenagers and adults. However, the negative correlation of age with treatment time was very small, r= -0.077 (Table 6).

Ethnic group

There was significant difference in treatment duration between the various ethnic groups (Table 2 and Fig.1). There was greater percentage of Indians and Malays with Class I, Class II Div1 and Class II Div 2 malocclusions than Chinese. And there were 5 times more Chinese and Malays with Class III malocclusions than Indians.

Dentition at start of treatment

The majority of patients (94.3%) were started in the full permanent dentition (Table 3). The mean treatment duration was 61.4 ± 26.3 months in

patients started in the mixed dentition compared to a shorter time of 43.5 ± 21.5 months in those started in the permanent dentition. There was significant difference in the duration between these two groups although the range of treatment duration was large (p<.0001).

Table 4. Patient compliance characteristics and treatment time

Variable	No. of patients (%)	Mean treatment time (S.D.) in months	Range (months)	Significance p<0.05
Inter-appointment				
<6 months	623 (71.4)	39.0 (18.9)	7.6-156.8	.0001†
>6 months	249 (28.6)	58.2 (23.7)	17.5-136.8	
No. of appointment change				
None	36 (4.1)	27.9 (12.6)	8.9-67.5	.0001*
1-5	444 (50.9)	34.6 (15.7)	7.5-107.5	
6-10	287 (32.9)	50.0 (17.3)	15.8-127.4	
11-15	73 (8.4)	71.5 (19.0)	31.7-26.1	
>15	32 (3.7)	89.6 (27.1)	47.3-56.8	
No. of rebonds/repairs				
None	279 (32.0)	36.5 (19.2)	7.6-111.6	.0001*
1-5	521 (59.7)	45.6 (20.3)	10.6-136.8	
6-10	54 (6.2)	66.1 (29.1)	23.7-156.8	
11-15	14 1.6)	64.0 (26.8)	18.2-107.3	
>15	4 (0.5)	88.3 (23.5)	65.5-120.4	
No. of clinic visits				
1-10	86 (9.8)	19.5 (6.0)	7.6-37.4	.0001*
11-20	431 (49.3)	34.8 (12.4)	18.1-82.1	
21-30	244 (27.9)	54.2 (14.0)	13.2-120.4	
31-40	88 (10.1)	74.9 (18.2)	13.9-156.8	
>40	23 (2.6)	100.7 (22.4)	12.8-137.7	

†Mann Whitney U test *Kruskal-Wallis test

Table 5. Correlation of quantitative factors with treatment time

Variable	Correlation with treatment time (P value)
Age at start of treatment	r= -.077 (p<.05±)
No. of extractions	r=.161 (p<.01 ‡)
No. of rebonds/ repairs	r=.341 (p<.01‡)
No. of Appointment changes	r=.638 (p<.01‡)
No. of oral hygiene visits	r=.142 (p<.01‡)
No. of operator change	r=.115 (p<.01‡)
No. of clinic visits	r=.850 (p<.01‡)

*Pearson's Correlation Coefficient ‡Spearman's Correlation Coefficient

Malocclusion type

Table 3 shows the majority of malocclusions were Class II Div 1 (52.4%) followed by Class I (28.2%), Class III (14.8%) and Class II Div 2 (4.6%). Mean treatment time was shortest in Class I (37.6 ± 19.3 months) followed by Class III (41.9 ± 19.6 months), Class II Div 1 (48.5 ± 23.1 months) and longest in Class II Div 2 (50.2 ± 23.9 months). There was significant difference in treatment duration between the types of malocclusion (p<.008).

Impacted tooth

65 cases (7.4%) had impacted teeth of which 46.2% were brought into alignment in the arch (Table 3, 4). Post hoc tests showed there was significant difference in treatment duration between all three groups of patients (p<.0001). Table 4 showed that alignment of the impacted teeth took about 1.5 times longer to finish than extraction of the impacted teeth and this was statistically significant (p<.0001).

Effect of number and type of extractions

The majority of cases (70.3%) required extractions excluding molars. 3.9% of cases needed extractions of molars and 26.1% were treated non-extraction (Table 4). Extractions and the number of teeth extracted were significant factors influencing treatment duration ($p<0.0001$). However, Post hoc tests (Bonferroni) showed there was no significant difference between extractions including or excluding molars. Mean treatment time was 38.0 ± 20.1 months in non-extraction and was increased to 46.2 ± 21.7 months with extractions of four teeth (Table 4).

Table 6. Multivariate explanatory model

	Coefficients		Coefficients			Interval for B	
Model	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
(Constant)	19.587	2.622		7.470	.000	14.441	24.733
No. of extractions	1.622	.296	.128	5.476	.000	1.041	2.204
No. of operators	2.386	.847	.064	2.816	.005	.723	4.048
No. of rebonds	1.334	.182	.168	7.320	.000	.977	1.692
Appt changes	2.654	.133	.498	19.922	.000	2.393	2.916
Inter-appt duration	9.037	1.145	.184	7.893	.000	6.790	11.284
Align impacted teeth	9.033	2.850	.074	3.169	.002	3.439	14.627
Dentition at start	-6.529	2.257	-.068	-2.893	.004	-10.958	-2.100
Treatment type	9.273	1.284	.173	7.220	.000	6.752	11.794
a. Dependent Variable: Treatment time in months							
R=0.577; Adjusted R^2=0.573							

	Unstandardized Coefficients		Standardized Coefficients			95% Confidence Interval for B	
Model	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
(Constant)	19.587	2.622		7.470	.000	14.441	24.733
No. of extractions	1.622	.296	.128	5.476	.000	1.041	2.204
No. of operators	2.386	.847	.064	2.816	.005	.723	4.048
No. of rebonds	.334	.182	.168	7.320	.000	.977	1.692
Appt changes	2.654	.133	.498	19.922	.000	2.393	2.916
Inter-appt duration	9.037	1.145	.184	7.893	.000	6.790	11.284
Align impacted teeth	9.033	2.850	.074	3.169	.002	3.439	14.627
Dentition at start	-6.529	2.257	-.068	-2.893	.004	-10.958	-2.100
Treatment type	9.273	1.284	.173	7.220	.000	6.752	11.794
a. Dependent Variable: Treatment time in months							
R=0.577; Adjusted R^2=0.573							

Treatment type

The majority of cases (78.8%) were treated with fixed appliances, followed by 8.5% with fixed appliances and upper removable appliances (URA) and 8.1% with fixed and functional appliances (Table 4). Only 3.4% of fixed cases required additional minor surgery and 1.1% required fixed appliances and orthognathic surgery for jaw correction. The two most popular functional appliances used were the bionator (37.1%) and Twin block (35.5%) followed by activator (24.2%) and 2 cases of Herbst appliance (3.2%).

Treatment type was a significant factor influencing treatment duration ($p<0.0001$). The shortest mean treatment time was in patients requiring only fixed appliances (41.3 ± 20.5 months). The longest mean treatment time were cases requiring fixed appliances and other surgeries (62.7 ± 25.6 months) although the range is very large from 14.3-118.5 months. A two-phase treatment with functional and fixed appliances showed mean treatment time of 58.7 ± 27.4 months. Fixed appliance and orthognathic jaw surgery took a mean treatment duration of 52.8 ± 19.7 months.

Influence of operator changes

Operator change was a significant factor influencing treatment time (p<0.0001). Treatment time under a single operator was 42.3 ± 19.4 months. Treatment duration increased with more than two operators and almost tripled with change of 4 or more operators (Table 4).

Table 7. Multivariate Predictive model

Model	Unstandardized Coefficients		Standardized Coefficients			95% Confidence Interval for B	
	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
(Constant)	18.431	2.331		7.907	.000	13.856	23.006
No. of extractions	5.542	.890	.137	6.225	.000	3.795	7.290
No. of rebonds	1.103	.161	.150	6.852	.000	.787	1.419
Appt changes	2.604	.117	.528	22.268	.000	2.374	2.833
Inter-appt duration	8.894	1.006	.197	8.841	.000	6.920	10.869
Align impacted teeth	10.777	2.477	.097	4.351	.000	5.915	15.639
No. of operators	1.550	.747	.045	2.075	.038	.084	3.017
Dentition at start	-4.256	2.022	-.048	-2.104	.036	-8.225	-.287
Treatment type	9.089	1.109	.184	8.195	.000	6.912	11.267

a. Dependent Variable: Treatment time in months
Adjusted R^2=0.621

Frequency of dislodged / broken / lost appliances

The majority of patients (59.7%) had at least 1-5 number of rebonds/repairs compared to 32% with no rebonds / repairs. Mean treatment time was the shortest (36.5 ± 19.2 months) when there were no rebonds or repairs done during the duration of appliance wear (Table 5). Treatment duration increased with the frequency of rebonds or repairs (p<.0001).Treatment time more than doubled with frequency of rebonds / repairs more than 15 times in 0.5% of patients.

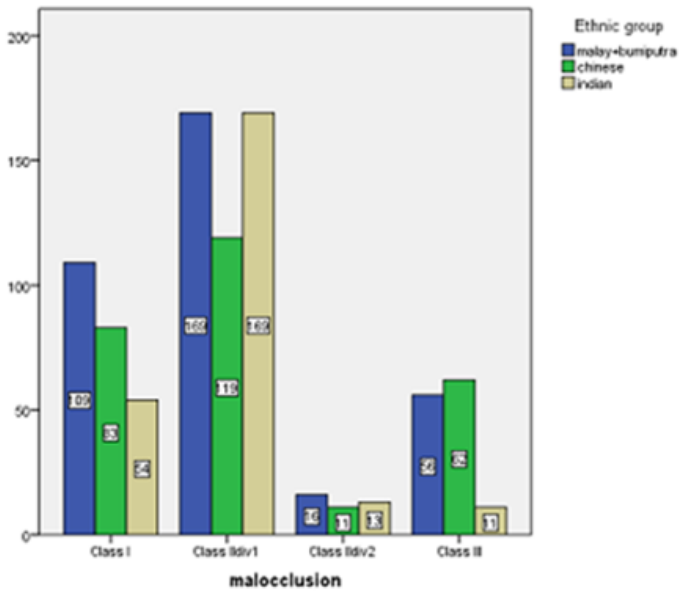

Figure 1. Malocclusion in different ethnic groups.

Change of appointments

The majority of patients (83.8%) had 1-10 change of appointments (Table 5). Only a small number (4.1%) did not have any appointment change and mean treatment time was shortest (27.9 ± 12.6 months). 12.1% of patients with more than 10 appointment changes had more than double the treatment time. Mean treatment time increased with the frequency of appointment change and this was a significant factor influencing treatment duration (p<.0001).

Effect of long Inter-appointment duration

The norm in the clinic protocol was to review patients regularly between 1-2 months. The long inter-appointment duration was mainly due to patients rescheduling their appointments or due to no-show at scheduled appointments. This was indicative of patient non-compliance. Most patients (71.4%) were seen regularly within 6 months although quite a substantial number (28.6%) had at least one appointment which was more than 6 months apart (Table 5). There were some patients who had lapsed of appointments for more than 12 months on more than one occasion. The mean treatment duration was 39.0 ± 18.9 months for patients with regular appointments and increased almost 1.5 times in those with long lapse of appointments (p<.0001).

Frequency of clinic visits

The majority of patients completed treatment in 11-30 clinical sessions (77.2%) for both scheduled and unscheduled appointments (Table 5). About 12.7% had more than 31 appointments to complete their treatment. The mean treatment time was increased with increased frequency of clinic visits (p<.0001).

Correlation of quantitative factors with treatment duration (Table 6)

Although age at start of treatment and the number of extractions, rebonds / repairs, appointment changes, additional oral hygiene visits, operator changes and clinic visits were factors which had a statistically significant difference in treatment duration, there was generally weak correlation except in clinic visits (r=.850) and appointment changes (r=.638).

Multivariate Explanatory model (Table 7)

Backward stepwise regression analysis was performed with inclusion of all factors (except type of malocclusion) which had statistical significance with treatment time. Malocclusion type had high collinearity with type of treatment, thus only 2 categories of treatment was included in the model, that is, 'fixed only' or 'fixed + other appliances or surgeries'. Age, extraction pattern and frequency of oral hygiene visits were not significant in the regression analysis. These factors were then removed from the model and the multiple regression analysis run again. The final explanatory model had an intercept of 19.6 months and indicated that treatment time increases by an average 1.6 months with number of teeth extracted, 2.4 months with number of operators, 1.3 months with rebonds, 2.7 months with change in appointments, 9.0 months with inter-appointment more than 6 months, 9.0 months with alignment of impacted tooth, 6.5 months more in mixed dentition, and 9.3 months with fixed appliance combined other appliances or surgeries. R2 was 0.577 and the adjusted R2 value (coefficient of determination) was 0.573.

Multivariate Predictive model (Table 8)

Explanatory variables which were not significant in the model were removed and the regression model analysis tested again. Tests of normality showed that the residuals were normally distributed. Residual analysis showed there was a pattern in the distribution of the residual points. The residual points increased in value from left to right. This was probably due to autocorrelation or the extreme values of outliers as indicated in the Casewise Diagnostics. 17 case numbers with extreme values were dropped to satisfy the assumptions of linearity. This was verified by the random scatter plot obtained. All explanatory variables were run in a stepwise regression until a model with the best 'goodness-of-fit' was obtained for the predictive model.

The best-fit predictive model had adjusted R2 value (coefficient of determination) of 0.621. The predictive model had an intercept of 18.4 months and indicated that treatment time increases by an average 5.5 months with number of extractions, 1.6 months with change in operators, 1.1 months with rebonds, 2.6 months with change in appointments, 9.1 months with interappointment more than 6 months, 10.8 months with alignment of impacted tooth, 9.1 months if fixed appliance plus other appliances or procedures, and 4.3 months if started in the primary dentition.

Limitations of study

Other factors such as severity of overjet / overbite and crowding, skeletal growth pattern, anchorage requirements and space closure methods which might possibly influence treatment time were not studied as this was a retrospective study.[4] Some of the commonest limitations that are very difficult to assess are the variability in time spent detailing and finishing the occlusion, the appropriateness of the original diagnosis and treatment plan carried out and operator competency.[12,13] These variables may vary greatly between clinicians.[5]

DISCUSSION

The current study was a diverse group although they were all treated with conventional pre-adjusted Edgewise metal brackets in .022" slots. We found that treatment duration was influenced by gender, ethnic groups, age, presence of deciduous teeth at start of treatment, malocclusion type, treatment type, extractions and alignment of impacted teeth which were similar to those in previous studies.[1,4,5,6,14,15,16,17] The mean treatment time observed in our study was 44.5 (S.D.22.2) months with a wide range from 7.6 to 156.8

months. This was much longer than observed in other studies that reported much shorter mean orthodontic treatment duration about 24-28 months.[5,6,17,18] One of the possible reasons may be due to slower space closure with elastomeric ligatures or continuous elastomeric chain consistently used by the operators in the current study although this factor was not evaluated as an influencing variable.[19,20,21,22]

Various clinical studies have shown that the rate of space closure was faster in Ni-Ti coil springs than an elastic module due to less force degradation over time, although method of space closure has not been reported as one of the factors associated with treatment time in the systematic review by Dimitrios and Athanasiou (2008).[1,19,21,23,24] However, Nightingale and Jones disagreed and reported that the rate of mean weekly space closures were 0.21mm for elastomeric chain and 0.26mm for Ni-Ti coil springs.[25] They did not find any difference in rate of space closure with Ni-Ti coil springs and elastomeric chain in clinical use although Ni-Ti coil springs maintained at least 50% of their initial force over a slightly longer period.

It was obvious that patient compliance played a major role in influencing treatment duration (Table 4,5) in the current study. In patients with no appointment changes, the mean treatment time was only 27.9 ± 12.6 months and those with no rebonds or repairs was 36.5 ± 19.2 months. There was strong correlation between these two variables with treatment duration; r=.638 for appointment changes and r=.341 for rebonds/repairs. For every rebond/repair, there was an estimated additional increase in 1.3 months. This observation was echoed in the study by Robb et al. which compared adults and adolescents with 4 premolar extractions.[15] They found that the number of broken appointments and appliance repairs explained 46% of the variability in treatment time. Beckwith et al. observed that each failed appointment was associated with a little over 1 month additional estimated treatment time and explained 17.6 per cent of their variation in treatment time.[5] Fink and Smith similarly found 0.8 months of treatment time was added per broken appointment although inclusion of this variable added only 5.2% to the amount of explained variance.[12] Skidmore et al. similarly reported that failed appointments, appliance breakages, rebonding / repositioning of brackets and poor elastic wear contributed to the increased treatment time.[17]

However, we still could not pinpoint the reasons for the much longer mean treatment time in our study because our cases with Class I, non-extraction, non-alignment of impacted teeth, routine fixed appliance only or single operator still took about 36-42 months to complete. This was in contrast to a similar study by Loke on a local population that mean treatment time was 15.9 months (range 4 to 43 months) and 90% of patients were completed within 24 months by a single operator.26 However, that study did not find significant association between type of malocclusion, extractions or number of missed appointments with treatment duration. This was probably due to the very small number of missed appointments (mean <4) compared to 45% of patients with 6 or more appointment changes in the current study.

The chronologic age of child and adolescent patients did not demonstrate a significant association with orthodontic treatment duration in many studies in contrast to the findings in our study which showed a statistically significant association but weak correlation.[5,12,15,28] Beckwith et al. observed that the number of treatment phases or starting earlier in the mixed dentition was more directly associated with treatment time than chronologic age.[5] They found that patients treated in two or more phases wore appliances nearly 8 months longer than those treated in a single phase. Von Bremen and Pancherz reported that patients in the early mixed dentition required an average of 57 months, late mixed dentition for 33 months and in the permanent dentition for 21 months to treat.[29] This factor was related to the combination of fixed and functional appliances used in the younger patients and time for eruption of the permanent teeth.

The current study also found an increased treatment time of about 18 months more for patients starting treatment with deciduous teeth and in those requiring removable or functional appliances (Table 3, 4). Fisher et al. observed that age was not the critical factor; rather the presence or absence of deciduous teeth at pre-treatment.[6] Using odds ratio (ORcrude), they reported that patients were 2-3 times more likely to have short

treatment times if there were no deciduous teeth (ORadj=3.0; 95% CI, 1.5-5.9) compared to 2-3 times more likely to have long treatment if there were deciduous teeth at start of treatment (ORadj=1.9; 95% CI, 1.0-3.4). This was similarly observed in the current study where presence of deciduous teeth at start of treatment rather than chronologic age was a significant influencing factor in treatment time. Dimitrios and Athanasiou concluded that age differences did not seem to play a role in the duration of treatment, provided that patients were in the permanent dentition.[1]

The 57.3% variation in orthodontic treatment time that was explained by our explanatory model (by using 8 of the original 17 variables) was higher than Beckwith et al. (46%), Turbill et al. (41%) and Skidmore et al. (38%) respectively.[5,7,17] Fisher et al. reported that pre treatment characteristics associated with treatment time were severe crowding, deciduous teeth, increased overbite and extractions.[6] They found that treatment which took 20 months or less were those requiring no extraction, no deciduous teeth at start of treatment, less than 80% overbite, less than 6 mm of maxillary crowding and good oral hygiene. Conversely, long treatment time which took 30 months or longer were in patients with decreased lower facial height, extractions, presence of deciduous teeth, excessive overjet, 80% or more overbite and 6 mm or more of maxillary crowding.

Ethnicity has not been reported as a treatment time factor in previous studies. Our study observed significant differences in treatment duration between the Malays, Chinese and Indians. Earlier studies have reported intrinsic ethnic differences in malocclusion and cephalometric norms between these three groups which may influence the type of treatment and clinical decisions.[30,31,32] Other studies also reported different craniofacial characteristics and soft tissue profile in many ethnic groups; Chinese, North and central Indians, Caucasians, African American, Hispanics, Japanese, Korean and Saudis.[33,34,35,36,37,38,39,40]

Janson et al. found that treatment duration was shorter in 2-premolar extractions (23.52 ± 5.86 months) compared to 4-premolar extractions (28.12 ± 7.59 months).[41] Although the current study observed significant difference between nonextraction and extraction cases, and increase in treatment time with the number of extractions, the correlation of extractions with treatment time was weak (r=.161). This was in contrast to the conclusions by Dimitrios and Athanasiou.[1] Different clinic protocols may possibly lengthen treatment time as it was observed in the present study that extractions were quite routinely carried out only after cementation of orthodontic bands and there may be delay in the extractions. And some appointments appeared to be non-productive when the patients were only seen by nurses.

Vu et al. found that increased treatment time was associated with time spent aligning in Ni-Ti wires, Class II malocclusion and more severe or complex treatment.[4] Routine patients with Discrepancy Index (DI) score >20 took 32.9 months. They observed that Class II cases had increased treatment time by 7.4 months over Class I. This was similarly reported by Skidmore et al., Robb et al. and the current study.[15,17]

Stewart et al. reported that treatment time was 22.4 months for control group, 25.8 months for unilateral impacted group and 32.3 months for bilateral impaction in palatally impacted maxillary canines.[42] Treatment time was observed to be related to age of patient at start of treatment and severity of impaction.[42,43] They found that patients older than 25 years were more difficult to treat and required on average 30 additional visits. It was not possible to compare with the present study as we included impactions of all teeth. Our mean treatment time for aligning impacted teeth was very long (64.7 ± 20.9 months) and this may be influenced by different techniques or delay in surgery.

The number of clinic visits has been suggested as a more realistic measurement in terms of assessing difficulty and costs to the treatment instead of treatment duration. If the treatment was not working well, it may involve more frequent monitoring or change in treatment procedures.[43] Obviously the number of clinic visits was directly associated with treatment duration ($p<.0001$) in the current study and this was the most strongly correlated variable with treatment time (r=.850) in the study by Loke.[26]

Earlier studies have shown that poor cooperation from patients resulted in increased treatment time.[4,5,17,27] Trulsson et al. reported that treatment time was shorter in the older group of

children possibly due to better cooperation and fewer missed appointments.[27] And the longest treatment time was in Class II Div1 patients treated with a combination of fixed and removable appliances and shortest in Class I treated with fixed appliances in one jaw. Skidmore et al. also reported that failed appointments, appliance breakages, rebonding / repositioning of brackets and poor elastic wear contributed to the increased treatment time.[17] Failed appointments and rebonds/ repairs similarly were associated with increased treatment duration in our study.

In the current study, most of the required oral hygiene measures such as scaling and oral hygiene instructions/ reinforcements were carried out at the same visit for routine appointments. Patients who were referred to other dentists or clinics for scaling or periodontal treatment were not recorded. Our study found statistical significance but weak correlation of oral hygiene with treatment duration, but this was not a significant factor in multiple regression analysis (Table 6, 7). There were few patients (10.5%) who required additional visits for oral hygiene purposes with the majority needing only 1-2 visits. However, Beckwith et al. reported an associated increase of 0.67 months per chart entry of poor oral hygiene and Skidmore et al. found that 3 or more 'poor oral hygiene' entries increased treatment time by 1.2 months.[5,17] Patient compliance factors are probably inter-related as patients with good oral hygiene may be more likely to cooperate with other aspects of treatment.

McGuinness and McDonald compared orthodontic treatment by postgraduate students in a district general hospital and observed that the average treatment time by one operator was 17.67 (SD 4.15 months) months while treatment time for patients treated by more than one operator was significantly longer, 26.1±6.78 months ($p<.0001$).[16] They found that change of operator contributed significantly to treatment time by an average of 8.43 months whereas Fink and Smith indirectly related treatment duration to individual operator difference as an important source of unexplained variation.[12] In our study, treatment time increased significantly by almost 30 months when there was change in 3 or more operators. Sources of increased treatment time may possibly be due to the delay in contacting the new operator / clinic by patients, delay in obtaining new appointments from clinics, longer inter-appointment duration due to the added burden to the existing operator and individual operator differences in technique and competency.

There were only 10 patients who had undergone orthognathic jaw surgery in the current study. The mean treatment time was not very different from those requiring fixed appliance with URA or functional appliances. However, treatment may be prolonged if the surgery was inadvertently delayed or postponed. This was similarly observed in other studies where no explanatory variables had a significant influence on the total duration of orthodontic treatment in orthognathic surgery cases.[44,45] Vu et al. found that patients needing surgery required an average increase in treatment time of 7.4 months if requiring extractions.[4] Luther et al. found pre-surgical orthodontic preparation took 17 months (SD 7-47 months) and the only factor that appeared to affect this treatment duration was the orthodontist.[28] Dowling et al. similarly reported that extractions resulted in significant increase in presurgical and overall treatment time.[13] It was interesting they found that a more experienced orthodontist (treated 10 or more pts during study period) had significant reduction in treatment time overall in all phases. This observation implied operator experience and competency were variables influencing treatment duration which was not evaluated in other studies.

There are possibly many other variables which may be associated with treatment duration but it is not possible to investigate all of them. The collinearity of some of the variables also contributed to difficulty in accurate evaluation. Treating all patients to the same high standard of completion with similar protocols by a single operator can limit potential variation due to clinician, thus providing a more accurate prediction of treatment time. Previous studies found no significant relationship between orthodontic treatment duration and clinical outcome, meaning that clinicians generally finish their patients to a high standard unless it was not possible; for instance if the patient terminated treatment early, refused recommended treatment or had very poor compliance.[4,16]

Two separate multivariate models were developed in the current study to present the data in a way that is useful to the clinician in everyday

practice (Table 7,8). The explanatory model explained 57.3% of the variability and the clinician can use this model as a motivating tool for better patient compliance. The predictive model explained 62.1% of the variance in treatment time. Although this means that treatment duration cannot be predicted with absolute accuracy, this knowledge might be sufficiently useful to give correct information to the patient and obtain a reliable estimate of the treatment time and possibly project the overall cost of the treatment.

CONCLUSION

The mean treatment time was 44.5 (S.D.22.2) months with a wide range from 7.6 to 156.8 months. Factors which influenced treatment time were gender, ethnicity, age at pre-treatment, malocclusion type, mixed or permanent dentition at start of treatment, treatment modality, extractions, alignment of impacted teeth, number of operators, inter-appointment duration, number of appointment changes and number of rebonds/repairs. The explanatory model of significant variables explained 57.3% of the variation in treatment time whereas the predictive model explained 62.1% of the variance. Although it is not an exact science, it is possible to predict treatment duration for a patient based on a small number of patient characteristics, behaviour and treatment decisions.

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