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An assessment of the effect of gender and Frankfort mandibular planes angle on orthodontic tooth movement: a single centre RCT

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ABSTRACT

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Objectives: To determine the effect of gender and FMPA on extraction space closure.

Setting and sample population: 11-18 year olds undergoing upper and lower fixed appliance therapy following the loss of a premolar in each quadrant at a district general hospital.

Methods: 100 patients were randomised with stratification on two age ranges (11-14 years, 15-18 years) and three FMPAs (high, medium, low). Allocation was to one of three treatment groups: conventional, active or passive self-ligating brackets (1:2:2). All subjects were treated using the same archwire sequence and space closing mechanics. Space closure was measured on models taken every 12 weeks throughout treatment, by one operator.

Results: 98 patients were followed to completion. Data were analysed using linear mixed models and demonstrated no statistically significant difference between bracket types with respect to space closure. Therefore data were pooled to determine the effect of gender and FMPA. At all stages of space closure there was a significant effect of gender (effect size, lower and upper 95% CI, probability) *i.e.* passive [1.064,0.521,1.607,0.001], active [0.825,0.312,1.339,0.002] and total space closure [1.029,0.527,1.531,0.001]. There was no statistically significant effect of FMPA on space closure.

Conclusions: Space closure during fixed appliance therapy is affected by gender but is unaffected by FMPA.

Keywords: Orthodontics, space closure, gender, FMPA

CLINICAL RELEVANCE

There is little evidence to suggest how gender and FMPA affect orthodontic space closure. This randomised controlled trial demonstrates that whilst FMPA has no effect, we should aim to coincide space closure using fixed appliances with the time of the pubertal growth spurt. To optimise space closure we should treat boys slightly later than girls.

INTRODUCTION

Much has been made of the factors that might affect efficiency and outcome in orthodontics, including appliance, operator and patient factors(1,2). Appliance factors include type(3), mechanics(4) and adjuncts e.g. vibration devices and surgery(5). Operator factors include training, location and continuity of care(6), whilst patient factors include age, gender and compliance(7). The findings of studies on outcome and efficiency are often inconclusive, or contradictory and the effects often based purely on anecdote e.g. a low Frankfort-Mandibular Planes Angle (FMPA) being associated with a slow rate of space closure and a high FMPA associated with rapid space closure(8). Although Fink and Smith (1992) (9) did find a relationship between MMPA and treatment length, their explanation was the additional time to alter the overbite. No mention was made of space closure.

Gender is another factor that might be considered to have an effect, but once again the evidence is not compelling. It has traditionally been taken into account when planning functional appliance treatment because they are thought to affect not only tooth positions, but also jaw relationships. With up to 20% of any observed treatment change being due to skeletal effects (10), such appliances have traditionally had their use restricted to the time of the pubertal growth spurt i.e. 10-12 years in girls and 12-14 years in boys. In the case of fixed appliances there are traditionally fewer restrictions on the timing of use. However, is this correct and should the timing of fixed treatment also be influenced by gender?

The retrospective analysis by Skidmore *et al*. (2006) (7) on 366 patients aged 10-20 years and found that the average treatment time for males was 1.6 months greater than for females, but that age had no effect. The mean age of the patients were 13.6 years for females and 13.9 years for males. The effect of gender may therefore have been down to compliance rather than effects such as growth. Other studies have no found influence of gender on treatment time (9,11).

The aim of this current investigation was to consider the effect of both gender and FMPA on space closure during fixed appliance therapy.

MATERIALS AND METHODS

A randomised controlled clinical trial was performed with two principal aims. The first aim was to determine the effect of bracket type on tooth movement and has been reported elsewhere (12, 13, 14). The second aim was to determine the effect of gender and FMPA on the rate of tooth movement and is the substance of this report.

The full methodology of this study has been published previously (14). 100 patients were recruited into this clinical trial following Clinical Research Ethics Committee (06/Q2202/6) and the Research and Development (N23270/1) Committee approval. At the time of planning this investigation, there were no existing studies comparing space closure with self-ligating and conventional brackets in order to determine a power calculation and no requirement to register this trial. It was decided to recruit 90 patients. In order to allow for a 10% dropout in total 100 patients were recruited with 36 subjects allocated to each self ligating groups and 18 to the conventional bracket group.

The CONSORT diagram (Figure 1) demonstrates the 3-arm parallel design with its 2:2:1 allocation ratio. Block randomisation was used to ensure that each patient was randomly allocated to one of three groups: the conventional bracket group (n=20), the passive self ligating bracket groups (n=40) or the active self-ligating group In-Ovation R (n=40). Telephone randomisation prior to bond up facilitated allocation concealment from the researchers. Randomisation was also stratified to take into account patient age and Frankfort Mandibular Planes Angle (FMPA). Eligible participants were divided according to age at the start of the trial, either 11-14 years old or 15-18 years old. There were three FMPA groups: low (FMPA<22º), average (FMPA 22º to 32º) and high (FMPA>32º). This was assessed

using a pre-treatment lateral skull radiograph and cephalometric analysis. The block size was 10 (2 for the conventional brackets, 4 in each of the other two arms) and blocks were used in each of the six strata formed by the two age categories and three Frankfort mandibular planes angle categories.

The inclusion/exclusion criteria were: Extraction of one premolar in each quadrant (first or second premolars or combinations thereof); Upper and lower fixed appliances; < 18 years at the start of treatment. The exclusion criteria were: Subjects who did not understand English; Subjects with incomplete labial segments.

98 patients were followed to completion of treatment with 2 dropouts. All of the subjects were treated in one hospital orthodontic department by one of three consultants or five registrars. Eligible participants and their guardians were provided with information about the study prior to inclusion in the trial.

Patients were treated using one of three types of preadjusted edgewise appliance; a conventional bracket (Omni, GAC Orthodontics, Bohemia, NY, USA), a passive self ligating bracket (Damon 3MX, Ormco, Glendora, CA, USA) or an active self-ligating bracket (In-Ovation R ,GAC Orthodontics, Bohemia, NY, USA). All brackets were 0.022" slot size, had a Roth prescription and were bonded using the same protocol. Molar bands were placed on the first permanent molars (GAC Orthodontics, Bohemia, NY, USA) and although the second molars were not routinely included in the initial bond-up, if it was required as part of the specific treatment plan they were bonded with second molar tubes (American Orthodontics, Wisconsin, USA). All patients received the same archwire sequence namely: 0.014" and 0.018" Copper Nickel Titanium (Ormco, Glendora, CA, USA), 0.016" x 0.022" Stainless Steel and finally 0.019" x 0.025" SS (GAC Orthodontics, Bohemia, NY, USA). Elastomeric ligatures (OrthoCare, Bradford, UK) were used with the conventional brackets and the clip was fully closed with the self-ligating brackets prior to progression to the next wire size.

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Lacebacks were not used. Patients with the conventional brackets were seen routinely every 6 weeks and patients with self-ligating brackets every 12 weeks, as is normal practice.

Alginate impressions were obtained prior to bond-up and every 3 months throughout treatment (Orthoprint, Zhermack, Italy) and in all cases were cast up within one hour, using extra hard dental stone (Novadur, South West Industrial Plasters, UK).
Beading wax was used to facilitate easy removal of the impression and to ensure the bracket type would remain concealed on the study models during subsequent measurement.

Active space closure was carried out on the 0.019"x 0.025" stainless steel archwires using 150g NiTi coil springs to crimpable hooks. Intra-oral elastics were used where clinically justified on stainless steel archwires. At any emergency visit, the appliance was repaired using the same bracket type and archwire. Only the model assessor was blinded during the study.

Using the study models taken throughout the treatment, tooth movement was measured using digital Vernier callipers (FV. Fowler, Newton, USA) by a single researcher (GS). Prior to this a reproducibility study was undertaken by measuring 10 randomly selected models on two occasions one week apart by the same operator (GS). To ensure repeatability, all measurements were taken under similar conditions and using a strict protocol to within 0.01 mm. Space closure measurements were divided into two, namely passive space closure (from initial bond/wire placement until the visit when the NiTi springs were fitted) and active space closure (lasting from the time of fitting the NiTi springs until the space closure was complete). The sum of the active and passive space closure constituted the total space closure.

The data was analysed using Stata version 13 (Stata Corp., Texas, USA) with a predetermined significance of $\alpha = 0.05$. The experimental design was repeated measures with time being recorded in days from the start of treatment, rather than the 'nominal times' in

weeks when the patient was scheduled for an appointment. This was therefore an intention to treat analysis. As there were 98 patients, individual plots of the dependent variable against time were too cluttered to show any trends in the data. The results of this trial on the effect of bracket type on initial alignment and space closure demonstrated a significant effect of bracket type on initial alignment, but not on space closure (14). It was therefore possible to pool the space closure results to investigate the effect of gender and FMPA on space closure. The data was collected at irregular time intervals and so a mixed models rather than standard repeated measures anova (15, 16, 17) analysis was used. Stata module 'xtmixed' was used with restricted maximum likelihood estimation, and effects were compared using margins in conjunction with Sidak's adjustment for multiple comparison. Although two participants dropped out of the trial their data was included in the analysis.

RESULTS

100 patients were recruited and 98 were followed to completion. The flow of patients through the trial is illustrated in the CONSORT flow diagram (Figure 1).

Demographic data on sex distribution, FMPA, age, and initial Little's index for each of the bracket groups is shown in Table 1. The age ranges were similar in each of the bracket groups as was the distribution of FMPA and Little's index at commencement of treatment.

Repeatability data for space closure were analysed using Lin's concordance correlation coefficient (18). The accuracy and the concordance correlation coefficient over the two time periods was $Cb = 1.00$ and $\rho_c = 0.999$ [0.998, 0.999].

The null hypothesis was that neither gender nor FMPA has a significant effect on space closure. The results are presented as (es,[ci],p) (where es is the effect size as measured by the contrast calculated from the predictive margins from the mixed modelling, [ci] its associated 95 % confidence interval, p is the probability associated with the statistical test).

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The effect size is the pairwise difference for the response variable as measured by the contrast calculated from the predictive margins from the mixed modelling. It is the effect of a covariate on the response adjusted for the other covariates in the model (19).

There was a significant effect of gender on space on all three types of space closure, passive [1.064, 0.521, 1.607, 0.001], active [0.825, 0.312, 1.339, 0.002] and total space closure (*i.e.* the passive + active) [1.029, 0.527, 1.531, 0.001]. There was no statistically significant effect of FMPA on space closure. The analysis is presented as probabilities associated with the main effects (Table 2) and interaction plots Figures 2 and 3 total space closure. Due to the non-linear response to space closure, along with the variable time intervals involved, a figure for rate of tooth movement in terms of mm per month would not be particularly meaningful. The effect of gender and the non-linear response to space closure is illustrated by the cubic spline plot (Figure 4).

DISCUSSION

The findings from our original trial on space closure with the three bracket types (13, 14) demonstrated no statistically significant effect of bracket type on space closure. For this reason the data were pooled in order to assess whether gender and FMPA had any effect. With all three types of space closure, passive, active and total, there was a statistically significant effect of gender, with space closure occurring more rapidly in male patients. The evidence that orthodontic treatment, especially that involving extractions, should be carried out during a period of maximal growth has until now been anecdotal (20, 21). It has also been suggested that in order to obtain the most rapid rate of space closure, both males and females should be treated during their pubertal growth spurt. On average this will be 14 (+/- 2) years in males and 12 (+/- 2) years of age in females (22). In the present investigation the mean ages of the male and female patients were similar, at 14.2 years and 13.7 years respectively. This might therefore explain the observed effects on tooth movement during space closure in the males, as they were treated during their pubertal growth spurt, whereas the females had already undergone much of their pubertal growth spurt. This conclusive effect of gender on orthodontic tooth movement has never been previously demonstrated. A recent study by Dudic *et al*. (23) investigating buccal premolar tooth movement in a group of 30 patients, aged 11.3-43 years, found gender to have no effect. This is perhaps not surprising if tooth movement in relation to the timing of the pubertal growth spurt is important, as the mean age of the patients in their study was 17.7 years, and was after the pubertal growth spurt. They did however conclude that tooth movement was more rapid in younger patients.

The findings of the current study is the first time a positive relationship between gender and tooth movement has been demonstrated and has important implications not only for orthodontics, but also other areas of medicine and dentistry. It would suggest that in order to optimise treatment efficiency for child patients undergoing treatment with fixed

appliances, treatment should be timed to coincide with the pubertal growth spurt, treating boys at a later age than girls.

The effect of gender and therefore timing of treatment is not unique to orthodontics. The most common hip disorder in adolescents, slipped capital femoral epiphysis, occurs in 30-60/100,000 patients and is related to the rapid growth spurt during puberty. As a result it occurs approximately 1.5 years later in boys than in girls (24) and requires active treatment at approximately 12 years of age in girls (25) and 13.5 years of age in boys. Similarly the incidence of distal forearm fractures peaks at the time of the pubertal growth spurt and is most common in girls aged 8-11 years and boys aged 11-14 years (26). This is not just thought to be related to increased physical activity, but also to an increase in cortical bone porosity as a result of greater bone turnover during puberty (27). It is perhaps hardly surprising then that teeth move more rapidly in a period of rapid bone turnover.

The finding that space closure is unaffected by FMPA was another surprising finding of this study. Once again, anecdotally it would be anticipated that the rate of space closure would be greater in the case of a patient with a high FMPA and slower in the case of a low FMPA, and this might be expected to be related to bite force. This finding has implications for treatment planning and in particular anchorage management.

When space closure (the dependent variable), passive, active and total is plotted against the two independent variables, gender and FMPA, there appears to be an interaction in each case (Figures 2 and 3). In the case of gender this might be a reflection of the normal age range of the pubertal growth spurt, with some overlap between males and females. The same might also be true of FMPA, in that there is likely to be normal biological variation in terms of tooth movement between individuals within the arbitrary limits FMPA.

Although this trial has some limitations such as possible performance bias as a result of the treating clinicians not being blinded to bracket type, age or gender, this study not only

highlights the need to customise the timing of orthodontic treatment according to gender, but also the need to carefully match sex in both control and experimental groups when analysing and interpreting the results of clinical trials.

CONCLUSIONS

1. There was a statistically significant effect of gender on the time to passive, active or total space closure, with space closure being more rapid in the case of the male patients.

2. There was no statistically significant effect of FMPA on the time to passive, active or total space closure.

ACKNOWLEDGMENTS

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FIGURE LEGENDS

Figure 1 - Consort diagram

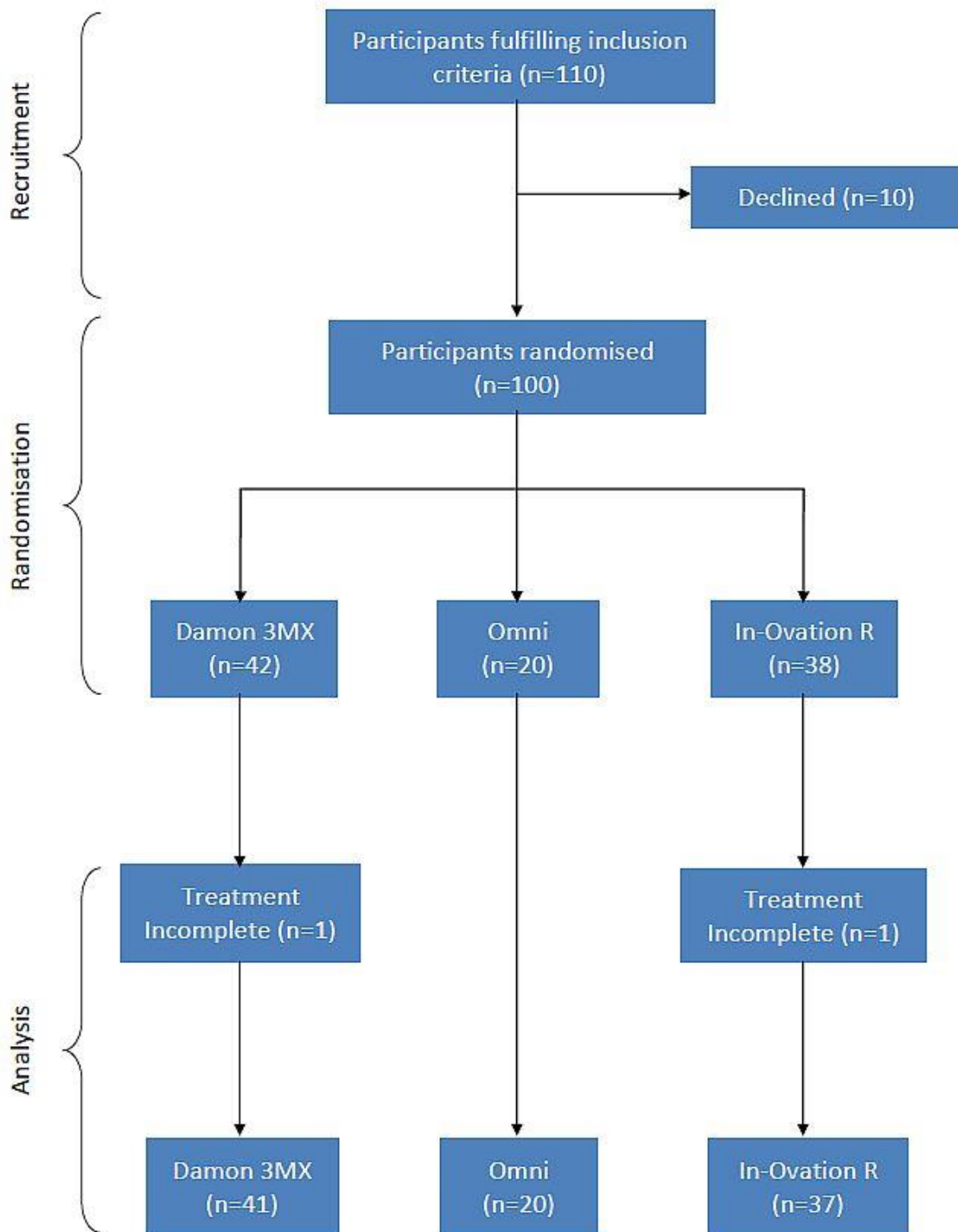**Figure 2** – Interaction plot of gender against total space closure

Figure 3 – Interaction plot of FMPA (L~Low, A~Average, H~High) against total space

closure

Figure 4 – Restricted cubic spline plot showing the effect of gender on total space closure

TABLES

Table 1 - Demographic data: Sex, Age (mean age and standard deviation (years), FMPA

(L~low, A~Average, H~High) and Little's Index (mean, minimum /maximum (mm))

Table 2 - The effect of gender and FMPA on space closure - mean, 95%CI and probabilities

Figure 1 Consort diagram charting the flow of participants through the trial
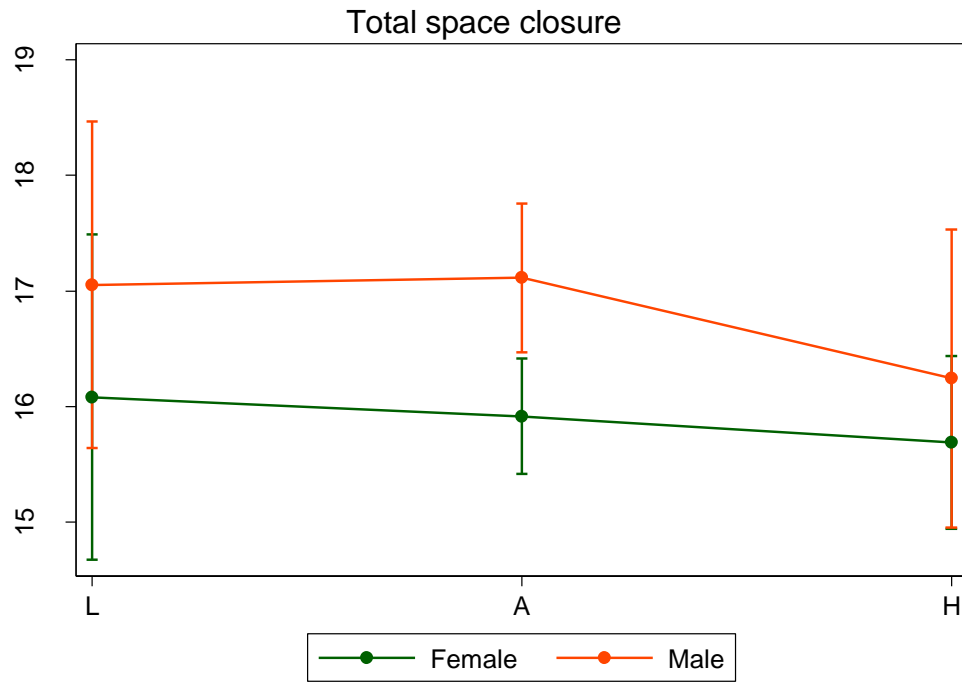
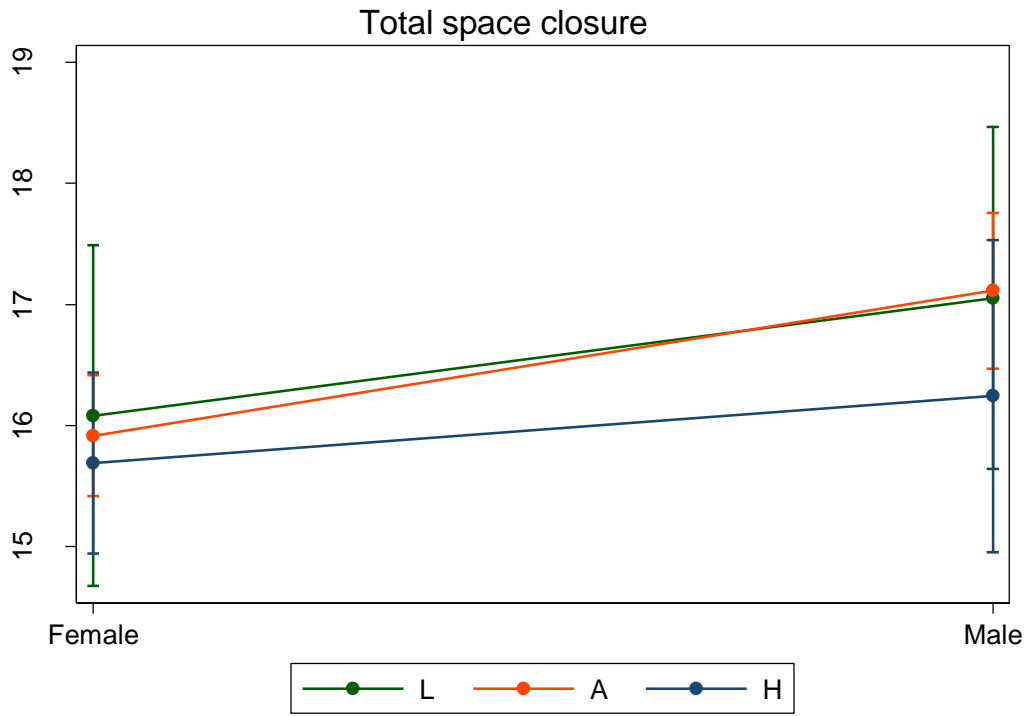Figure 2 – Interaction plot of gender against total space closure

Figure 3 – Interaction plot of FMPA (L~Low, A~Average, H~High) against total space closure
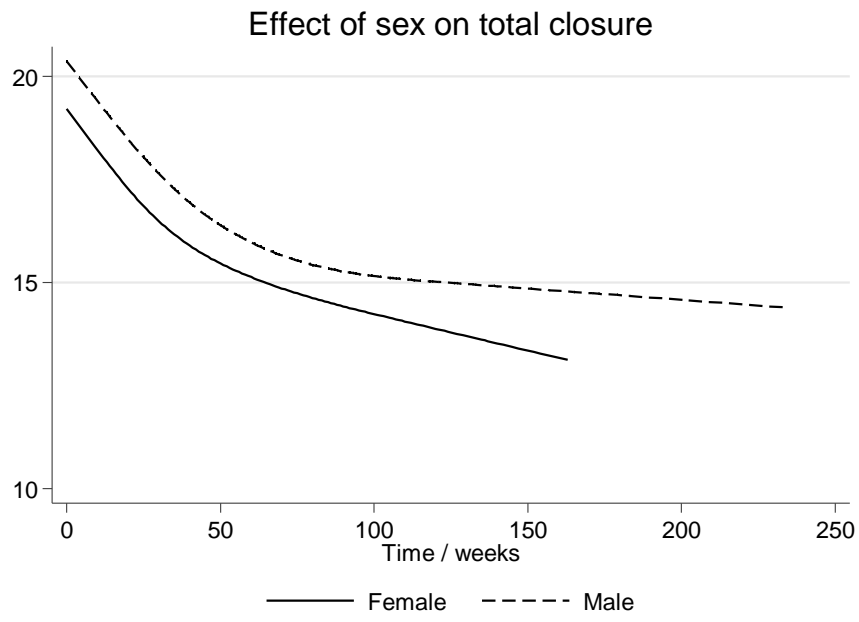
Figure 4 – Restricted cubic spline plot showing the effect of gender on total space closure

		Damon 3MX	In-Ovation R	Omni
Male	N	17	12	8
	Age	14.3(1.1)	14.1(1.5)	14.3(0.9)
Female	N	25	26	12
	Age	14.2(1.3)	13.8(1.4)	13.2(1.5)
FMPA	L (<22°)	4	4	2
	A (22° to 32°)	27	26	14
	H (>32°)	11	8	4
Little's Index	Maxilla	11.42 (1.89 to 25.82)	12.17 (2.66 to 23.52)	10.59 (3.28 to 19.98)
	Male	12.94 (3.19 to 25.82)		
	Female	10.71 (1.98 to 22.30		
	Mandible	8.80 (4.01 to 19.75)	8.17 (2.60 to 14.51)	6.75 (2.15 to 15.55)
	Male	8.09 (1.71 to 15.55)		
	Female	8.24 (2.33 to 19.75)		

Table 1 Demographic data for: Sex, Age (mean age and standard deviation (years), FMPA (L ~ low, A ~ Average, H ~ High) and Little's Index (mean and minimum / maximum (mm))

Space closure		Comparison	Effect	L95 %	U95 %	p
Passive space closure	Sex	M-F	1.064	0.521	1.607	0.001
		A-L	0.097	-0.992	1.186	0.995
	FMPA	H-L	-0.375	-1.580	0.831	0.841
		H-A	-0.471	-1.224	0.281	0.352
Active space closure	Sex	M-F	0.825	0.312	1.339	0.002
		A-L	-0.106	-1.132	0.920	0.993
	FMPA	H-L	-0.627	-1.782	0.528	0.478
		H-A	-0.521	-1.263	0.222	0.257
Total space closure	Sex	M-F	1.029	0.527	1.531	0.001
		A-L	-0.053	-1.050	0.945	0.999
	FMPA	H-L	-0.527	-1.640	0.587	0.593
		H-A	-0.474	-1.182	0.234	0.295

Table 2 The effect of gender and FMPA on space closure - mean effect size, 95% confidence intervals and probabilities