

# Bite force and its association with stability following Class II/1 functional appliance treatment

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**SUMMARY** The aims of this study were to investigate the value of pre-treatment maximal molar bite force as a predictive variable in determining post-treatment changes and stability following functional appliance treatment in Class II malocclusion children. Twenty-eight Class II malocclusion children having undergone functional appliance treatment were followed for at least 1 year post-treatment. Maximal molar bite force measurements, lateral cephalograms, and study casts were taken before treatment, after treatment, and after post-treatment follow-up. Relationships between pre-treatment maximal molar bite force and dental or cephalometric changes post-treatment were examined. Patients were divided into stable and unstable groups, based on dental sagittal changes (overjet and molar relationship), and differences between the two groups of patients determined.

Post-treatment changes varied widely. Thirteen children showed dentoalveolar sagittal relapse, namely a shift in molars towards a Class II relationship and an increase in overjet, while 15 did not. The unstable group demonstrated a lower pre-treatment maximal molar bite force, as well as a more obtuse gonial angle, than the stable group. The gonial angle was found to be negatively correlated to maximal molar bite force and may thus be a cephalometric indicator partly reflecting the functional condition of the masticatory muscles.

Children with a lower pre-treatment maximal molar bite force were more prone to dentoalveolar sagittal relapse following functional appliance treatment.

## Introduction

Long-term stability following Class II malocclusion treatment is the fundamental key to a successful treatment outcome, and of prime concern for patients and orthodontists alike. A large amount of variability is seen between patients as regards post-treatment changes, implying that in some patients the result is stable while in others this is not the case. Relapse, however, cannot be predicted at an individual level. In some patients, relapse tendencies are inevitable, but their extent and clinical significance are variable (Herzberg, 1973; Fidler *et al.*, 1995).

Several factors have been proposed to explain variability in the stability of treatment results. A major factor contributing to stability is the growth pattern of the patients (Ormiston *et al.*, 2005). A favourable growth pattern, in addition to correct diagnosis, treatment, and retention protocols in motivated patients, probably increases the likelihood of stable long-term treatment results (Lerstøl *et al.*, 2010). Prediction of relapse and/or stability after orthodontic treatment seems to be difficult as the dentition constantly changes throughout life, with or without orthodontic treatment (Bondevik, 1998). Besides growth, forces derived from the surrounding orofacial tissues are believed to promote stability (Melrose and Millet, 1998). When dental changes are in harmony

with the tongue and facial muscles, the result is thought to be more stable (Nanda *et al.*, 1993).

Good occlusal intercuspitation following Class II malocclusion treatment has been reported to be necessary to prevent skeletal and dental relapse (Pancherz, 1991; Wieslander, 1993). Nanda *et al.* (1993) suggest good occlusion and cuspal interdigitation, a constant intercanine width, and no proclination of the lower incisors as some of the most important factors for long-term stability following orthodontic treatment. Intercuspitation, as a proposed factor affecting stability, would come into play when the teeth are in occlusion. In healthy patients without parafunctions, the teeth come into occlusion during mastication and swallowing, and forces derived from the masticatory musculature and the soft tissues are important in performing these functions.

A factor that may, therefore, influence the stability of treatment results, following functional appliance treatment in Class II malocclusion children, is the functional capacity of the masticatory muscles. These muscles, which are directly involved in the mode of action of functional appliances, may also play a role in determining the post-treatment effects once the functional appliance is discontinued.

The aim of this study was to investigate the predictive value of pre-treatment masticatory muscle functional

capacity, as evaluated by maximal molar bite force measurements, in determining post-treatment changes, and relapse potential, following functional appliance treatment in Class II division 1 malocclusion children.

## Material and methods

### Subjects

Twenty-eight children in the mixed dentition and with a Class II division 1 malocclusion (16 male and 12 female), between the ages of 8.5 and 14.2 (mean age 10 years 6 months) at the start of the study, were chosen according to the following criteria: the presence of a skeletal Class II relationship ( $ANB > 4^\circ$ ), a retrognathic mandible ( $SNB \leq 78^\circ$ ), a distal molar relationship of at least one premolar cusp width on one side and half premolar cusp width on the other side, an overjet  $\geq 6$  mm, and no transverse discrepancies. This sample of children was derived from a larger sample of Class II division 1 malocclusion children mentioned in [Kjellberg \*et al.\* \(1995\)](#).

### Treatment procedure and experimental design

The children were treated with an activator according to Schwarz ([Graber and Neumann, 1977](#)) by a single operator (HK) for a period of approximately 1 to 2 years (mean, 1.6 years; SD, 0.4). They were subsequently followed for at least 1 year after the completion of treatment (mean, 2.2 years; SD, 0.9) without any further fixed appliance or other treatment during this period. Before treatment (T1), after treatment (T2), and after the post-treatment follow-up period (T3), height measurements, maximal molar bite force measurements, maximal finger force measurements, lateral cephalograms, and impressions for study casts were taken.

### Bite force

The maximum voluntary molar bite force (measured in Newtons) was determined using a bite force recorder as described by [Helkimo \*et al.\* \(1975\)](#). The subject was seated upright, the bite fork placed between the first molars on each side, and instructed to bite as hard as possible, without inflicting pain. All recordings were made twice in each position. To obtain as high bite force levels as possible, the subjects were encouraged to 'do their best'. The highest value recorded was used as the maximum bite force level.

Maximal finger force, as an indicator of general muscle force ([Kiliaridis \*et al.\*, 1993](#)), was similarly recorded with the bite fork placed between the thumb and index fingers of both left and right hands, and recorded twice for each hand. The higher of the two values was recorded for each child.

### Cephalometry

Lateral cephalograms were taken of all children in centric occlusion using the same machine ([Figure 1](#)). The

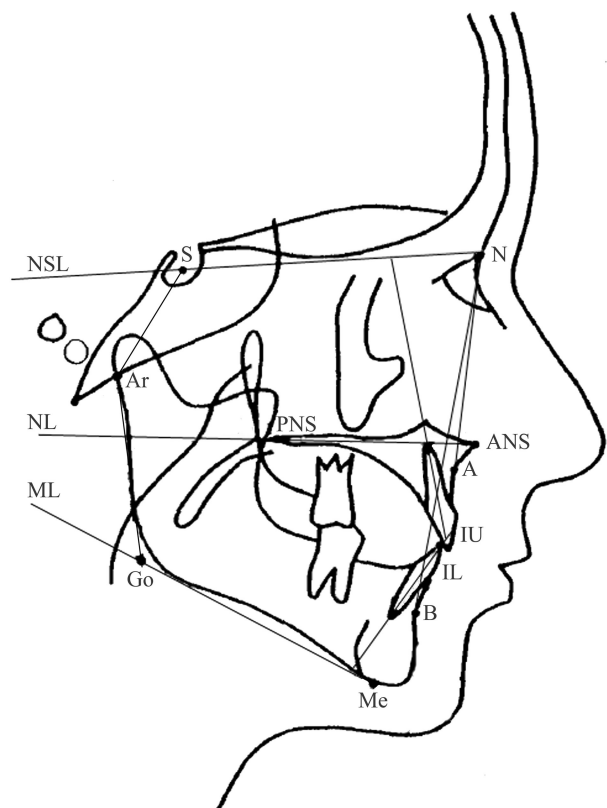
radiographs obtained were digitized and analysed twice, by one operator (HK), using a computerized cephalometric analysis (PC-DIG version 5.1 data system; Dr John McWilliam, Karolinska Institute, Stockholm, Sweden). The mean values between the two measurements were used in the study.

### Study casts

Overjet, overbite, and molar relationships were measured by one operator (GA). The molar relationship was recorded as a percentage of the Angle Class II relationship. An Angle Class I relationship of molars was denoted by 0 per cent and a full Angle Class II relationship of molars was denoted by 100 per cent ([Staudt and Kiliaridis, 2010](#)). Dental developmental stage was recorded, using the classification of [Thilander \*et al.\* \(2001\)](#).

### Stability

As an evaluation of post-treatment stability of dental changes, patients were separated into two groups, namely stable and unstable. Cases with a shift towards a Class II molar relationship (at least one molar was shifted  $\geq 25$  per cent towards a Class II molar relationship) and with an increase in



**Figure 1** Landmarks and reference lines used in the cephalometric analysis. S, sella; N, nasion; ANS, anterior nasal spine; PNS, posterior nasal spine; A, cephalometric point A; B, cephalometric point B; Me, menton; Ar, articulare; Go, Gonion; NSL, nasion-sella line; NL, maxillary line; ML, mandibular line; IU, upper incisor; IL, lower incisor.

overjet ( $\geq 0.5$  mm) post-treatment were judged as unstable, whereas cases where no post-treatment relapse in overjet or molar relationship occurred were judged as stable. Cases where the molars were towards a Class III relationship after treatment and shifted to a Class I relationship after follow-up were judged as stable despite a shift in molar Class, since a Class I molar relationship was the final result. In cases that lost the second deciduous mandibular molars during the follow-up period, changes in overjet were given priority.

### Statistics

All statistical analyses were performed using the Statistical Package for Social Sciences version 15.0 (SPSS Inc, Chicago, Illinois, USA). Maximal molar bite force and maximal finger force changes during the treatment and follow-up periods were evaluated using paired *t*-tests. Multiple regression analyses were used to determine possible correlations between initial maximal molar bite force and dental or cephalometric changes during the follow-up period, controlling for age, gender, and initial dental or cephalometric relationships. Since there was a rather large variation in the duration of the post-treatment follow-up period, changes were annualized and the statistical analyses were carried out with the annualized values. The correlations were considered significant at the  $P < 0.05$  level.

Considering the stable and unstable groups of patients, independent sample *t*-tests were performed looking at differences between the two groups in maximal molar bite force, height, height changes, age, age changes, dental developmental stage, dental and cephalometric variables, and dental and cephalometric changes. Chi-squared statistics were used to evaluate the differences in gender, post-treatment dental developmental stage, as well as post-treatment intercuspitation (Class I molar versus Class II molar) between the stable and unstable groups.

### Error of method

Dahlberg's formula (Dahlberg, 1940) was used to determine the error of the method for bite force, cephalometric, and study cast measurements. In using Dahlberg's formula ( $\sqrt{\sum d^2/2n}$ ),  $\sum d^2$  denotes the sum of the squared differences between pairs of recordings, while  $n$  denotes the number of duplicate measurements.

The methodological error for maximal molar bite force measurements was studied by repeated measurements of 20 randomly selected patients on two separate occasions, 2 to 4 weeks apart, and found to be 69 N.

The error of the method for the cephalometric and study cast variables was calculated by duplicate determinations on 15 randomly selected cephalometric radiographs and study casts with a 2-week interval between the measurements. For linear cephalometric measurements the error of the method did not exceed 0.7 mm, while for angular measurements

this did not exceed 0.9 degrees except for the incisal angle measurements, where the error varied from 1.0 to 1.5 degrees. For linear study cast measurements, the error of the method was 0.3 mm for both overjet and overbite. For the molar relationship measurements, the error of the method was 8 per cent (where 100 per cent represents a full cusp width).

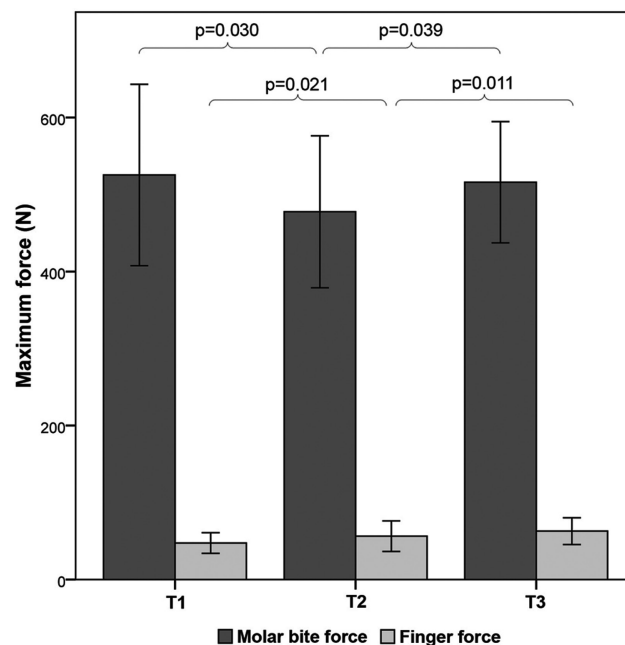
## Results

### Dental development

The children at T1 were all in the mixed dentition phase, either the late-mixed dentition stage (20 children) or the early-mixed dentition stage (8 children). At T2, 11 of the children were in the late-mixed dentition stage while 17 of the children were in the permanent dentition stage.

### Bite force and finger force changes

Maximal molar bite force was seen to decrease during the treatment period (T2–T1), while during the post-treatment period (T3–T2) maximal molar bite force increased, reaching approximately the pre-treatment levels. Finger force, on the other hand, increased progressively throughout the treatment and post-treatment periods. No associations were found in this sample between bite force and either gender or age (Figure 2 and Table 1).



**Figure 2** Maximal molar bite force and finger force measurements of the patient sample. Bars represent means while whiskers represent standard deviations for each time period (T1, T2, T3). The *P* values for the differences in maximal molar bite force and maximal finger force between the time periods are also shown.

**Table 1** Maximal molar bite force and finger force changes in the patient sample.

	T2-T1				T3-T2			
	Mean	SD	lower 95% CI	upper 95% CI	Mean	SD	lower 95% CI	upper 95% CI
Maximal molar bite force changes (N)	-47.7	116.9	-90.6	-4.9	32.1	71.8	5.30	61.2
Finger force changes (N)	8.6	20.5	1.4	16.4	10.8	18.2	2.7	18.9
Maximal molar bite force annualized changes (N)	-29.7	66.1	-53.9	-5.5	13.5	53.7	2.7	36.2
Finger force changes annualized (N)	4.9	13.3	0.1	9.8	5.5	12.1	0.2	10.9

Mean, standard deviation (SD), and 95% confidence interval (95% CI) values for maximal molar bite force and maximal finger force changes during the treatment (T1 to T2) and post-treatment (T2 to T3) periods are shown.

### Dental and skeletal changes

The observed changes, after 1.6 mean years of functional appliance treatment, were characterized by an increase in SNB and subsequent decrease in ANB, a decrease in the intermaxillary angle (ML/NL), retroclination of maxillary and proclination of mandibular incisors, a decrease in overjet, and an improvement in molar relationships. The post-treatment response during the 2.2 mean years of follow-up varied. Some children showed relapse, namely a shift towards a Class II molar relationship and increase in overjet, while others showed no relapse or an improvement during the post-treatment period. Statistical significant post-treatment changes were the following: a closing of the mandibular plane angle, intermaxillary angle, and gonial angle, and a retroclination of the mandibular incisors (Table 2).

### Regression analyses

Regression analyses did not show any significant correlations between pre-treatment (T1) maximal molar bite force and annualized cephalometric or dental changes during the post-treatment follow-up period (T3-T2) and when controlling for gender, age, and pre-treatment cephalometric values.

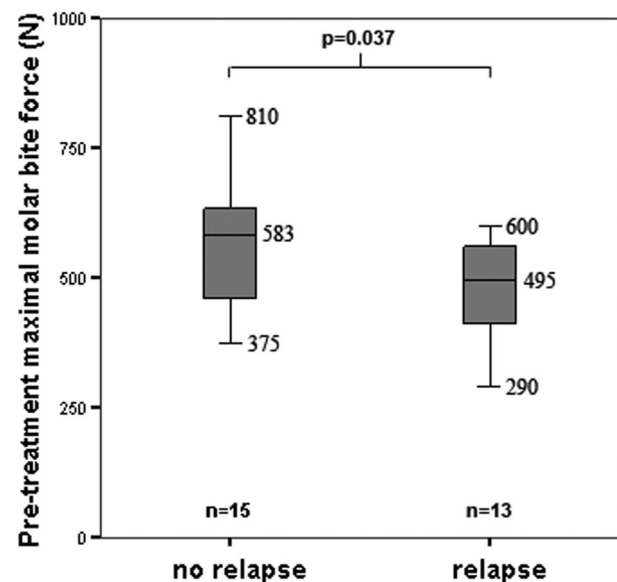
No correlations were found when looking at age, treatment (T2-T1) and post-treatment (T3-T2) duration, height, height changes, or dental developmental stage in relation to dental or cephalometric changes during the post-treatment follow-up period (T3-T2).

### Stable and unstable groups

When cases were divided into stable or unstable, referring to their post-treatment (T3-T2) dental changes, the stable group consisted of 15 patients, while the unstable group consisted of 13 patients. The unstable group revealed a mean increase in overjet of 1.4 mm (SD, 0.9 mm), and a relapse of the molar sagittal relationship towards a Class II situation of 18.3 per cent (SD, 10.4 per cent). How was the

change in the stable group? No significant differences were found between the two groups as regards gender, dental developmental stage, age, treatment or post-treatment duration, height, and height changes (Table 3).

Cases judged as stable showed a significantly higher pre-treatment (T1) maximal molar bite force than those judged as unstable (Figure 3). Maximal molar bite force at T2 and T3, although higher in the stable group, did not show significant differences between the groups. When comparing initial (T1) dental and cephalometric characteristics, only the gonial angle showed a significant difference ( $P = 0.035$ ), where the unstable group presented a larger gonial angle pre-treatment than the stable group (Table 4). In this sample, pre-treatment maximal molar bite



**Figure 3** Box plots of pre-treatment maximal molar bite force in the stable (no relapse) and unstable (relapse) groups. The boxes in the box plots display the lower quartile, median, and upper quartile. The whiskers display the smallest observation (minimum) and largest observation (maximum). The sample size in each group is indicated by  $n$ . The  $P$  value for the independent sample  $t$ -test comparing pre-treatment maximal molar bite force values in the two groups is also shown.

**Table 2** Cephalometric and dental characteristics of the patient sample.

	T1		T2		T3		T2-T1		P	T3-T2		P
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		Mean	SD	
Sagittal (Cephalometric)												
SNA (°)	81.3	2.9	81.0	2.9	81.3	3.2	-0.3	1.3	0.641	0.3	1.1	0.898
SNB (°)	75.4	2.9	76.5	2.9	76.7	3.1	1.1	1.0	<0.001***	0.2	1.2	0.440
ANB (°)	5.9	1.5	4.5	1.8	4.7	2.0	-1.4	0.9	<0.001***	0.2	1.0	0.840
Vertical (Cephalometric)												
ML/NSL (°)	32.8	4.8	32.6	5.1	32.2	5.6	-0.2	1.4	0.274	-0.4	1.6	0.010*
NL/NSL (°)	7.0	2.4	7.6	2.3	7.5	2.6	0.6	1.6	0.069	-0.1	2.2	0.690
ML/NL (°)	26.0	4.0	25.0	4.4	24.7	4.8	-1.0	1.8	0.018*	-0.3	1.6	0.006**
Gonial angle (Ar-Go-Me) (°)	123.5	4.6	123.9	5.1	122.4	4.7	0.4	2.2	0.306	-1.5	2.6	0.001**
Dental (Cephalometric)												
IU/NL (°)	112.8	4.9	108.3	4.7	108.4	5.8	-4.5	4.3	<0.001***	0.1	4.0	0.704
IL/ML (°)	98.4	5.2	99.6	5.0	97.8	4.7	1.2	3.9	0.041*	-1.8	3.6	0.022*
Dental (Study models)												
Overjet (mm)	8.6	1.2	4.4	1.3	4.7	1.2	-4.2	1.8	<0.001***	0.3	1.3	0.196
Overbite (mm)	3.2	1.7	2.7	1.2	3.0	1.4	-0.5	1.0	0.008**	0.3	0.8	0.074
Left molar relationship (% Class II)	85.5	28.0	30.6	27.2	34.6	30.2	-54.9	40.0	<0.001***	4.0	28.9	0.444
Right molar relationship (% Class II)	84.7	24.7	23.4	27.3	25.0	31.6	-61.3	34.1	<0.001***	1.6	26.6	0.989
Average molar relationship (% Class II)	85.1	20.1	27.0	23.1	29.8	26.6	-58.1	31.0	<0.001***	2.8	22.8	0.495

Mean and standard deviation (SD) values of measured cephalometric and dental variables are shown for each time period (T1, T2, T3) as well as for changes during the treatment (T1 to T2) and post-treatment (T2 to T3) periods. P-values (P) presented refer to the paired t-tests carried out. P < 0.05 is considered significant.

\*P < 0.05; \*\*P < 0.01; \*\*\*P < 0.001.

**Table 3** Age, treatment and post-treatment duration, height, and height changes in the two groups of patients (stable and unstable).

	Stable group		Unstable group		P
	Mean	SD	Mean	SD	
Pre-treatment age (years)	10.5	0.8	10.5	1.4	0.989
Post-treatment age (years)	12.1	0.9	12.3	1.6	0.670
Post follow-up age (years)	14.2	1.3	14.5	1.8	0.533
Treatment duration (years)	1.6	0.4	1.8	0.4	0.150
Post-treatment follow-up (years)	2.1	1.0	2.2	1.1	0.681
Pre-treatment height (cm)	145.4	8.0	148.4	9.8	0.360
Post-treatment height (cm)	155.1	8.8	159.1	7.4	0.187
Post follow-up height (cm)	166.2	9.8	172.2	5.7	0.086
Change in height during treatment (cm)	9.7	2.4	10.7	3.8	0.414
Change in height post-treatment (cm)	12.0	7.5	13.4	4.4	0.589
Annualized change in height during treatment (cm)	6.5	2.6	6.1	2.1	0.664
Annualized change in height post-treatment (cm)	5.6	2.3	6.7	2.9	0.320
Post-treatment/treatment change in height ratio	1.3	1.0	1.3	0.5	0.826
Annualized post-treatment/treatment change in height ratio	1.0	0.6	1.1	0.5	0.857

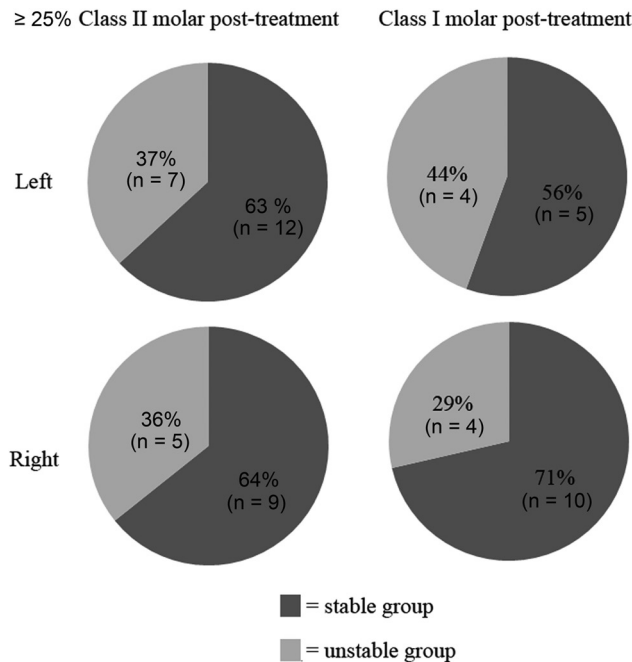
Means and standard deviations (SD) are shown. P-values (P) presented refer to the independent sample t-tests carried out.

force showed significant correlation with the pre-treatment gonial angle (Pearson correlation, -0.386; P = 0.032).

Evaluating post-treatment (T2) overjet as a variable in determining relapse potential, no significant difference was found between the stable and unstable groups. Evaluating post-treatment (T2) intercuspitation as a variable in determining relapse potential, no differences were found in the presence of relapse of molars between those that finished treatment in a Class I molar relationship versus those that finished treatment in a ≥25 per cent Class II molar relationship (Figure 4).

**Discussion**

In this patient sample, consisting of growing children with dental and skeletal Class II relationships treated with functional appliances, the post-treatment response varied. Some children showed relapse, while others showed a more stable post-treatment result. Bite force may be associated with sagittal stability of functional appliance treatment, whereby children with a lower pre-treatment maximal molar bite force may be more prone to sagittal dentoalveolar relapse.



**Figure 4** Pie charts displaying the number and proportion of post-treatment (T2) molars in a Class I compared to a ≥25 per cent Class II relationship (on the left or right sides) that were stable or unstable during the follow-up period (T3–T2). A comparison between the two groups using a chi-squared test did not show statistical significance.

*Bite force changes*

A stable occlusion has been shown to be a prerequisite for maximal muscle activity during biting (Ingervall and Egermark-Eriksson, 1979; Ingervall *et al.*, 1979; Bakke and

Møller, 1980). During functional appliance treatment (T1–T2), maximal molar bite force decreased. This was possibly due to mild muscular atrophy because of the decreased functional activity of masticatory muscles, related to occlusal instability. This decreased functional activity showed a certain amount of recovery after the interruption of functional appliances, increasing post-treatment (T2–T3). This increase in maximal molar bite force is in all probability the result of normal growth, and may be associated with a general increase in muscle force, evaluated in this investigation by measuring finger force.

*Bite force and post-treatment changes*

It has been previously proposed that, generally speaking, individuals with a lower bite force or thinner masseter muscles seem to show a greater dentoalveolar sagittal change in response to functional appliance treatment (Kiliaridis *et al.*, 2010; Antonarakis *et al.*, 2012). The proposition put forward to explain this difference in treatment outcome is that the exertion of weaker masticatory forces may decrease the anchorage of the mandibular dentition, suggesting that it is easier to ‘jump’ the occlusion in those with a weaker bite force. Weaker masticatory forces in the present investigation were associated with a less stable dentoalveolar sagittal result and thus with a greater tendency towards relapse, namely an increase in overjet and a shift of the molar relationship towards a Class II. A possible reason for this difference may be that in those with a weaker bite force, even though it may be easier to jump the occlusion, it may also be more difficult to maintain the sagittal relationship, implying an easier shift

**Table 4** Pre-treatment (T1) cephalometric and dental characteristics of the two groups of patients (stable and unstable).

	Stable group		Unstable group		P
	Mean	SD	Mean	SD	
<b>Sagittal (Cephalometric)</b>					
SNA (°)	81.0	3.0	81.7	2.8	0.458
SNB (°)	75.3	3.0	75.5	2.9	0.830
ANB (°)	5.7	1.2	6.2	1.7	0.310
<b>Vertical (Cephalometric)</b>					
ML/NSL (°)	32.6	5.0	33.0	4.8	0.793
NL/NSL (°)	7.3	2.8	6.7	2.0	0.505
ML/NL (°)	25.6	4.2	26.4	4.0	0.627
Gonial angle (Ar–Go–Me) (°)	121.8	4.7	125.2	3.9	0.035*
<b>Dental (Cephalometric)</b>					
IU/NL (°)	111.7	4.8	114.1	4.8	0.178
IL/ML (°)	98.4	4.8	98.4	5.7	0.994
<b>Dental (Study models)</b>					
Overjet (mm)	8.3	1.2	8.8	1.1	0.250
Overbite (mm)	3.0	1.9	3.5	1.5	0.485
Left molar relationship (% Class II)	82.8	28.5	88.3	28.1	0.591
Right molar relationship (% Class II)	82.8	23.7	86.7	26.5	0.673
Average molar relationship (% Class II)	82.8	18.2	87.5	23.1	0.538

Means and standard deviations (SD) are shown. P-values (P) presented refer to the independent sample t-tests carried out. P < 0.05 is considered significant.

\*P < 0.05.

back towards a Class II relationship. This may be explained by the eruption pattern of teeth following different jaw rotations, namely that those with a forward rotation of the jaws show a resulting forward eruption path of the molars and a forward shift of the lower dental arch, as opposed to a more vertical or backward eruption path in those exhibiting a backward rotation (Björk and Skieller, 1972). Hence, children with a stronger bite force may show more forward eruption of the lower molars and hence a better chance for dentoalveolar stability and conservation of the molar relationships.

Another possible reason for the differences is that bone density may also be important as regards stability. The mandibular trabecular bone is subject to physiological remodeling throughout life, and can be influenced by masticatory demands (Jonasson and Kiliaridis, 2004), thus individuals with a lower bite force may exhibit lower bone density, and hence easier tooth movement. In rats, lower bone density has been associated with faster orthodontic tooth movement, than in those with significantly higher bone density (Bridges *et al.*, 1988).

It is also interesting to note that the group of patients that showed a more unstable result post-treatment tended to have not only a weaker bite force pre-treatment, but also a more obtuse gonial angle. Ingervall and Helkimo (1978) found that individuals with a lower bite force have on average a more obtuse gonial angle than individuals with a higher bite force, which was also found in the present patient sample. The gonial angle can be assumed to be a cephalometric indicator partly reflecting the initial condition and functional capacity of the masticatory muscles. Different responses post-treatment in individuals with obtuse or acute gonial angles may not be due to the cephalometric difference as such, but rather to the functional capacity of the masticatory muscles, investigated by measuring bite force. The gonial angle is known to be an adaptive morphological region of the mandible, which can adapt to function.

Our findings are in line with those of Pancherz and Anehus (1978), who found that the electromyographic activity from the temporal and masseter muscles seems to be less on average in patients who show relapse than in those where the treatment is considered stable.

#### *Comments on material and methods*

Maximal molar bite force measurements are associated with a rather large type II error that might mask possible associations. No associations were found in the present sample between initial bite force and either gender, age, or dental developmental stage. Bite force variation in the present patient sample was thus due principally to individual variation rather than to heterogeneity of the sample. Gender, at the ages of the children examined, does not seem to have an important influence on bite force (Kiliaridis *et al.*, 1993).

The sample size of this study is limited. This is especially true when dividing the patients into two groups, namely stable and unstable, thus diminishing the statistical power

of the study. When performing independent sample *t*-tests to detect differences between the two groups, the statistical power was approximately 75 per cent. The findings should thus be corroborated with further evidence.

#### *Relapse and growth*

All occlusal traits relapse gradually over time (Al Yami *et al.*, 1999). Changes obtained during the active treatment period of a successful functional appliance therapy tend to relapse towards the initial malocclusion in the post-treatment years (DeVincenzo, 1991). It is not possible, however, to identify if relapse post-treatment is the result of actual relapse following orthodontic treatment alone, or the result of physiological changes in the dentition and surrounding tissues during the follow-up period (Bondemark *et al.*, 2007). Mandibular growth seems to be important both during and after active treatment. It has thus been proposed that significant long-term changes in occlusal relationships can be achieved with functional appliance therapy only when the functional treatment includes the growth spurt (Faltin *et al.*, 2003). In the present patient sample, growth changes did not seem to influence stability.

#### *Variation in post-treatment stability*

Variation in post-treatment stability following Class II malocclusion treatment may depend on several factors besides growth, such as malocclusion severity, intercuspitation, molar change, and overjet reduction. Janson *et al.* (2004) found that initial Class II malocclusion severity and molar relationship did not present any correlation with relapse, but that initial overjet did. Moreover, if there was a greater molar change during treatment, this was less stable. Pancherz and Hansen (1986) also noticed that a greater molar change during treatment is more prone to relapse. Correspondingly, Drage and Hunt (1990) found a small correlation between the amount of overjet corrected during functional appliance therapy and relapse. In this study, no such correlations were found. This may have been due to the small size of the sample investigated or the short length of the follow-up period.

Some authors suggest that good clinical intercuspitation is necessary to prevent skeletal and dental relapse (Pancherz, 1991; Nanda *et al.*, 1993; Wieslander, 1993). This, however, was not found in this study when comparing relapse in patients who finished treatment in a Class I versus a 25–50 per cent Class II molar relationship, which is in accordance with Fidler *et al.* (1995). Ferguson (2010) maintains that post-treatment ideal sagittal molar intercuspitation does not guarantee post-treatment stability.

#### *Masticatory muscle factors and relapse*

It is known that among growing individuals, the size of the masticatory muscles varies widely (Raadsheer *et al.*, 1996). This variation in muscle thickness may imply a variation in bite force, which may explain in part the variation in

treatment and post-treatment outcomes. The masticatory muscles are thought to play a pivotal role not only in contributing to the etiology of malocclusions and the application of treatment mechanics but also in the potential success of treatment outcomes (Hunt, 2010) and perhaps in the stability of treatment and post-treatment changes.

## Conclusions

In this sample, children who showed dentoalveolar sagittal relapse following functional appliance treatment were more likely to have a lower bite force pre-treatment, as well as a more obtuse gonial angle. The functional capacity of the masticatory muscles may play a role in contributing to the variation seen as regards post-treatment outcomes and stability.

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