



# The Effects of Class II Functional Appliance Treatment Are Influenced by the Masticatory Muscle Functional Capacity

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## Abstract

Large variation exists amongst patients with regards to treatment outcomes following functional appliance treatment in growing children. Various factors have been assessed with regard to this variation, but evidence is scarce. Recent studies suggest that the initial condition of the masticatory muscles may be one of the factors that influences treatment and post-treatment functional appliance outcomes. Children with weaker masticatory muscles show greater dentoalveolar change, as witnessed by incisor compensation and molar movement. Following functional appliance treatment, children who show greater dentoalveolar treatment change may also be those with a more likely post-treatment sagittal relapse. The gonial angle may also be a variable determining treatment outcomes with functional appliances in that more incisor compensation and a greater likelihood for relapse is evident in those with a more open gonial angle. The gonial process is the site of muscle attachment for the masseter and median pterygoid muscles, and the thickness and force of these muscles can have an effect on the process and its contribution to mandibular morphology. By extrapolation, cephalometric analysis of the gonial angle can perhaps provide insight into the amount of incisor proclination expected to be observed during and after functional appliance treatment.

**Keywords:** Class II Malocclusion, Functional Appliances, Masticatory Muscles, Treatment Outcomes, Stability, Ultrasonography, Bite Force

## 1. Context

Functional appliances have as an objective the alteration of the sagittal and vertical position of the mandible (1), and are often used to treat class II malocclusion in growing patients. When the appliance is worn, the mandible is displaced downwards and forwards, and this in turn causes the soft tissues and muscles to stretch, as well as myotatic reflexes (2, 3). Forces exerted on the teeth and the skeletal structures when wearing functional appliances are proposed to be produced by the combination of myotatic reflexes and viscoelastic muscle properties. These forces can result in correcting the malocclusion (1). Dentoalveolar change is brought about by a shift in the dental arches towards a class I molar relationship, and by incisor compensation which is a combination of uprighting of maxillary incisors and proclination of mandibular incisors (4, 5). Skeletal changes are thought to be due to an acceleration of mandibular condylar growth (6-11) and fossa advancement (4, 12-14). Functional appliances also produce a headgear-like effect, whereby maxillary growth is restricted to some extent (4, 5, 14-19).

The results of treatment with functional appliances are in many cases favourable clinically, but the question of whether growth modification truly occurs is debated. Evidence is inconsistent as to the use and effectiveness of these appliances (3, 20-25). Some studies report significant effects, while others fail to demonstrate any reliable change, with skeletal treatment changes being on average, not very large, with large inter-individual variation, and most importantly not predictable (2, 3, 23, 26).

On the whole, the literature supports the notion that skeletal relationships are somewhat improved with the use of functional appliances in growing children (20-22, 25, 27-30). Results obtained in individual studies however may not be applicable to different or larger population samples, and for this reason any changes recorded may neither be predictable nor different to a significant extent than changes occurring with no active treatment or with fixed appliance treatment (26). Factors such as study design (31, 32), patient collaboration, and the difficulty in controlling the quantity and direction of growth of the mandible (27) may be the reason why large variation is seen between

individuals (23), leading to small mean changes found in studies. With regard to compliance however, even in studies where fixed functional appliances are used, and therefore the problems of compliance eliminated, results still display large variation (33-35).

Even if it is accepted that a small amount of skeletal improvement is acquired through the use of functional appliances, it is known that the majority of the improvement is through dentoalveolar compensation (36). Meta-analyses show that functional appliance use leads to a small but significant skeletal changes (36-41) and dentoalveolar changes which are namely mandibular incisor labial tipping, maxillary incisor uprighting, mesialisation of mandibular molars and distal movement of maxillary molars (36, 40).

An important deduction from studies investigating functional appliance treatment outcomes is that not all individuals respond the same way to these appliance. The masticatory muscles and their functional capacity may be another variable that could have a role in explaining variation observed between children. Antero-posterior intermaxillary forces exerted by functional appliances during treatment display wide variation in magnitude ranging from 0.25 to 5 Newtons, and in direction (42, 43). This variation is present both between patients as well as for the same patient during the treatment period. In parallel, the expression of the masticatory musculature, as measured through bite force (44-47) or masseter muscle thickness (48) also shows considerable variation. In line with this reasoning, the quantity or direction of forces exerted on the dental and skeletal tissues may be related to a child's functional muscular capacity (49).

Large variation exists amongst patients with regards to the treatment outcome following functional appliance treatment. Large variation also exists in the masticatory muscle characteristics amongst patients, and these characteristics, namely muscle strength and masseter muscle thickness, have been proposed to be under genetic control (50). Based on the current knowledge, it is unclear whether variations in the functional capacity of the masticatory muscles in children with class II malocclusions undergoing functional appliance treatment may be responsible in part for the variation in treatment outcome. This review aims to look into this question, asking whether the variables of muscle strength and thickness can be predictive in defining whether functional appliance treatment will be favourable and stable in the long-term.

## 2. Evidence Acquisition

Literature was searched using PubMed in order to locate articles pertaining to the influence of bite force or

masseter muscle thickness on functional appliance treatment outcomes or stability. The search strategy used was the following: (bite force OR muscle thickness AND functional appliance AND class II) with the last search performed on 13th May 2018. This search yielded 25 articles, 4 of which were deemed relevant to our clinical question (51-54).

## 3. Results

### 3.1. Masticatory Functional Capacity and Treatment Outcome

Muscles of mastication may be important players not only in their contribution to the aetiology of malocclusion but also in determining success following functional appliance treatment (55). The initial condition of the masticatory musculature and its functional capacity may influence dentoalveolar and skeletal treatment effects. From the results of a recent prospective study, when looking at masseter muscle thickness in relation to changes during functional appliance treatment, growing children with thinner masseter muscles prior to treatment show a greater amount of mandibular incisor proclination in relation to the mandibular plane and distalisation of maxillary molars during treatment (51). When looking at maximal molar bite force in relation to changes during functional appliance treatment, a retrospective study has shown that growing children with lower maximal molar bite force show a more important reduction in overjet and improvement in molar relationships (52).

On the other hand, children with thicker pre-treatment masseter muscles seem to develop a greater ramus height, mandibular unit length, and posterior facial height during treatment (55). The stimulation of the mandibular gonial angle by the masticatory muscles, which is correlated with maximal molar bite force, may explain these results. The gonial process is the site of attachment of the masseter and medial pterygoid muscles, and it has been postulated that the relative development and organisation of these muscles, providing a mechanical stimulus for bone formation, influence its morphology (56, 57). Children with a larger gonial angle have been shown to display more dentoalveolar compensation during functional appliance treatment, seen by a larger amount of proclination of mandibular incisors and/or retroclination of maxillary incisors. The relationship between the mandibular gonial angle and the amount of incisor compensation highlights the interplay between the masticatory muscles and the dentoalveolar response. Gonial angles that are more obtuse may indicate that they have been subject to less muscular mechanical stimulation, which may be seen in children with weaker

masticatory muscles and weaker contractile forces. Masseter muscle volume has also been found to correlate with the mandibular gonial process (58), whereby those with a larger gonial angle have smaller muscle volumes. Similarly, those with weaker bite forces show more open gonial angles than those with stronger bite forces (47, 59).

Results from a study that tried to identify variables that could predict growth changes in the mandible following class II functional appliance treatment concluded that a smaller gonial angle may be able to predict an increase in total mandibular length and hence a favourable treatment outcome (60). By extending their line of result, it is possible to make the assumption that children with a smaller gonial angle have stronger masticatory muscles and hence more skeletal mandibular change, and less dentoalveolar change is likely when using functional appliances to correct a class II malocclusion. Part of the variation observed in the outcomes following functional appliance treatment can thus be explained.

The above-mentioned findings have been corroborated by a recent longitudinal prospective controlled study which also found that the response to functional appliance treatment in class II malocclusion children depends in part to the functional capacity of their masticatory muscles (53). Even though a shift in sagittal occlusal relationships occurs in all compliant children treated with functional appliances, individuals with thinner or weaker masticatory muscles may display greater dentoalveolar changes (mesial mandibular molar movement, distal maxillary molar movement, consequent change in molar class, and mandibular incisor proclination) compared to individuals with thicker or stronger masticatory muscles. These findings support and strengthen the already existing evidence linking masticatory muscle functional capacity to the outcomes of class II functional appliance treatment. This may however only be one of many predictive factors determining response to class II functional appliance treatment.

Summarizing the above findings (Table 1), weaker masticatory muscles are associated with a greater amount of dentoalveolar compensation in class II functional appliance treatment, as made visible by mandibular incisor proclination, and molar displacement resulting in changes in molar relationships. Those with stronger masticatory muscles show larger resistance to this effect. Likewise, the headgear-like dentoalveolar effect of functional appliances is more pronounced in children with a weaker bite force. When intermaxillary occlusal relationships are shifted from a class II to a class I using functional appliances in children, weaker vertical intermaxillary forces may show less resistance to this effect. Even though these vertical occlusal forces are of short duration, they are im-

portant with regard to tooth movement. Research shows that due to the presence of an interarch obstacle, tooth movement can be partially impeded (61). When using functional appliances, this may be important during the time of day when the child is not wearing their appliance. Stronger masticatory muscles can perhaps increase the vertical anchorage of the dentitions because of the exertion of larger masticatory forces making 'jumping' or shifting of the occlusal relationships more difficult, because of the higher vertical forces exerted on the inclined planes of the occlusal cusps.

The quality of the mandibular alveolar bone may be another factor that is related to masticatory muscle characteristics and therefore perhaps to variation in treatment response. Physiological remodelling of the trabecular mandibular bone occurs throughout life, and masticatory demands can influence this process (62). It has been found that mandibular alveolar bone mass is determined by masseter muscle thickness (63). Lower bone density in rats has been associated with faster orthodontic tooth movement (64, 65). By extrapolating these results, children with weaker masticatory muscles may have a lower bone density, and consequently more dentoalveolar changes during treatment with functional appliances, since teeth may be easier displaced in less dense alveolar bone.

### 3.2. Masticatory Functional Capacity and Post-Treatment Stability

In the treatment of class II malocclusion children, sagittal relapse is sometimes observed, but does not always compromise an otherwise successful correction of the class II malocclusion (66). Class II malocclusion treatment is only successful as long as the outcome is stable in the long term, from the point of view both of the orthodontist and the patient. Variability is large when assessing long-term stability and changes occurring post-treatment, whereby outcomes are stable in some patients but not others. Relapse tendencies are observed in some patients, although their extent and clinical significance are variable (66, 67). Relapse, however, following orthodontic treatment cannot be predicted at an individual level (68).

We know that relapse occurs in some class II malocclusion patients but not others, but to date one is not able to accurately identify those individuals more prone to relapse. Trying to determine what factors are responsible for relapse in a subgroup of class II malocclusion patients is crucial for individualised patient management protocols. Several factors have been studied that may influence relapse, but without having established well-understood and confirmed predictive factors (69). Factors that have been studied include patient characteristics such as the severity of the initial occlusal conditions, growth stage and

**Table 1.** Summary of the Observed Associations Between Masticatory Muscle Functional Capacity and Class II Division 1 Functional Appliance Treatment Outcomes<sup>a</sup>

Dentoalveolar Sagittal Treatment Outcome	Kiliaridis et al. (51)	Antonarakis et al. (52)	Antonarakis and Kiliaridis (53)
Improvement in molar relationships		X	X
Distalisation of maxillary molars			X
Mesialisation of mandibular molars	X		X
Overjet reduction		X	
Mandibular incisor proclination	X		X

<sup>a</sup> An 'X' indicates that in the cited study, thinner masseter muscles OR/AND a weaker bite force was associated with a greater change in the respective treatment outcome.

continuing growth patterns, and treatment characteristics such as treatment modality, changes in arch forms, and final occlusion after orthodontic treatment (70-72). There is however a lack of consensus in the literature regarding which factors may influence relapse and stability (68).

It has been reported that following the treatment of a class II malocclusion, good occlusal intercuspitation is necessary in order to prevent skeletal and dentoalveolar relapse (34, 73, 74). Fidler et al. (66) however evaluated patients with successful occlusal results (good intercuspitation and incisor occlusion) and found that despite this, there were significant changes seen post-treatment. Ferguson (75) emphasized that ideal sagittal molar relationships after treatment cannot guarantee long-term stability. Good occlusal contacts as such may therefore not be sufficient in order to maintain good stability. What may be more important in this respect are masticatory muscles and soft tissues, which may play an important role in conserving the intermaxillary occlusal position by the delivery of occlusal forces. This suggests that masticatory muscle characteristics may play a role in stability and the relapse potential following functional appliance treatment. It has been proposed that the risk of relapse can be reduced only by neuromuscular balance, brought about by extensive adaptation of the masticatory musculature as a response to changes in sagittal jaw relationships (76).

The functional capacity of the masticatory muscles has been shown to be related to the predisposition for relapse, in that individuals with weaker masticatory muscles show more relapse (54). Individuals that show relapse following class II functional appliance treatment, tend to have smaller pre-treatment maximal molar bite force. Pancherz and Anehus (77) found similar results, showing that masticatory muscles showed less electromyographic activity in children who showed relapse than in children with more stable treatment outcomes. Therefore weaker masticatory forces are associated with a less stable dentoalveolar sagittal result, and this difference may be due to the fact that in children with weaker masticatory muscles, the occlusion can more easily jump back to a more class II relationship.

The eruption pattern of teeth following different jaw rotations may help explain this observation, by observing that in children with an anterior rotation of the jaws, the eruption path of the lower molars is also more anterior, favouring the dentoalveolar shift of the mandibular dental arch, in comparison to children with a posterior jaw rotation and more vertical or posterior eruption paths (78). Hence, in those with stronger muscles, a more anterior eruption path of the mandibular molars may be evident, leading to a better chance for dentoalveolar stability and the maintenance of the molar relationships. Pancherz (79) found that class II patients who relapse following functional appliance treatment had more posterior jaw rotation than those who were stable. Individuals with strong masticatory muscles have been found to have a more homogeneous facial morphology than those with weak masticatory muscles (59). This may imply that individuals with stronger masticatory muscles can be expected to show more stable results while individuals with weaker masticatory muscles may show more heterogeneous results as regards stability.

Another important point worth raising is that in children with a less stable post-treatment outcome, not only is the masticatory system weaker, but they also have a more obtuse gonial angle. This finding can perhaps be explained, similarly to the findings where a more obtuse gonial angle is associated with greater changes in incisor proclination during treatment, by the muscular stimulation on the gonial angle of the mandible, this being a site of muscle attachment. In patients with a more obtuse gonial angle, the gonial process may not be subject to as much stimulation from the masticatory muscles due to the contraction forces being lower, and thus less anchorage of the mandibular dentition being present, allowing easier shifting and relapse of the occlusion. Another possible reasons for the differences in relapse following class II malocclusion treatment related to masticatory muscles is bone density, as was similarly described previously when discussing treatment outcome. Individuals with weaker masticatory muscles may have less dense alveolar bone, and by conse-

quence, tooth movement is easier which predisposes to relapse.

The different factors possibly influencing stability following class II malocclusion treatment can be pieced together using masticatory muscles as the connecting factor. When talking about interdigitation of teeth in occlusion, one may assume that those with stronger masticatory muscles may better be able to maintain this interdigitation with stronger masticatory forces preventing the teeth shifting back into class II occlusion. In addition, when bringing to mind post-treatment growth and its influence on stability, one may argue that those with stronger masticatory muscles are more likely to have more of an anterior growth pattern, which plays in favour of sagittal stability.

Little evidence is available to support the influence of the various predictive factors in determining which patients are prone to relapse following functional appliance treatment for class II malocclusion (69). Functional factors however make up perhaps the most plausible explanation that can affect class II malocclusion relapse tendencies and thus good quality robust studies in this direction in the future are warranted.

### 3.3. Clinical Implications

The thickness of the masseter muscle and maximal molar bite force are perhaps capable of suggesting what the outcomes and relapse potential of functional appliance treatment may be. Orthodontists treating patients with functional appliances however, do not usually have access to an ultrasound machine which can measure masseter muscle thickness or to a bite force gauge in order to measure maximal molar bite force, therefore a simple clinical recommendation can be proposed in line with the findings concerning the gonial angle in relation to incisor compensation, as well as to stability. The gonial angle which is a site of masticatory muscle attachment can provide a good estimation of the masticatory muscle functional capacity. This angle can simply be measured on a cephalometric radiograph and be used as a predictor of dentoalveolar/incisor compensation. In other words, children with a larger gonial angle make the treating orthodontist anticipate more incisor compensation during functional appliance treatment, than in children with a smaller gonial angle. Moreover, the gonial angle can also be used as an indication of expected stability, preparing the treating orthodontist to expect a larger probability for post-treatment relapse following functional appliance treatment in children with a more obtuse gonial angle.

Raising the orthodontist's awareness is important regarding variation and expected long-term outcomes following removable functional appliance treatment in children with class II malocclusion. With more research in this

area, it may be possible in the not too distant future to discuss the potential of modifying a growing child's masticatory muscle characteristics, by focused training of these muscles, prior to commencing treatment with functional appliances, but this warrants exploration in further studies.

## 4. Conclusions

The functional capacity of the muscles of mastication may be one of the factors that influences treatment and post-treatment functional appliance outcomes. Children with weaker masticatory muscles show greater dentoalveolar change, as witnessed by incisor compensation and molar movement. Following functional appliance treatment, children who show greater dentoalveolar treatment change may also be those where post-treatment sagittal relapse is more likely. Children with a large gonial angle are also perhaps more prone to display more incisor compensation during treatment, and more relapse risk during post-treatment follow-up. The gonial angle, which is a site of masticatory muscle attachment, defining mandibular morphology, can provide valuable information regarding the masticatory muscles. In practice, this angle can be measured on lateral cephalograms and used as a possible predictor of the amount of incisor compensation expected as well as potential for post-treatment relapse.

## Footnotes

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