The use of functional appliances in contemporary orthodontic practice

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PRACTICE

IN BRIEF

- Describes the different types of functional appliance.
- Explains the different ways in which functional appliances work.
- Explores the evidence behind claims that functional appliances affect skeletal growth.
- Outlines how functional appliances are used in orthodontic practice and their limitations.

Functional appliances have been used for over 100 years in orthodontics to correct Class II malocclusion. During this time numerous different systems have been developed often accompanied by claims of modification and enhancement of growth. Recent clinical evidence has questioned whether they really have a lasting influence on facial growth, their skeletal effects appearing to be short term. However, despite these findings, the clinical effectiveness of these appliances is acknowledged and they can be very useful in the correction of sagittal arch discrepancies. This article will discuss the clinical use of functional appliances, the underlying evidence for their use and their limitations.

INTRODUCTION

The term functional appliance refers to a large and diverse family of orthodontic appliances designed mainly to correct Class II malocclusion. They were developed primarily in Europe but have been adopted by orthodontists in many countries. They all work by posturing the lower jaw forward, the stretched musculature and soft tissues creating a force, which is transmitted to the dentition. In addition, the soft tissue envelope surrounding the teeth is changed. This results in tooth movement, establishment of a new occlusal relationship and reduction of the overjet. The efficiency of these appliances in the correction of sagittal discrepancies in growing patients has intrigued orthodontists for many years, particularly the question of whether they significantly affect skeletal growth. There has been a lot of mystery and misinformation associated with their use, often supported by quasi-scientific theories of growth. Many of the claims made in association with these appliances are in the form of case reports, or retrospective studies, using unreliable and over-complicated cephalometric analyses, with all the inherent bias associated with these types of study.[1] More recently, the results of several large prospective clinical trials have provided the best evidence of what these appliances can do and equally importantly, what they do not do.

The development and use of functional appliances was pioneered in Europe early in the twentieth century, at the same time that fixed appliances were being developed in the USA. A simple monobloc appliance was described by Pierre Robin in 1902[2] for use in mandibular retrognathia and functional jaw expansion, it was the precursor of the appliance used for the treatment of Class II malocclusions described by Viggo Andresen while working at the dental school in Oslo. The story goes that following fixed appliance therapy on his daughter he fitted her with a modified upper Hawley type retainer with a lower lingual flange that guided the mandible forward into an ideal inter-arch relationship. The appliance was fitted as a retainer during her three month summer holidays to be worn at night, and it corrected her Class II relationship. Andresen refined the technique and appliance, with the assistance of Karl Häupl, and coined the phrase 'functional jaw orthopedics' to encapsulate their philosophy of how the appliances worked. A detailed history on functional appliances and the personalities involved has been published by Levrini and Favero.[3]

TYPES OF FUNCTIONAL APPLIANCES

Functional appliances can either be removable or fixed. Numerous different types and designs have been described usually bearing the name of their inventor and incorporating components reflecting their philosophy. Functional appliances all have a postural effect on the mandible, although how this is achieved and the auxiliary components they incorporate vary between different systems.

Fig. 1 Modified Andresen activator. The original design did not have lower incisor capping or Adams cribs, which have both been added for retention

Removable functional appliances

Activators

The original Andresen-Häupl activator was constructed from a single block (or monobloc) of Vulcanite, which was later replaced by acrylic (Fig. 1). The postural element of the appliance is achieved by a lingual extension of the bloc in the lower arch. It was deliberately made loose to encourage activation of the protractor and elevator muscles to keep it in place. Apart from this postural effect it is designed to be a passive appliance, although guided eruption of the buccal dentition can be achieved by facets cut into the bloc. Numerous variations of the activator have been developed. Increased

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vertical opening of the appliance has been described by Herren, Harvold and Woodside. An increase in vertical opening beyond the freeway space supposedly activates the viscoelastic pull of the tissues, similar to the stretch reflex, as opposed to just relying on activation of the muscles. Other activators are designed for use with headgear to restrain maxillary growth, such as the Teuscher appliance (Fig. 2). This appliance incorporates spurs on the upper incisors to prevent lingual tipping of the teeth while high-pull headgear is applied. Another variation of the activator is the Bionator developed by Wilhelm Balters, who reduced the bulk of the appliance making it easier to wear (Fig. 3). Others such as the Bass or Dynamax appliances remove direct contact with the lower incisors to try and prevent their proclination. Posturing of the mandible forwards is achieved by lingual spurs or springs that sit in the mandibular lingual sulcus (Fig. 4).

The most significant modifications of the activator appliance are the function regulators developed by Rolf Fränkel in the former German Democratic Republic.[4] These appliances are deliberately designed to have minimal tooth contact and consist of a metal framework with buccal shields and anterior lip pads designed to relieve cheek and lip pressure and disrupt any abnormal perioral muscular activity (Fig. 5). Fränkel developed these appliances to be worn full time combined with oral exercises and, of all the functional appliances, the function regulator is probably the one that lives up to best to the description of functional.

Twin blocks

All the activator variations described above are essentially one-piece appliances. This means that they cannot be worn during eating. To overcome this, William Clark developed the Twin Block appliance[5] (Fig. 6), which consists of upper and lower removable appliances with bite blocks composed of bite ramps set at about 70 degrees. When occluding, the lower block bites in front of the upper to posture the mandible forwards. Generally, the Twin Block appliance is robust and well tolerated, and has become very popular in the UK.

Fixed functional appliances

A major problem with any removable functional appliance is compliance, because they do not work unless they are worn for the required number of hours each day. This can be overcome by the use of a fixed functional appliance. The most well-known and popular fixed functional appliance is the Herbst appliance. This was first described by Emil Herbst in 1905, which makes it almost as old as the speciality of orthodontics itself.

Fig. 2 Teuscher-type activator with torquing spurs and headgear tubes

Fig. 3 Modified Balters Bionator with lower incisor capping

Fig. 4 The Dynamax appliance. Mandibular protrusion is achieved by lingual springs or spurs that rest behind shoulders on a lower fixed lingual arch

However, it disappeared into obscurity until it was rediscovered and popularised by Hans Pancherz in the late 1970s.[6] Since then, it has grown in popularity and is now one of the most widely used and researched functional appliances in the world. It consists of separate superstructures cemented to the mandibular and maxillary dentition, and constructed from either orthodontic bands or cobalt chromium cap splints connected by telescopic pistons that provide the protrusive force to the mandible (Fig. 7).

Such is the prevalence of Class II malocclusion in developed countries and the desire for a predictable and compliance-free way of correction that numerous variations of the fixed Class II corrector based on the Herbst principle have been described. They usually have exciting and promising names but most are introduced without being properly clinically tested. A few persist and prove to be clinically useful. An example of this is the FORSUS® spring from 3M. This is similar in design to the Herbst, but attaches directly to the molar bands of a fixed appliance and the lower arch. It consists of a piston and nickel titanium spring that produces a protrusive force on the lower dental arch (Fig. 8).

Fig. 5 A modified functional regulator (FR 2) appliance with lower incisor capping

Fig. 6 A Twin Block appliance

Fig. 7 A Herbst appliance

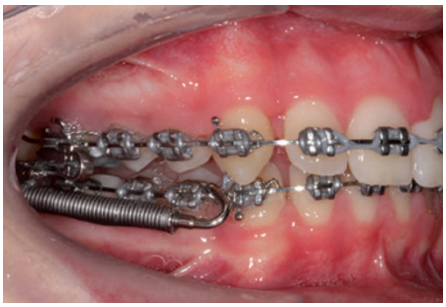

Fig. 8 FORSUS® spring

HOW DO FUNCTIONAL APPLIANCES WORK?

There is no doubt that a functional appliance in a growing patient can be very effective in reducing even a very large overjet. However, controversy remains about how they actually achieve this. Proponents of their use believe they have a direct and lasting effect on the facial growth, particularly of the mandible. Evidence for this has proved elusive and they appear to work by a combination of altering the soft tissue envelope that surrounds the teeth, disrupting the occlusion and by creating an intermaxillary force.

Changing the soft tissue environment

The teeth sit in a zone of soft tissue balance between the lips and the cheeks on one side and the tongue on the other. Certain functional appliance systems, such as the function regulators developed by Rolf Fränkel, incorporate buccal and labial shields or pads that displace the lips and cheeks away from the teeth. This allows the dental arches, especially the upper, to expand as the force of the soft tissues is removed. However, there is no evidence that this type of expansion is any more stable than other more active forms of expansion, especially across the lower inter-canine width, which is particularly prone to relapse.

Posturing the mandible forward will also change the position of the lower lip. With an increased overjet, the lower lip often rests behind the upper incisors, proclining them and retroclining the lowers. This is often referred to as a lip trap. By posturing the lower jaw forward, the lower lip moves in front of the upper incisors, freeing the lower incisors to procline and applying a force to the upper incisors, which retroclines them. Following treatment, it is important that this relationship is maintained, with the lower lip resting in front of the upper incisors creating an anterior oral seal, because if the upper lip drops back behind them the overjet will increase.

Class II effect

Orthodontists routinely pitch one jaw against the other when they use inter-maxillary elastics to help correct antero-posterior problems and provide anchorage support. Functional appliances produce a very similar effect through the muscles and soft tissues surrounding the teeth. Many of the activator-type appliances were specifically designed to be loose in the mouth, activating the elevator and protractor muscles of the jaws to keep the appliance in place. The forces generated were transmitted to the jaws and teeth. As these forces are intermittent, this force would be reduced at night and therefore some of the appliances were designed to open the bite vertically to a much greater extent than Andresen's orginal activator. The theory was that this then enlisted the elastic properties of the muscles and connective tissues or 'viscoelastic forces', which would be maintained even if muscle activity fell off. The appliance was also more likely to stay in place at night. As such, appliances such as the Harvold or Woodside activators open the bite much further than the freeway space and similar changes would be expected from the Twin Block appliance.

Early research focused on how the postural component of these appliances affected activity of the muscles of mastication, particularly the lateral pterygoid, the fibres of which run directly into the condylar cartilage.[7] Use of electromyography (EMG) showed hyperactivity of this muscle on protrusion of the mandible and the conclusion was that this would result in bony remodelling and growth at the condyle and glenoid fossa. However, while EMG studies have given equivocal or even contradictory results,[8] there is no doubt the postural element of the appliance imparts considerable force between the maxillary and mandibular dentitions. This results in distal tipping and movement of the maxillary teeth and mesial movement of the mandibular teeth, which aids Class II correction. This can be facilitated by introducing faceting into the acylic of the appliance to guide eruption of the buccal dentition. Clinically, the dentoalvolar effects are most apparent with proclination of the mandibular and retroclination of the maxillary incisors. These dental changes are most apparent with fixed functional appliances, where rapid tipping of the teeth and changes in the occlusal plane are consistently seen due to the full-time directional forces.

DO FUNCTIONAL APPLIANCES GROW JAWS?

It has been known since the nineteenth century that bone will remodel and adapt to mechanical loading. This is further supported by cultural practices, such as foot binding and the of use neck rings, which show that environmental factors can change and mould the skeleton. However, these types of forces are provided from birth when the greatest amount of growth is occurring. Therefore, while functional appliances might be expected to have some effect on growth of the facial skeleton, this is likely to be a relatively short-term influence during wear of the appliance. However, this has proved to be an attractive and enticing proposition for both clinicians and patients, even though the evidence that functional appliances can significantly influence jaw growth is limited.

Animal studies in rodents and primates have shown if the mandible is postured forward, cellular changes do occur at the condyle and glenoid fossa, particularly in juveniles and growing animals.[9–11] These changes consist of an increase in mitotic activity of the prechondroblastic cell layer in the condyle and bony remodelling of the anterior border of the glenoid fossa. However, rodents and primates grow and mature faster than humans which has the effect of magnifying these changes. Moreover, these experiments generally consist of converting a normal occlusion into a malocclusion, as opposed to correcting an underlying existing skeletal discrepancy. These appliances also invariably impose on the animal a treatment regime that would be difficult for a human patient to tolerate. Finally, the physiology and anatomy is different, particularly of rodents, and therefore the direct application of any results to humans needs to be done with caution.

Other evidence for the effects of functional appliances on growth has come from clinical studies, primarily using cephalometric radiography. Early studies tended to be retrospective case series reporting on the effects of the appliances. As such, they were susceptible to bias and tended to over-emphasise the positive effects of treatment.[1] They did not report on success rates and often compared patients treated with functional appliances with untreated subjects from unrelated historic growth studies. Measurements tended to be taken from lateral cephalograms taken immediately following functional appliance treatment, using unreliable and convenient cephalometric points to measure skeletal change and not taking account normal expected growth. It is, therefore, unsurprising that many of these investigations reported that functional appliances could significantly increase mandibular length.[12]

Over the last decade, three large randomised clinical trials have been undertaken, two in the USA and one in the UK. These have shown that initially there is a significant increase in mandibular length, which can be measured cephalometrically in patients who are treated with a functional appliance, compared with controls.[13–15] However, as these patients were followed through adolescence, these favourable growth changes were lost and ultimately, patients treated with functional appliances and those treated with other types of appliances were essentially the same.[16–18] Critics of these studies have suggested that they do not represent 'real world' orthodontics, often carried out in university departments by students less experienced with the appliances. However, the UK-based study was carried out in hospital departments by experienced consultants and it came to the same conclusions. Functional appliances did not result in a significant long-term increase in mandibular length as measured cephalometrically. It can be argued that the measurements used do not take into account the growth rotations of the mandible that occur and have been described by the implant studies of Björk and therefore under estimate mandibular growth.[19] There is also the wide variation and unpredictability in response to the appliances, with a percentage of patients' jaw relationships improving

on their own without treatment which makes interpretation to a mean difficult. However, combined, these clinical trials have provided data for well over 300 patients which makes it difficult to ignore their findings.

In terms of the effects of different types of appliances, a series of controlled clinical trials in the UK have compared Twin Block appliances with other types of functional appliances, including Bionators, miniblocks, Bass and Dynamax appliances, by systematically matching samples by age and gender and targeting treatment at early puberty. The outcome was a consistently greater increase in mandibular length with the Twin Block, with much of this length being expressed as an increase in the vertical dimension. The overall increased length was clinically significant vertically, especially with a longer treatment period, but limited to additional forward movement of the chin of around 3 mm over a 15 month period,[20–23] However, while the results of this series of studies are promising only the short-term effects of the appliances are presented. In the long term it is unlikely that the average size of any growth changes will be clinically important or significant, echoing the results of the long-term randomised clinical trials.

So, if functional appliances do not increase mandibular protrusion by any great extent, how do they produce such dramatic and usually lasting Class II correction? Much of the affect is dentoalveolar, tipping the maxillary teeth distally and the mandibular dentition mesially. They also disclude the mandible from the maxilla or 'jump the bite' while restricting maxillary growth. This establishes a new occlusal relationship while the patient is actively growing. The mandible will always grow more than the maxilla during normal growth, but in untreated Class II cases this extra growth does not usually manifest itself as Class II correction, because the Class II occlusal cuspal relationship is maintained and the jaws grow forward together. However, if a new Class I occlusal relationship is established and maintained while the patient is growing, the natural greater growth of the mandible compared to the midface allows the condyles to grow back into the glenoid fossae, while restricting forward movement of the maxilla.[24] This is why a similar effect can be achieved with the use of headgear or Class II elastics, as utilised with Begg or Tip Edge mechanics.

CLINICAL USE OF FUNCTIONAL APPLIANCES

Timing of treatment

The general dental practitioner plays a very important role in facilitating the successful use of functional appliances by referring the patient at the appropriate time. An increased overjet and Class II division 1 type of malocclusion may well present in the primary dentition but more markedly in the early mixed dentition, with eruption of the permanent incisors. The temptation is therefore to start treatment at this stage with a functional appliance to rapidly reduce the overjet. However, starting treatment in the pre-adolescent period, while usually effective, will often necessitate an extended period of retention to allow the permanent dentition to establish itself before a second course of treatment with fixed appliances to detail the occlusion. There is evidence that the outcome following early treatment is not any different from that obtained from one course of treatment carried out in adolescence.[16–18,25] Indeed, the effect of these appliances appears to be better in children entering their adolescent growth spurt.[26] So generally, while treatment is often started in the mixed dentition in the USA, in the UK, treatment with functional appliances is more routinely started in the late mixed or early permanent dentition. This allows immediate transition into fixed appliances following the functional phase of treatment, reducing the overall treatment time and burden on the patient (Fig. 9). Therefore, in most patients, referral for an orthodontic assessment should be made in the late mixed so treatment will coincide with the peak in adolescent growth and be as efficient as possible. In girls, however, puberty can occur before this period and therefore if there are signs they are entering their adolescent growth spurt they should be referred earlier. Failure to refer at the correct time can result in a lost opportunity for the patient to have even fairly severe skeletal discrepancies corrected simply with functional appliances, necessitating the use of orthognathic surgery for correction, which carries greater risk and cost.

There is some evidence that early treatment may reduce the incidence of dentoalveolar trauma.[25] Also an increased overjet can have psychosocial implications, making a child more susceptible to being bullied and early treatment does appear to result in a temporary, but probably important, improvement in self-esteem.[27] Therefore, in certain individuals who are either deemed to be at greater risk of trauma or are particularly concerned about the appearance of their teeth and being teased or bullied, treatment may be started earlier on the understanding that overall treatment time will either be extended or a further course may be required.

Functional bite

Having decided to correct an increased overjet with a functional appliance, an important question is whether this should be done in one treatment episode, or through progressive forward posturing of the mandible. An overjet of up to 10 mm can theoretically be corrected with a single advancement, but posturing beyond this is more difficult to tolerate, so in these circumstances an appliance will need to be reactivated or a second appliance used once some overjet reduction has been achieved. Activator appliances can be reactivated by sectioning them and advancing the lingual flanges; Twin Blocks by the addition of acrylic to the block and Herbst or other fixed functional appliances by added rings or crimpable shims to the male component of the telescope or piston. Some clinicians, however, advocate instead of reducing the overjet in one go, it should be reduced gradually by reactivating the appliance. They claim this will improve tolerance and wear of the appliance while optimising the effects on growth. In reality, the effects of either correction with maximum protrusion or by gradual advancement seem to be very similar.[28]

Clinical management

Following the fitting of an appliance the patient is usually seen a few weeks later. Progress is monitored by a measuring the overjet, which should reduce if the patient is wearing the appliance as instructed. It is essential to make sure that the patient is not habitually posturing the mandible forward and the degree the patient does this from the occlusal position should be checked, referred to as the reversed overjet.[29] The buccal segment relationship should also change from a Class II to a Class I or even to a Class III relationship. Other indications that the appliance is being worn include a return of speech to normal and evidence of general wear and tear associated with the appliance. A Twin Block appliance will produce a lateral open bite within a few weeks of full-time wear. Indications that the appliance is not being worn are no reduction in the overjet or correction of buccal segment relationship, no improvement in speech and repeated breakages as the appliance is being removed too frequently.

The reduction in overjet can occur rapidly, within a few months with appliances such as the Twin Block. However, it is unwise to discontinue use of the appliance as soon as the overjet is reduced. Initially, a lot of the change is postural so if the appliance is stopped too early the overjet will increase as the condyle will drop back into the glenoid fossa. Therefore, the postured position of the mandible needs to be maintained while hard

Fig. 9 Treatment of Class II division 1 malocclusion with functional and fixed appliances. Upper left panel shows the presenting malocclusion in late mixed dentition. Upper right panel shows the occlusion following 9 months treatment with a Twin Block functional appliance: note the lateral open bites. Lower left panel show fixed appliances being used to settle and detail the occlusion. Lower right panel shows final occlusion following removal of appliances

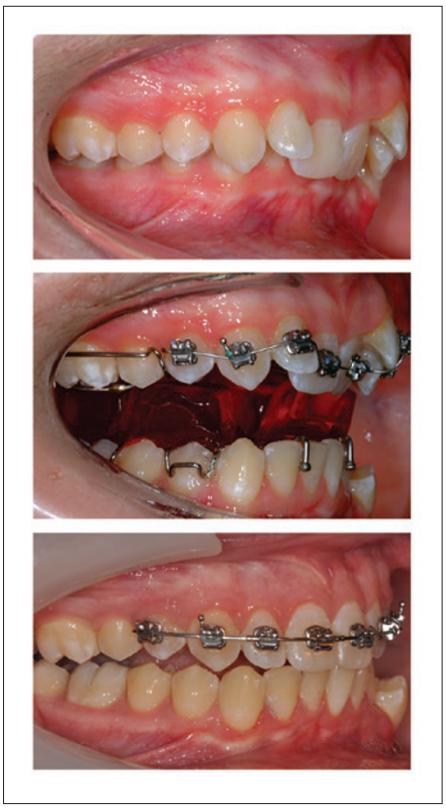

Fig. 10 Treatment of a Class II divison 2-type malocclusion with a Twin Block appliance and a sectional fixed appliance to decompensate the upper labial segment

tissue adaptation and growth of the condyle consolidates the new position of the mandible. The longer the functional appliance can be maintained, the more stable the result appears to be. In an ideal world the postured position of the mandible would be maintained until the end of adolescent growth although this is rarely practical, particularly if fixed appliances are planned, because it would extend treatment time unrealistically. Some clinicians reduce the wear of the appliance to night-time only to allow some occlusal settling. However, the problem with this approach is that any newly formed bone at the condyle or glenoid fossa will be immature, highly vascular and susceptible to resorption until it fully calcifies, which is only possible if it is not loaded. It takes time for this bone to mature, meaning if the appliance is withdrawn too early or only worn part time any bony remodelling or change may well be lost. This is supported by some clinical evidence that shows by extending the time period that functional appliances are worn, the changes produced appear to be more stable.[23]

A period of fixed appliance treatment is usually needed after functional appliance therapy as many cases also present with crowding. The corrected occlusion will also need consolidating and detailing. This is particularly notable with Twin Block appliances, as these do not allow free eruption of the buccal dentition and leave lateral open bites at the end of the functional phase of treatment. Establishing a good Class I buccal segment relationship will aid in stability (Fig. 9).

LIMITATIONS OF FUNCTIONAL APPLIANCES

There is no doubt that functional appliances can produce spectacular results in a relatively short period of time; however, this is not always the case. Much of the early research undertaken in relation to these appliances was retrospective and therefore susceptible to bias, often over-reporting the successful outcomes. From prospective studies we get a more realistic picture of what happens.

The main problem with removable functional appliances is compliance. These are often difficult appliances to wear as they can affect speech and oral function and therefore not all patients tolerate them. From prospective studies failure rates have been reported of up to 34% for Twin Blocks.[30] This is primarily due to non-compliance. Fixed functional appliances theoretically remove the problem of cooperation but are more prone to breakage and are more expensive, which means that compared to other parts of the world they are not as popular in the UK. The amount of tooth movement by tipping is also more marked and the shorter course of treatment more prone to relapse, as any increased bony development needs time to be established.

A certain percentage of patients will not grow well and therefore not respond well to treatment with functional appliances. These tend to be the high angle cases with reduced overbites or anterior open bites who exhibit a predominantly vertical rather than horizontal facial growth pattern. This can be compounded by the use of a functional appliance, as it will tend to increase the lower face. This makes them ideal in patients with average or reduced lower face heights but not patients with increased lower face height. In addition an increased lower face height at the end of treatment is unlikely to be helpful in developing an anterior oral lip seal and lip competence, which is important for stability of overjet reduction. Therefore, these types of cases tend be more prone to relapse.

Finally, it should be remembered that much of the effect of functional appliances is dentoalveolar, with proclination of the lower incisors and retroclination of the uppers occurring almost uniformly. Proclining the lower incisors is inherently unstable and tends to relapse. Therefore, the use of functional appliances is not ideal in patients who present with proclined lower incisors. However, they can be used in Class II division 2 malocclusions if the upper labial segment is proclined or decompensated, either before or during the functional phase of treatment (Fig. 10).

CONCLUSIONS

Despite the lack of evidence that functional appliances have any clinically significant lasting effect on mandibular growth, they are very effective appliances for the treatment

of Class II malocclusion and the reduction of an increased overjet. This appears to be achieved through a combination of dentoalveolar effects, alteration of the soft tissue environment and the utilisation of greater mandibular growth potential compared with the maxilla, at a point when the patient is actively growing. However, many of these appliances are difficult to wear and tolerate, which can make compliance difficult. Therefore, treatment is not always universally successful. As such, any potential patient needs to be carefully selected, at an appropriate age and skeletal morphology and informed of the need for excellent cooperation before embarking on what can be very demanding but ultimately very effective and rewarding treatment.

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