REVIEW ARTICLE

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Skeletal effects of bite jumping therapy on the mandible – removable vs. fixed functional appliances

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Structured Abstract

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Objective – Based on an extensive review of the literature, the aim of this study was to explore the mainstream consensus on the controversial topic of whether the bite jumping treatment could enhance mandibular growth.

Design – The data for removable and fixed functional appliances were respectively comprehended and analyzed with regard to their attributes in mandibular growth modification. Furthermore, numerous reported findings were assessed by relating them to some important factors influencing the effects of bite jumping, such as treatment timing, treatment duration and post-treatment follow-up, to allow for a more objective and accurate evaluation.

Results – The key differences between removable and fixed appliances are working hours (intermittent vs. continuous), length of treatment time (long vs. short), optimal treatment timing (before puberty growth vs. at or after puberty spurt), and mode of bite-jumping (considerable vertical opening vs. limited vertical opening). These different features lead to different treatment effects on mandibular and TMJ growth, such as the intensity of possibly increased growth (clinically less significant vs. significant), the direction of enhanced growth (vertical vs. horizontal), and the stability of treatment changes (unstable vs. stable). The short-term or long-term post-treatment relapse mainly relates to the rebound of dental position.

Conclusion – The immediate effects of bite jumping functional appliances on the mandibular growth enhancement are convincing during actual treatment. This extra gain of growth might be sustainable during the short-term and long-term post-treatment period.

Key words: bite jumping; growth modification; mandible

Introduction

Severe overjet is a common malocclusion and its prevalence is reported to be 10% in Chinese (1) and 15% in Caucasians (2). This malocclusion often reflects on a disharmony in the jaw relationship, i.e. the average pattern in Chinese with severe overjet is a protrusive maxilla and a retrusive mandible (3). In Caucasians, it has been reported that increased overjet more often is because of a retrusive mandible only (4,5). Since the mandible is too far back or too small in most patients with severe overjet, one sensible orthodontic treatment option in growing patients is to bring the mandible forward, aiming to enhance growth of the condyle (6,7) and remodeling of the glenoid fossa (8,9). The vertical dimension differs among the patients with severe overjet, from decreased to increased lower facial height. The mandibular and facial growth pattern varies within this group of patients, from favorable vertical-forward condylar growth direction and clockwise rotation of the mandible, to unfavorable sagittal condylar growth direction and counter-clockwise rotation of the mandible (10,11). The growth direction of the posterior cranial base varies and results in an open or closed skull base angle. Subsequently, the glenoid fossa can be in a more posterior or anterior position, which decides the position of the mandible. Therefore, a retrusive mandible can be of 'normal' size with its condyle in a glenoid fossa which is located posteriorly, or of a small size and/or abnormal shape with its condyle in a glenoid fossa which is located more anteriorly. In conclusion, patients with severe overjet are not homogenous in either overall facial or mandibular morphology or growth pattern. This will, at least to some extent, explain the often considerable individual variations in response to various orthodontic treatment mechanisms, such as bite-jumping therapy using functional appliances (12–14).

Since the late 19th century many types of bite jumping functional appliances (BJFA) have been advocated to treat growing patients (15). The fundamental principle for all BJFA is to keep the mandible in protrusive position in an attempt to evoke condylar and then mandibular growth, which in turn consolidates the repositioned mandible. The removable BJFA are mainly of activators, bionator, Clark twin block and Fränkel functional regulator II (FR II) with various modifications (15). For fixed BJFA, the fundamental design and biomechanics are well represented by Herbst appliance that was originated in as early as 1905 and rejuvenated in the early 1970s by Pancherz. The telescope mechanism creates a continuous mandibular protrusion.

The 'classical functional appliances' are loose fitting appliances (e.g. Monoblock, Andresen activator, Herren activator, Harvold activator, Woodside activator). During the past 30 years, several authors recommended that functional appliances be attached to the dental arches with clasps (e.g. twin block, Bass appliance, Hansa Platte) and/or be held to the maxillary dental arch via occipital headgear (e.g. Headgear activator ad modum Teuscher, Bass appliance, Headgear activator ad modum Van Beek, Hansa Platte). The authentic fixed functional appliances, e.g. Herbst applaince, are banded or splinted (acrylic and/or casting) to the dental arch and therefore somewhat restrict mandibular lateral movement (16). The use of resilient push rod in Jasper–Jumper allows for mandibular excursion but somewhat compromises solid mandibular protrusion (17). The recent renovations and clinical application of fixed BJFA, e.g. Twin Force Bite Corrector (18,19), have shown clinical advantages mainly in two aspects: 1) the coil-spring mechanism by using superior quality of NiTi alloy secures a forcible advancement of the mandible with sufficient flexibility of mandibular functional movement, and 2) the direct and easy placement of the appliance into upper first molar and lower canine significantly simplifies the clinical procedure and reduces patient's discomfort. However, the simplicity in appliance design has somehow weakened the anchorage reinforcement which may arouse the concern over the dental compensation in lower labial segment.

In spite of a widespread application of bite jumping treatment for severe overjet malocclusion, controversy remains on its clinical efficacy in mandibular growth enhancement. The following three factors might account for this controversy: 1) the reports on the success degree of the skeletal effects are very much varying, 2) the parameters adopted to quantify the skeletal changes are often created and determined by the individual researchers and are not of consistence and compatibility between studies (20), and 3) it is extremely difficult, for reasons of ethics and patient's compliance, to design and implement a randomized controlled trial only from which could we seek the truth. This review, with its focus extensively on clinical studies, was conducted to comprehend and analyze the data in literature based upon the categorization of removable and fixed BJFA, and to explore their respective effects on mandibular growth modification under the circumstances of various treatment timing (early and late), treatment duration and post-treatmental follow-up (short- and long-term).

Mode of bite jumping

Proportion in vertical opening and horizontal protrusion

The mandible's working mode depends on the 'construction bite' which decides its position in the sagittal and vertical planes, and also possibly in the transversal plane. In vertical dimension, the magnitude of the construction bite (low, moderate and high) determines the amount of bite opening (i.e. the amount of downward position of the condyle). Andresen's and Häupl's original concept maintains that condylar adaptation is induced by a loose appliance in which mandible is anteriorly displaced with no obvious bite opening. Based on this concept, it has been advocated that the vertical bite opening should be limited within 4 mm, or a minimal magnitude which is not beyond postural rest position (21). Contrary to the concept of minimal vertical opening, some authors (22–24) hold the view that viscoelastic properties of muscle and the stretching of soft tissues are decisive for activator action. This primarily requires dislocating the mandible not only in an anterior positioning, but also creating bite opening up to 10–15 mm, well beyond the postural rest position (24). Between these two extremes, some others (25,26) suggest a modest bite opening of 4–6 mm, in an attempt to achieve the combined isometric muscle contraction and soft tissue stretching.

In the sagittal plane, the mandible might be advanced with varied magnitudes, from minimal (21), moderate (27), incisal edge-to-edge (28,29) to even reverse overjet (30). The significant difference in growth stimulation on condyle/mandible has been claimed between varied magnitudes of horizontal protrusion (31), and insignificant difference has also been reported (32).

Some authors (25,33) contend that the proportion of bite jumping magnitude in vertical and horizontal direction cannot be individually considered, emphasizing the importance of the correlation or link between vertical opening and horizontal protrusion. That is, the magnitude of horizontal protrusion should be determined upon the consideration of that of vertical opening, and vice versa. When the magnitude of the forward position is large (7 or 8 mm), the vertical opening should be small (2–4 mm) so as not to overstretch the muscles. When the bite opening exceeds 6 mm, mandibular protrusion should be very moderate (3–5 mm) (33).

Activation of bite jumping

A single maximal advancement to edge to-edge relationship has been favored by some authors (34–36), claiming that a major initial advancement could best stimulate mandibular growth. Others (37–40) have advocated progressive small activations. There are indications from animal experimental studies (41) and clinical studies (42,43) that step-by-step advancement of the mandible results in a more forward position of the mandible compared with initial maximal jumping of the mandible. This could be justified by the animal experiments (41,44). In these studies, it was shown that an increase in activity of the lateral pterygoid muscle because of bite jumping was followed by an adaptive growth response at the condyle. The activity of the muscle decreases, however, after 6–8 weeks. By advancing the mandible several times during the treatment (i.e. every other month), the ligaments attached to the condyle were stretched repeatedly, leading to further increase in muscle activity followed by possible new condylar adaptation. By comparing the treatment effects between Bass appliance and Herbst appliance, Bendeus *et al.* (45) also recognize that stepwise activation of mandibular advancement might evoke more skeletal changes than does single activation.

The effects of bite jumping on TMJ and mandibular growth

During normal growth, the mandible is translated downward and forward as the actual growth occurs at the mandibular condyle and along the posterior surface of the ramus. The body of the mandible grows longer by periosteal apposition of bone on its posterior surface, while the ramus grows higher by endochondral replacement at the condyle, together with the remodeling of glenoid fossa straight down and posteriorly (46). When the mandible is held in a forward position by BJFA, the condyle is brought downward and forward from its original position. The ligaments of the disc attaching to the posterior aspects of both condyle and the glenoid fossa are stretched and affect the tissue involved. In animal experiments, it has been shown that the proliferation of chondrocytes in condylar cartilage increases, and the bone deposition in posterior of glenoid fossa is evident (47,48).

The mesenchymal cells within the articular layer of both condyle and glenoid fossa are main source for bone formation. In an attempt to elucidate the mechanism by which mesenchymal cells proliferate and differentiate in response to mandibular protrusion, Rabie *et al.* (49) identified the temporal sequence of cellular changes in posterior aspect of TMJ in rats. The mesenchymal cells were found to be stretched and oriented in the direction of the pull, which might trigger the biophysiological path of mesenchymal cells differentiating into bone making cells in TMJ.

There have been reports on animal experiments that deny any substantial adaptive changes in TMJ in response to bite jumping (50,51). However, the recent studies at molecular and genetic level have predominantly confirmed an increased endochondral ossification in the condyle of growing rats in response to mandible protrusion, by examining the growth markers such as type X collagen, VEGF and neovascularization – related factors (52–54).

Removable BJFA

The effect of the removable BJFA on mandibular growth is mainly expressed in a vertical direction (55–58). Mandibular growth in vertical dimension is beneficial to the correction of class II malocclusion with an anteriorly rotating growth pattern of the mandible because this tends to open the bite and direct mandibular growth in a more vertical direction (33). The mechanism of the growth stimulation in the vertical component might reflect in the bite opening beyond the vertical dimension of postural rest, which is facilitated by vertical construction bite of the appliance.

Many clinical studies, however, reported that the effect on the mandible with removable BJFA is insignificant and no more than what could be attributed to normal growth; and the treatment changes are only dento-alveolar (45,58–60). The results from clinical studies on the effect of activator treatment seem to indicate that mandibular growth is not affected by the treatment, i.e. the mandibular growth is no difference from the normal as a result of treatment (61). The clinical success rate seems to be dependent on the selection of the cases, e.g. the success rate for 'suitable activator cases' has been reported to be 50–60% (62). Unsuccessful treatment results in this sample of 'suitable activator cases' were because of 'lack of cooperation' and 'unfavorable growth pattern' (62).

In an attempt to master unfavorable downward growth of the maxilla and enhance condylar growth and remodeling of the glenoid fossa, the amount of the mandibular displacement was increased by making the construction bite considerably higher, well beyond the rest position of the mandible (23,24). It was assumed that by stretching the muscles well beyond rest position of the mandible, sufficient force should be transmitted via the appliance to the maxilla to restrain its downward growth. This attempt to control vertical growth of the maxilla and enhance mandibular growth was unsuccessful (23). Headgear was added to activators for the same reason, resulting in some restrain effect on maxillary forward and downward growth only, and the mandibular effect showed no difference from normal growth (38,45,63).

Fixed BJFA

The key differences in mode of bite jumping between removable and fixed appliances lie in the duration of mandibular protrusion and the magnitude of vertical bite opening. In fixed appliances, the continuation of bite jumping is secured but the dimension in vertical bite opening is limited. These features might lead to skeletal adaptation that differs from that caused by removable functional appliances.

The treatment effects of Herbst appliance on mandibular growth have been reported in the past two decades. These findings might also be comparable with the fixed appliance of other types (i.e. Jasper Jumper), on the grounds that they share similar mechanisms of action; treatment effects produced by the flexible force module presumably are similar to those of the Herbst appliance (17).

The Herbst appliance has been shown to enhance mandibular growth (6,35,64–66). It accelerates the growth of the condyles and result in a change in the growth direction of the condyles, in most cases, into a more sagittal direction (67,68). Sagittal condylar growth was increased while vertical condylar growth was unaffected by Herbst appliance therapy (69). This differs from the removable appliances which might affect mandibular or condylar growth dominantly in the vertical direction (55,56). In fabrication of removable functional appliance, the bite construction with proper dimension of vertical opening is a necessity to stimulate the condylar growth in vertical direction. The Herbst appliance, on the other hand, brings the mandible forward with limited inferior displacement. This might be attributed to the increased condylar growth dominating in horizontal direction.

The effects of bite jumping related to the timing of treatment

Removable BJFA

The pattern of the mandibular growth curve follows that of the general growth curve (70). Mandibular growth is characterized by an adolescent growth spurt and its peak closely coincides with that of the maxilla and general growth (70). The pubertal growth period is the most favorable time to attack many orthodontic problems with skeletal manifestations. When correction of the malocclusion has been achieved, the patient would reach the late adolescent growth period in which the growth rate would slow down.

For removable appliances, however, the treatment is preferably started in the pre-adolescent period for two reasons: 1) The treatment time with removable appliances is usually as lengthy as 2 years. The commencement of treatment, therefore, should be planned prior to the pubertal growth period, in order to overlap as much treatment time with pubertal growth as possible (71), and 2) Second-phase treatment with fixed appliance is usually needed upon the fulfillment of removable orthopedic intervention, to accomplish the entire correction during the adolescence years (72). Therefore, the treatment timing for orthopedic intervention with removable functional appliances should be ahead of pubertal growth, in order to secure that the late orthodontic treatment with fixed appliances could share part of pubertal growth period.

Dentofacial orthopedic changes were believed to be more dependent on the adaptability of skeletal tissues than the dentofacial growth (73). The dentofacial tissue was more adaptive at a younger age and the tissue adaptability decreased with increase of age. Early treatment with removable functional appliances at pre-adolescent years has been claimed to cause increased growth in mandible (71,73,74).

The commencement of treatment prior to the pubertal growth spurt, however, imposes disadvantages. Early treatment faces the risk of unpredictable post-treatment growth changes (75,76). The long duration of potential jaw growth after the active treatment would pose an uncertainty on the stability of the corrected occlusion (77).

Fixed BJFA

Unlike removable functional appliances which require a lengthy treatment duration, the fixed bite jumping appliances (e.g. Herbst appliance), impose a short treatment time of 6–12 months (78). This leads to the considerable flexibility in the selection of treatment timing. On a short-term basis, the most favorable time to treat patients with Herbst appliance is at, or just after, the peak of the pubertal growth spurt (64,65,79). At this time the influence on mandibular condylar growth is greatest and the risk of undesirable dental effects on the mandible (e.g. proclination of the lower incisors) is comparatively small (64,78). Taking into consideration other factors, such as the long-term stability of treatment results and the efficiency of retention, the ideal period for starting treatment should be when the permanent dentition stage has been reached and at, or just after, peak height velocity of growth. It was claimed that this would promote occlusal stability after treatment and shorten the retention period (77).

However, the amount of enhanced mandibular growth seems to be similar regardless the commencement time of the treatment in growing individuals (79). The major difference in mandibular treatment changes during various growth periods seems to be mainly because of the variations in the basic mandibular growth rate (79). At long-term follow-up there seems to be no difference in length of the mandible between patients treated in different growth periods (80).

The effects of bite jumping related to post-treatment follow-up

There are only a few reports on the short-term and long-term effects of removable appliances. This might be because of the difficulties in recalling the patients for re-evaluation. However, the evaluation for short-term and long-term effects of Herbst appliances has been documented extensively (16,78). The amount of gain in mandibular growth during treatment is small compared with the total growth after treatment; the individual variations of both parameters are large, and the sample size is sometimes too small and not homogenous, which makes it impossible to reveal any possible long-term effects of mandibular bite jumping (16,78).

The treatment effects on mandibular growth a short-term period after treatment with removable functional appliances have been reported to be stable (81) or to decline (82). Nelson *et al.* (60), however, found no growth stimulation on a short-term basis. A limited number of studies on long-term effects of removable BJFA on mandibular growth have almost invariably reported some relapse after 3–20 years after treatment (12,36,83,84). A recently reported long-term (up to 4 years) follow-up study on twin block appliances claimed that much of the significant increase in mandibular length achieved during the active phase of treatment was still present after 3–4 years when the subjects had matured into permanent dentition stage (85).

For fixed functional appliances (e.g. Herbst appliance), the direction and the amount of mandibular growth can be temporarily altered, but return to their pre-treatment pattern after treatment on short-term basis (76,86). The dentoalveolar and skeletal relapse, which occurred primarily during the first 6 months after treatment, was about 30% of the accomplished treatment effect and was mainly of dental origin (13,67). This is further confirmed by a recent randomized controlled trial on headgear Herbst with step-by-step activated mandibular advancement (66). In the study, it was found that a significant enhancement on mandibular growth occurred during the initial treatment phase (6 months), which declined in the late treatment phase (12 months) and after retention phase (18 months). The corrected jaw relationship maintained over this short-term (12 months) and a small relapse of overjet and molar relationship was the result of dental changes only. On a long-term basis, the clinically significant effects on mandible growth remain despite that mandibular growth appears to return to its earlier pattern after treatment (76). Long-term studies, i.e. 5–10 years follow-up, showed that the mandible effects remained and the reason for relapse was the changes in tooth position (77). In the Herbst-treated patients, the sagittal arch relationship is generally stable and comparable with normal and 'ideal' samples from the Bolton Standards (87). Some studies indicate that mandibular growth is enhanced during active treatment compared with controls, but during the follow-up period the mandibular growth seems to slow down in BJFA patient group. Subsequently in long-term there is no obvious increase in mandibular length even in the samples of patients with an initially favorable response to bite jumping, compared with controls (61).

Consequently, it appears that the unfavorable post-treatment changes occurring after the removal of removable or fixed BJFA, are dominantly dental related. This might be because that the long-term effect of treatment on mandibular growth is difficult to assess, and the increase in sagittal condylar growth and the changes in mandibular morphology seen during treatment could not be verified several years after the therapy had been ceased (42). Any orthopedic appliances seem to have only a temporary impact on the existing skeletofacial growth pattern (i.e. growth rate and growth direction). After the orthopedic intervention period, mandibular growth seems to return to its previous patterns (67). However, these accelerated growth changes are maintained by the additional skeletal growth and dentitional changes (85).

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