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NEW CONCEPT IN DENTOFACIAL ESTHETICS: THE BIOLOGICAL ASPECTS OF ADULT ORTHOPEDIC FACE MASK THERAPY

(KONSEP BARU DALAM ESTETIKA DENTOFACIAL: ASPEK BIOLOGIS TERAPI TOPENG BEDAH TULANG DEWASA)

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Abstract

Orthopedic face mask has been introduced for more than 100 years ago, however, it is primarily indicated for growing patients. Its effectiveness in adult patients is still questionable. It is thought that in non-growing adults the degree of orthopedic movement is minimal, whether dental movement is more prominent. In addition, there is still controversial, whether patients' compliance or the existent skeletal growth determines the treatment success. The objective of this study was to propose a new concept for adult orthopedics face mask therapy based on functional and biological mechanisms involved in dentofacial remodeling. Conventional face mask therapy only depended on duration, magnitude and unidirectional elastic forces. In the reviewed case report, the inspiration for a new concept was evolved from the multidirectional forces which were resulted from continuous functional movements (i.e. chewing and speaking) during wearing face mask. These movements may lead to stimulate additional orthopedic or skeletal movements in adult patient. The explanation of this phenomenon could be explained not only by clinical result, but also with the biological mechanism of bone remodeling. In conclusion, regarding to the successful treatment result and its logical biological explanation, this new concept to increase the effectiveness of adult orthopedic face mask therapy is likely.

Key words: orthopedic face mask, adult patient, new concept

INTRODUCTION

The final goal of any orthodontic treatment should be not only to obtain good function but also to improve facial attractiveness. The main focus of concern for the Class III patient who presenting a concave facial profile, a retrusive nasomaxillary area and a protrusive lower face and lip, may be emphasized for the profile rather than the occlusion. However, achieving a harmonious soft tissue profile is sometimes difficult because a Class III malocclusion is one of the most challenging problems confronting the orthodontist.[1]

Orthopedics face mask is an appliance of choice for most Class III patients seen in early mixed dentition or late deciduous dentition. The younger the patient, the larger the therapeutic effect of this protraction therapy.[2-4] Eventhough the orthopedic face mask has been available for over 100 years, surprisingly few studies have dealt with the treatment effects produced with the face mask.[3] According to literatures, orthopedic face mask is able to protract the whole maxilla skeletally not as intraoral fixed appliances which only obtain dental movement. Nevertheless, it is indicated for growing patients and not indicated for adults.[1-7]

In adult patient Class III malocclusions, especially the skeletal type is indicated for orthognathic surgery. There were some important criteria related to facial skeletal deformities which indicated for orthognathic surgery as referred to American Association of Oral and Maxillofacial Surgeons (AAOMS)[8] is (1) maxillary/mandibular incisor relationship 5 mm or more, or zero to negative value (norm= 2 mm); and (2) maxillary/mandibular anteroposterior molar relationship discrepancy of 4

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mm or more (norm = 0-1 mm). However, in the reviewed report[9] adult orthodontic cases which actually need orthognathic surgery corrections, even the patients had less compliance but they still conducting functional movements (i.e. chewing and speaking) during wearing face mask, thus also altering force vectors, and the results were excellent. Usually, conventional face mask therapy disregarded functional movements and only based on duration, force magnitude and unidirectional force.[10] Therefore, based on this case report, new concept in face mask therapy which enhancing functional movements during wearing face mask will be postulated.

This article will discuss about the mechanisms involved on the proposed new concept for effective adult orthopedic face mask therapy. Immunological, biological mechanisms and functional movements involved in sutural bone remodeling are considered appropriate to elucidate the new concept.

DEFINITION OF ORTHOPEDIC FACE MASK

Face mask or reverse headgear is an extra-oral appliance which indicated for mild skeletal class III malocclusion and could be worn in adjunct with bonded maxillary splint or fixed orthodontics appliance (Figure 1). It must be worn minimal 14 hours/day; nevertheless, some literatures suggested until 20 h/d.[3] Keles et al.[5] suggested 16h/d for the first three months and 12 h/d for the second three months, with 500 g of force applied. According to the literatures, in order to obtain orthopedic forces, the amount of force had to exceed one pound (454g). Some investigators have applied forces that varied between 300 and 800 g.[3,5]

THE USE OF EXTRA-ORAL TRACTION WITH THE ORTHOPEDIC MASK IN THE TREATMENT OF CLASS III MALOCCLUSION

The following recommendations and advice can be given[6,7]: (1) Orthopedic treatment should be carried out as early as possible, either in the deciduous or at the beginning of the mixed dentition (before loss of the deciduous molars); (2) Before treatment, it is necessary to determine exactly, using A good cephalometric analysis, the skeletal anomalies that need to be corrected; (3) During treatment, the aim is, in all cases, to obtain not only maxillary advancement, but also development of the anterolateral components, and in Class III cases with open bite, to avoid extrusion of the molars; (4) At the end of therapy, just before treatment ceases, it is necessary to reassess by cephalometry for the evaluation of maxilla advancement.

According to Kim et al.[7], examination of the effects of age revealed greater treatment changes in the younger group. Results indicated that protraction face mask therapy is effective in patients who are growing, but to a lesser degree in patients who are older than 10 years of age, and that protraction in combination with an initial period of expansion may provide more significant skeletal effects.

DIRECTION OF FORCES

During the protraction procedure, rigid appliances are needed to withstand the heavy forces. For this purpose some investigators have used rigid wires, whereas others used an acrylic cap splint. Some investigators noted that increasing the number of teeth in the anchorage unit would increase the skeletal effect. In previous study a full-coverage acrylic cap splint–type RME appliance was used in order to increase the rigidity of the appliance, to prevent the occlusal interferences, and to maximize the skeletal effect of the protraction headgear.[5]

In order to minimize the counterclockwise rotation produced by the protraction forces, investigators have changed the point of force application and the direction of the protraction forces. Some investtigators applied the force from the canine region, at the premolar or deciduous molar region. Others moved the point of force application distal to the laterals, whereas some investigators changed the direction of force at an angle of 15°–30° from the occlusal plane. All of these attempts showed that the counterclockwise rotation of the maxilla during protraction was unavoidable.[2-5]

In the literatures, variation has existed between the studies locating the center of resistance of the maxilla.[5,10,11] According to some researchers, the center of resistance of the maxillary dentoalveolar complex is located in several locations, i.e. between the root tips of maxillary first and second premolars, at the level of the zygomatic buttress, or 5 mm above the nasal floor. Despite the differences of the location, each researcher also reported the successful treatment results.

EFFECT OF FORCES TO BONE CELLS IN MOLECULAR BIOLOGY BASIS (MECHANOBIOLOGY)

Exogenous forces do not directly induce sutural

growth, because they do not directly "communicate" with cells. Any exogenous force applied to bone is transmitted as mechanical stresses in bone, measurable as bone strain on the cortical surface or in craniofacial sutures.[10] The field of identifying cellular, molecular, and genetic pathways responseble for mechanical modulation of skeletal tissues is known as mechano-transduction. Although the precise mechanisms of mechanotransduction are not clearly understood at this time, certain myriad steps and pathways are involved.[10,11]

Oscillatory mechanical stimuli up-regulate sutural cell proliferation *in vivo*; increased numbers of sutural cells, quantified by computerized cell counting, in both the pre-maxillary and nasofrontal sutures upon small doses of oscillatory strain. This is true for both compressive and tensile microstrains, and in parallel with increased sutural width, indicating coordinated sutural growth rather than a unilateral increase in either cell proliferation or increased matrix synthesis.[10,11]

Application of sustained static tensile stresses upregulates sutural cell proliferation in a popular model of the rat interparietal suture. In explant culture, cell proliferation increases upon tensile strain for 24 hrs. Studies revealed that sutural cell proliferation in response differently to different mechanical stimuli (tension *vs.* compression) or oscillatory *vs.* static strain, and different magnitudes of mechanical stresses, one common shortcoming is that sutural cells are not clearly distinguished between fibroblastic and osteoblastic populations. Historically, mesenchymally derived cells of osteogenic and fibroblastic lineages were given distinct names as osteoblasts and fibroblasts.[10-12] Each fibrogenic and osteogenic cell lineage likely consists of an array of differentiating cells toward the final cell type of fibroblasts or osteoblasts. Distinguishing these cell populations at various stages of differenttiation in response to mechanical stimulation would be likely advance our understanding of sutural growth. In addition, sutural strain must be normalized against sutural cross-sectional area to obtain precise stresses experienced by sutural cells.[10,11]

Increasing numbers of genes and transcription factors have been found to be expressed in sutural growth. Several genes that are involved in sutural development have been found to participate in mechanotransduction, i. e. fibroblast growth factor 2 (FGF-2) that is up-regulated upon about 600-mN tensile stresses applied to the rat coronal suture. The key to "communicate" with sutural cells appears to be oscillatory strain, instead of static strain lacking oscillation in amplitude. Taken together, the next decade of suture biology and craniofacial orthopedics will be likely witness.[10-12]

Meikle reported that a short dose of mechanical stretch applied to cultured calvarial osteoblasts upregulates an early response gene; and tensile stresses inducesus tained up-regulationof bone morphogenetic protein 4 (BMP-4) gene expressions, followed by increasing expression of Cbfa1/Osf-2, an osteoblast-specific transcription factor. Additionally, type III collagen synthesis increases significantly with application of static mechanical stresses to explant suture.[12]

AN EXAMPLE OF ADULT ORTHOPEDIC FACE MASK THERAPY

In the reviewed case report,[9] a 22 year and 18 year old female had undergone fixed orthodontic treatment also wearing face mask therapy (Tubingen type, Fig.1) for about six months. Owing to the outdoor activities, the full time-basis (20 hours / day)[3] of face mask therapy could not be achieved perfectly. However, during their indoor activities, including eating snacks and speaking, they wore the appliance for minimal six hours/day. The finishing results were considered successful because they had improved facial esthetics (Fig 2a and 2b; Fig 4a and 4b), had almost ideal occlusion (Fig 3a and 3b; Fig 5a and 5b), and improved cephalometric measurement (Table 1).[9]

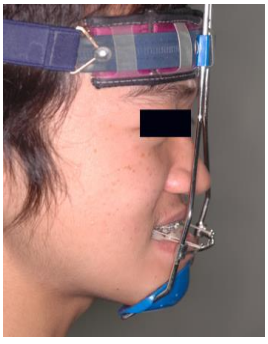

Figure 1. Orthopedic face mask Tubinger type

Fig. 2a. Before treatment

Fig. 2b. After treatment

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Fig. 3a. Before treatment

Fig. 3b. After treatment

Fig. 4a. Before treatment

Fig. 4b. After treatment

Fig. 5a. Before treatment

Fig. 5b. After treatment

Table 1. Cephalometric measurement

		Case 1		Case 2	
	Variable	pre	post	pre	post
1	SNA	80.5°	83.5°	77°	79°
2	SNB	86.5°	83.5°	86°	83°
3	ANB	- 6,5°	0°	-9°	-4°
4	FMA	24°	27.5°	29	31
5	ANS-Ptm	48°	50°	42 mm	44 mm
6	AO-BO	- 3 mm	+ 2 mm	- 3 mm	+ 3 mm

DISCUSSION

According to Graber et al., there were only few studies about orthopedic face mask therapy.[3] Most likely, since the majority of patients had inferior compliance, thus also poor results, the cases were not appropriate to be reported. There are several plausible reasons why achievement of maximum compliance in orthopedic face mask therapy is difficult. First, the uncomfortable feeling caused by maxillarybonded splint or rapid maxillary expansion (RME) appliance, which intended to disjoin the maxillary sutural system and promote maxillary protraction.[13-15] Second, orthopedic face mask must be worn on a full-time basis (20 hours per day) for 4 or 6 months.[3] Recently, the most probable major problems are increasing of outdoor activities and decreasingof children–parental contacts. Therefore, children's compliance is more difficult to be controlled by their parents.

Furthermore, in adult patients, they may worry about interpersonal relationship during treatments. Consequently, their compliances in using orthopedic face mask were still questionable. Surprisingly, in this case report,[9] they had satisfactory results either in intra oral teeth alignment and extra oral esthetics (Figure 3 and 4) or cephalometric measurements (Table 1). Regarding to this evidence, there should be another cause of bone or sutural remodeling which does not depend on either age or compliance.

According to Holberg et al., maxillary protraction therapy using a face mask is a well-proven procedure employed in prepubertal Class III therapy.[4] By applying an anteriorly directed, orthopedic force vector to the superior dental arch, growth of the maxilla should be encouraged in an anterior direction, whereby force vectors are applied to the maxillary structures by using various face masks such as those developed by Delaire[6] or by using reverse-pull headgear.[13] As a result of the anterior directed force vectors reproaching on the dental arch, a mesial movement of the posterior teeth and a protrusion of the anterior upper jaw teeth occurs, which facilitates a dental compensation of the skeletal dysgnathia for Class III cases.[4,6]

Studies related to the successful maxillary protracttion were still in controversial. Some studies revealed that maxillary protraction is more effective if (1) undertaken in the late or early mixed dentition, and (2) combined with RME, the aim of RME is to loosen the articulation of the maxillary complex from the rest of the skull.[6,11,13] However, in this adult case report, RME were not used, and the patients

only wore it during their limited indoor activities, but they could still speak and were able to eat snacks during using orthopedic face mask. It was in concordance with to Vaughn et al.[14] that the use of RME in face mask protraction therapy only needed in the presence of transverse discrepancy or a skeletal / dental posterior cross bite.

Other studies were disagreed with the efficiency the skeletal effect of maxillary protraction therapy, although there is agreement that a slight increase in both the SNA (Sella-Nasion-Point A) angle and the ANB (Point A-Nasion-Point B) angle occurs during maxillary protraction therapy. This clearly does not prove a skeletal effect of the apparatus since no differentiation was made between growth and apparatus effects in most of the papers published.[4] It is interesting that in this case report, besides increase of SNA and ANB, there was also increase of AO-BO (distance between projection of Point A-Occlusal Plane and Point B-Occlusal Plane) and ANS-Ptm (Anterior Nasal Spine–Pterygomaxi-llare) in both patients which were indicators of maxillary anterior movement or palatal advancement (Table 1).[9]

Disagreement also prevails regarding to the influence of patient age on the skeletal effectiveness of the protraction therapy. Literatures revealed that the younger the patient, the larger the therapeutic effect of protraction therapy and this effect strongly decreases after puberty.[2,4,7] There were also no significant differences could be shown in the therapeutic effect between the age groups of 5–8 years and 8–12 years. The skeletal effect of the maxillary protraction therapy, therefore, has not been proven in the studies published until now.[2,4]

Although the skeletal effectiveness of this therapy, even in children, still controversial, and skeletal maturation was considered earlier in women than men; women in this case report showed skeletal advancement (Table1). It was supported by Solomon article which revealed that the suture closure age was still in controversial.[15] In addition, referred to Wehrbein and Yildizhan's research, it was found that the suture closure age in men and women was inconsistent and ranged from 18–38 year.[16] As a result, skeletal advancement in these adult women should be possible.

Successful orthopedic face mask treatment also depends on the opening of cranial and facial sutures which is considered difficult in adults. Nevertheless, there are plausible explanations about how and why cranial and facial sutures in adults could be remodelled. There are two different kinds of sutural closure, one biochemical, the other mechanical, remodeling This phenomenon was applied in interesting animal study by Mao which showed that sutures exposed to a predominantly compressive strain will continue to grow.[10,11]

It is also a common belief that mid-palatal suture fuses at around age of 15 years. However, radiographic-histological study by Wehrbein and Yildizhan[16] concluded that radiologically invisible suture does not necessarily mean that the suture is fused histologically. In any event, undue focus on the palate that obscures the fact that the greatest resistance of RME comes not from the mid-palatal suture, but from the circum maxillary suture network that attaches the maxilla to the rest of the skull.[4,12]

Actually, these reviewed cases fulfill the criteria for orthognathic surgery referred to American Association of Oral and Maxillofacial Surgeons (AAOMS);[8] nevertheless, satisfactory treatment results were achieved. Concerning to satisfying results of these evidence-based cases, there should be some questions: how does it happen? is sutural closure only age-dependent?, and is force magnitude the most important matter in orthopedic face mask therapy?

According to Mao et al.,[10] mechanical stresses experienced in sutures, given the "right" characteristics, are capable of modulating sutural growth. Because mechanical stresses transmit through bone, their effects are experienced in a hierarchical manner sequentially as tissue-level bone strain, interstitial fluid flow that in turn induces cell-level strain on bone cells, and subsequent anabolic or catabolic responses. However, what optimal stimuli induce anabolic and catabolic sutural responses, both of which contribute directly to separate craniofacial orthopedic goals, is presently unknown.

Current clinical orthopedic devices exert static forces on craniofacial sutures for sustained periods of time. Orthopedic change of maxilla could be fulfilled when the force is of sufficient magnitude (1000 g/side) to be transmitted to the periodontal joints.[10,11]Nevertheless, recent experimental evidence indicates that repeated application of cyclic forces for as short as 10 minutes/day for 12 days is sufficient to induce significantly more sutural growth than static forces of matching peak magnitude and duration. It is probable that any mechanical force capable of modulating craniofacial growth exerts its therapeutic effects by generating mechanical strain in craniofacial sutures.[10,11]

Sutural growth is up-regulated to the degree that the orientation of the entire maxilla changes in response to either anterior forces or posterior forces. Sutures undergo anabolic changes such as increased sutural widths, angiogenesis, and bone apposition in

response to anteriorly directed forces. Conversely, bone resorption takes place in the zygomatic-otemporal and zygomaticomaxillary sutures in response to posteriorly directed forces.[10]

Despite the irreplaceable value of these data, the approach to the induction of bone adaptation by the application of continuous mechanical forces over several months is not efficient time. Thus, sustained static mechanical forces are not merely the optimal stimulus for sutural growth; this was coincidence with an investigation by Keles et al.[5] regarding to effect of varying forces in maxillary protraction. It was also in concordance with Mao et al.[10] that mastication which includes tension and compression forces had advantageous effect to suture remodeling.

Taken together, the components of sutural strain, rather than its peak amplitude, is anabolic stimuli for suture growth. In other words, small doses of static strain without variation in amplitude induced by small doses of static forces are not an effective anabolic stimulus for sutural growth; consequently, the importance of masticatory forces was essential.[5,10,11] In addition, according to Wehrbein and Yildizhan,[16] adult sunder 25 years still had incomplete obliteration of sutures. Regarding to these literatures, since the patients in this case report were under 25 years and they were still able to speak and chew at least snacks, the successful treatment results were possible.

It was concluded that based on this success-ful adult orthopedic face mask therapy, as long as patient had superior compliance, also conducting functional movements (i.e. speaking, chewing) during wearing the appliance; it is considered effective for adults less than 25 years old. Nevertheless, since the use of orthopedic face mask in adults is still uncommon, further researches should be done to evaluate its effectiveness and safety in adult patients.

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