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Transverse maxillary deficit and its influence on the cervical vertebrae maturation index

ABSTRACT

Aim *The aim of this study is to evaluate whether a transverse maxillary deficit can cause an alteration of vertebral development and therefore of the skeletal maturation comparing the cervical maturation stages index with the hand-wrist index.*

Materials and Methods *For the study were selected 200 patients aged 7 - 14 years, equally distributed by gender and divided into 100 study subjects with maxillary deficit and 100 controls without maxillary deficit. The skeletal maturation index (SM according to Fishman) was evaluated and compared with the hand-wrist x-rays and the cervical vertebrae maturation (CVM according to Hassel and Farmann).*

Results *Forty-one per cent of the subjects in the test group show a discrepancy between CVM and SM. Among these 73% (30 subjects) present an advanced stage of CVM compared with the corresponding SM. Only 16% of the subjects in the control group show a discrepancy between CVM and SM. Among these 69% (11 subjects) appear in an advanced CVM stage.*

Conclusion *The analysis of the CVM stage in subjects with transverse maxillary deficit appears to be altered compared with the SM identified through a hand-wrist x-ray. In the case of individuals with transverse maxillary deficit it is advisable to use also a hand-wrist x-ray, thus not relying only on CVM for the evaluation of the skeletal growth stages.*

Keywords *Cervical vertebrae; Children; Maxilla.*

Introduction

The transverse contraction of the upper maxillary bone is a malocclusion characterised by a high and narrow palate, unilateral or bilateral cross-bite and possibly also teeth overcrowding following contraction of the arches. The reduction of the transverse diameters in the upper maxilla seems to be related to pathological oral breathing by which some young patients are affected, due either to a real nasopharyngeal obstruction (forced oral breathing) or bad habit [Neeley et al., 2007; Tecco et al., 2005]. The upper arch therefore shows a reduction of the transverse diameters, given the scarce use of the nasal airways as well as a pressure imbalance between outer muscular power of cheeks and lips, and the inner muscles of the tongue, which is low and protruding. Moreover, oral breathing affects also the cranio-cervical posture, since in order to increase patency of the oropharyngeal airways a patient with nasal obstruction assumes a posture which entails overextension of the cranio-cervical complex, so as to obtain correct ventilation [Cerruto et al., 2012; Forsberg et al., 1985].

Several studies have analysed the changes of the nasal cavities in patients who undergo corrections of the transverse contraction of the maxilla. The following changes were detected after treatment: reduction of the nasal airway resistance, increased volume of the nasal cavities and increased total nasal volume following palatal expansion [Hartgerink and Vig, 1987; Farronato et al., 2011; Felisati et al., 2010; Bicakci et al., 2005; Oliveira et al., 2008].

The therapy with rapid palatal expander should take into account the age of the patient, in order to obtain permanent long term results, while minimising dental movements and maximising the skeletal growth development. Roykò [1999] states that duration of the orthodontic treatment and patient's compliance are inversely proportional: a reduction of treatment time will lead to an increase in patient's cooperation and satisfaction. Considering the importance of an optimal therapy timing to reduce treatment duration and increase patient's compliance, it appears obvious how damaging an evaluation mistake can be when assessing the skeletal maturation of the individual. The most reliable indicators for the evaluation of the skeletal maturity are carpal bones [Fishman, 1982] and cervical vertebrae [Hassel and Farman, 1995].

There are two general approaches for the evaluation of the hand-wrist x-rays. The first method involves comparison of the bone maturity of the patient's hand and wrist based upon a radiographic atlas. The most important atlases on the hand and wrist development stages have been created by Greulich and Pyle [1959] and Tanner and Whitehouse [1959]. The second evaluation method of hand-wrist radiographs relies on specific skeletal indicators in order to find the relationship between skeletal development and growth curve in puberty [Grave and Brown, 1976]. The main indicators described in literature are those presented by Fishman [1979; 1982], Bowden [1975], Bjork and Helm [1967].

Concerning the cervical vertebrae, it has been shown that these also can be used as indicators of skeletal maturity and are therefore useful for growth staging and patient's development. In the seventies, Lamparski [1972] had already studied the changes in shape and size of the cervical vertebrae, in order to establish maturity standards, and he identified 6 different categories. The validity of this method was confirmed by Baccetti et al. [2002], with an improvement: the 6-stage scale was changed into a 5-stage scale, with the mandibular growth peak placed between CVSM II and CVSM III.

Hassel and Farman [1995] established a direct link between carpal and vertebral indices. In fact they mached the 11 skeletal maturation indicators groups of Fishman [1979, 1982] with 6 maturity stages of cervical vertebrae maturation.

This study aimed at testing the validity of the Cervical Vertebrae Maturation (CVM) method of Hassel and Farman [1995] in the evaluation of the bone stage development, comparing it with the carpal index of the skeletal maturity of Fishman [1979; 1982] in a selected group of patients with contraction of the maxilla.

The issue to be cleared at this point is whether a postural alteration due to oral breathing can affect the development of the cervical vertebrae.

Materials and Methods

A group of 100 subjects was selected at the Department of Biomedical, Surgical and Dental Sciences of the University of Milan, based upon the following criteria: age between 7 and 14 years; transverse contraction of the upper maxillary bone (clinically assessed through plaster models and frontal cephalometric radiograph of the cranium); anamnestic, clinical and instrumental assessment of dental-maxillary-facial dysmorphia and severe skeletal asymmetries which would require orthodontic surgery; no previous orthodontic treatment.

Each individual underwent the following radiographic examinations: panoramic radiograph, lateral cephalometric radiograph showing at least the cervical vertebrae from C2 to C5; a frontal cephalometric radiograph; a hand-wrist radiograph taken within a month from the previous radiographies.

The selected patients suffered a transverse maxillary deficit, given the presence of mono- or bilateral cross-bite or a transverse palatal width less than 33-34 mm.

The final study group included 100 patients, 50 females and 50 males, with an average age of 10.8 years +/- 1.9 years. A control group of 100 patients was also selected, with individuals in the same age range (10.2 +/- 1.5) but without a transverse maxillary deficit.

The profile of cervical vertebrae C2 to C6 was marked on each radiograph. Two independent orthodontists blinded to group allocation assessed the morphology of the vertebrae. The measurements reported in this study are relative, and not absolute, and the percentage of enlargement of such radiographs is considered of scarce relevance. The two examiners, who were adequately prepared for the assessment of the vertebrae and hand development indexes, evaluated the following details on each lateral radiograph and hand-wrist x-ray: epiphysis development and ossification stage of the finger bones according to Fishman method and maturity stage of cervical vertebrae according to the CVM method of Hassel and Farman [1995],

Results

The test group shows a discrepancy between CVM and SM values in 41% of the subjects, against a 16% discrepancy in the control group. In particular, 30% of the individuals in the test group show an earlier stage of development of the cervical vertebrae compared with 11% in the control group. In the test group most of the subjects with early vertebral development are included among the initial stages of skeletal development (SM 1-3), while in the control group they appear to be evenly distributed, regardless of the SM maturity stage.

Almost half of the subjects (41%) with maxillary contraction at an initial stage (SM 1-2) and one half (31%) of those belonging to the following stage (SM) show an early change of conformation of the cervical vertebrae. A similar trend can also be found in the control group, and it probably indicates an early compensatory response to other possible alterations due to incorrect posture (Tables 1, 2).

Discussion

The hand-wrist radiograph has been traditionally used to determine the skeletal maturity stage. The main purpose of the introduction of the vertebral indexes is to avoid further exposure to radiation.

After Lamparski [1972], many authors have compared the CV method with the hand-wrist method, finding a correspondence between the two, thus validating the vertebral index [Baccetti et al., 2002; Hassel and Farman, 1995; O'Reilly and Yanniello, 1988].

Further studies were conducted in recent years in order to prove the validity of the CVM method comparing it with the carpal indexes. Their diagnostic value has now been widely recognised in the last 50 years, confirming the close relationship between the two methods to the point where they can both be considered highly significant and interrelated [Alkal et al., 2008; Joshi et al., 2012; Gandini et al., 2006].

As proven by Hassel and Farmann [1995] for each

	CVM					
SM	I	II	III	IV	V	Total
1	9	4				13
2	8	5	3			16
3	4	15	10			29
4		3				3
5			3			3
6		2	6	4		12
7			4	8	4	16
8			1	3		4
9					3	3
10					1	1
Total	21	29	27	15	8	100

TABLE 1 CVM stages and SM index in test group.

	CVM					
SM	I	II	III	IV	V	Total
1	9	1				10
2	12	2				14
3	2	14	2			18
4		6	2			8
5		1	8	1		10
6			15	2		17
7			1	8	1	10
8				4		4
9				1	5	6
10					3	3
Total	23	24	28	16	9	100

TABLE 2 CVM stages and SM index in control group.

vertebral development stage there are two development stages of the hand [Hassel and Farman, 1995]. However, in the present study the SM-CVM combination does not appear to be always valid and not so correlated. There is in fact a discrepancy between the two development stage evaluation methods: in 41 test patients the vertebral maturity stage does not appear to be in line with the criteria shown in SM index, in particular the vertebral development stage of 30 patients is more advanced compared with the hand (Table 3). In the control group there is a discrepancy between the two methods for 16 individuals; out of these, 11 exhibit a more advanced vertebral stage than that found analysing the hand-wrist x-ray (Table 4). The vertebral defects of the patients in this study are mainly located in the lower part of the vertebral bodies. The epiphysis of the cervical vertebrae are ring-shaped on the upper and lower perimeter of the vertebral bodies; this can easily lead to thinning of the epiphysial area, and subsequently to vertebral deformation caused by the surrounding soft tissue.

The analysis of the cervical vertebrae in subjects aged 7-14 has therefore established the presence of development anomalies in the vertebral bodies. As shown in a recent study, transverse maxillary deficit alters the morphological aspect of the cervical vertebrae. This is probably due to the postural changes which can be caused by oral breathing. We believe that this might affect not only the morphology, but also the development of the cervical vertebrae [Di Vece et al., 2010; Solow et al., 1984]. As a reference, we considered the development stage of the hand, being it a non-contiguous structure in relation to the craniofacial complex. In this respect, the hand cannot be affected by orthodontic problems, making it a reliable parameter. Although the effects of the transverse contraction of the upper maxilla on the respiratory pattern are not predictable, the link between cervical vertebrae and jaw can be explained by the functional matrix theory. The transverse contraction of the upper maxilla easily causes an alteration of the respiratory pattern because, given the anatomical proximity, the presence of a narrow palate involves a reduced transverse dimension of the nasal cavities and a reduction of the airway volume of the latter. The increase in airway resistance triggers compensatory mechanisms

	SM				
	1-2	3-4	5-6	7-8	9-10
CVM post	12	10	4	4	
CVM normo	17	18	9	11	4
CVM pre		4	2	5	
	29	32	15	20	4
%					
CVM post	41%	31%	27%	20%	0%
CVM normo	59%	56%	60%	55%	100%
CVM pre	0%	13%	13%	25%	0%

TABLE 3 The concordance (%) between CVM stages and SM index in test group. CVM pre = less advanced CVM stage compared to SM stage. CVM post = more advanced CVM stage compared to SM stage.

	SM				
	1-2	3-4	5-6	7-8	9-10
CVM post	3	4	3	1	
CVM normo	21	20	23	12	8
CVM pre		2	1	1	1
	24	26	27	14	9
%					
CVM post	12%	15%	11%	7%	0%
CVM normo	88%	77%	85%	86%	89%
CVM pre	0%	8%	4%	7%	11%

TABLE 4 The concordance (%) between CVM stages and SM index in control group. CVM pre = less advanced CVM stage compared to SM stage. CVM post = more advanced CVM stage compared to SM stage.

such as ventilation through the oral cavity in prone individuals and with a low threshold for adaptation. On a neuromuscular level the nasal obstruction stimulates a bio-feedback mechanism in order to recreate a correct size of the upper airways and to guarantee proper ventilation, such as the extension of the rachis, which in turn can alter the cranio-cervical posture [Di Vece et al., 2010; Solow et al., 1984; Hellsing et al., 1987; Webwe et al., 1981; Huggare and Laine-Alava, 1997; Vargervick et al., 1984; Sonnesen and Kjaer, 2008a,b; McNamara, 1981]. Due to altered head posture soft tissues press on the underlying bones, with subsequent change of the skeletal growth direction. The maximum concavity of the lordosis curvature is visible around the area of vertebrae C3, C4 and C5, where the fulcrum of the flex-extensor movements of the cervical rachides is located. These factors might play a role in the onset of vertebral defects in these specific cervical vertebrae. The cervical vertebrae of growing individuals can be easily modified, since they are not fully ossified. At the cervical rachis level, oral breathing becomes a "dysfunctional" factor, capable of disturbing and altering the functional matrix of the vertebrae. The subjects of this study showed a discrepancy in the development of the cervical vertebrae mainly in the stages CVM II-III and vertebrae C2 and C3. Such elongation can therefore be the main cause of a possible early development of the vertebrae. We need to remember that skeletal maturity is a continuous process, therefore it can be difficult to define the exact stage of borderline cases [Sonnesen and Kjaer, 2008b]. Therefore, it is advisable that orthodontists use all radiographic indicators available.

Conclusions

From the results of this study it appears that in the test group the presence of different development stages assessed with the two methods can be attributed to postural changes caused by oral breathing, and in particular the lordosis curvature of the cervical spine following an incorrect posture of the head.

This study shows the correlation between the presence of anomalies of the development in the cervical vertebrae and transverse maxillary deficit. It is therefore advisable that the assessment of the SM in a subject with a marked contraction of the maxilla, if carried out through observation of the cervical vertebrae, is accompanied by a hand radiograph in order to assess the real stage of development previously elaborated based upon CVM. Only then it will be possible to have a real picture of the development stage of the patient and to plan the treatment.

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