Analysis of rapid maxillary expansion using Cone-Beam Computed Tomography

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Abstract

Whenever a maxillary arch is diagnosed as skeletally atresic the treatment of choice is usually maxillary orthopedic expansion, involving separation of the midpalatal suture. Basically, this suture used to be assessed with the aid of a maxillary occlusal radiograph, which limited its posteroanterior evaluation. Similarly, quantifying this atresia in cephalometric x-rays always posed an obstacle for clinicians owing to considerable superimposition of facial structures. With the advent of computed tomography, this technology has revolutionized diagnostic methods in dentistry because it provides high dimensional accuracy of the facial structures and a reliable method for quantifying the behavior of the maxillary halves, tooth inclination, bone formation at the suture in the three planes of space, as well as alveolar bone resorption and other consequences of palatal expansion.

Keywords: Diagnosis. Radiographic images. Rapid maxillary expansion. Cone-Beam Computed Tomography.

INTRODUCTION

Recovery of transverse maxillary discrepancy seems to be essential for the proper treatment of various types of malocclusion. Several authors have investigated possible methods to expand the maxillary arch through different means. Proponents of rapid maxillary expansion (RME) argue that this method causes minimum tooth movement and maximum skeletal displacement. Conversely, advocates of slow expansion believe that this method produces less tissue resistance in neighboring maxillary structures while enhancing bone formation in the intermaxillary suture, and that these two factors help to minimize postexpansion relapse.[12,13]

Some authors have advocated the separation of the midpalatal suture to expand narrow maxillary arches.[11,15,20] Moreover, Graber,[7] in 1972, asserted that this technique is in decline as it develops open bite, relapse and improves nasal breathing only temporarily (REF). Furthermore, conventional orthodontic appliances have proved successful in accomplishing intermolar and intercanine maxillary expansion.

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Given the diversity of structures comprised in the craniofacial complex various therapeutic resources have emerged which are capable of modifying the position or morphology of these components. Lateral maxillary atresia is a very common condition in different malocclusions. This transverse deficiency, caused by genetic and/or functional[4] factors, may involve only the posterior dental segments, imparting excessive lingual tipping to these segments,[6] but it may also be associated with a skeletally compromised maxilla, which gives it a sicatréo appearance.[6,14] When this happens, the maxilla presents with a narrow[6] and gothic palate.[14] To remedy this situation, an expansion is required which is capable of effecting maximum orthopedic movement of the maxillary bones while maintaining the integrity of the tissues and reducing the resulting tooth inclination.[1,4,12,13,15,17,25] Rapid maxillary expansion (RME) meets these requirements, restoring the transverse dimensions of this bone structure and corresponding dental arch[14,25] by opening the midpalatal suture in conjunction with orthopedic reactions in other facial sutures and slight movements in the posterosuperior segments.[8]

Numerous studies have been conducted to investigate the changes caused in the maxillary bones and midpalatal suture as a result of rapid maxillary expansion. Histological experiments on animals showed new bone formation in the suture zone after palate splitting.[5,10,28] Radiographic studies in humans showed ossification in the region after expansion. However, the length of time that the palatal suture takes to restore its normal structure in humans is still the subject of considerable controversy. The vast majority of authors recommend that retention be performed with the appliance itself, after palate splitting, for a period of three months.[2,8,10,16,18,19,22]

The ability to measure these changes allows orthodontists to predict the effects of orthopedic treatment. Invasive techniques such as metal implants provide accurate information but are too aggressive for routine use. Histological control of tissue reactions is possible only in animal studies or autopsy material.[27]

Several authors have studied the skeletal and dental changes resulting from opening the midpalatal suture but the literature is still inconclusive regarding dimensional changes in dental arches and maxillary displacement as a whole, and whether or not these changes are transient.[4,11,12,30]

According to Sato et al,[23] posteroanterior cephalometric radiography provides an assessment of the transverse dimensions of the face by broadening the scope and thus facilitating the diagnosis of crossbites and orthopedic changes inherent in the rapid opening of the midpalatal suture. Because it is an image in two dimensions, radiographic overlays of anatomical structures hamper the precise location of cephalometric landmarks, which are instrumental for diagnosing and assessing the maxilla before or after any intervention, notably in the maxillary middle third.[9]

Assessment of frontal radiographs shows that the maxillary bones are displaced laterally with the fulcrum located close to the frontomaxillary suture while lower skeletal expansion progresses. The maxillary central incisors usually move mesially and, in general, undergo uprighting after appliance stabilization. Such movement aids in closing the wide median diastema produced by the orthopedic effects of the appliance. As these teeth are uprighted, part of the arch length benefits obtained with the expansion is lost. The occlusal radiograph shows that the intermaxillary suture experiences a non-parallel opening accompanied by a further, V-shaped expansion, greater in the anterior than in the posterior region.[30]

In frontal view, a pyramid appears in the region of this suture, whose base is turned inferiorly. Thus, real bone mass gain occurs with a consequent increase in arch perimeter.[4,10,11]

Occlusal radiographs have been widely used for monitoring the recovery of the suture after palatal separation. However, standardizing how x-rays are performed is not a simple matter.

The occlusal view showed that in the anteroposterior direction the opening of the suture would be twice as large in the incisor than in the molar region, allowing the visualization of a new triangle with the base facing the anterior region. Apparently, the amount of opening varies with each individual. By comparing the opening of the intermaxillary suture with the dental effects it was found that the amount of suture separation would be equal to or less than the amount of expansion in the dental arch.[10]

The advent of Cone-Beam Computed Tomography (CBCT) has made possible three-dimensional assessment. Today, it is increasingly applied in dentistry mainly because it is more affordable and entails lower radiation exposure.[9]

To compare the biological effects of radiation on various parts of the body, effective equivalent dose is used, which yields a comparison of the biological effects of different types of ionizing radiation and allows adjustments to be made in the volume and radiosensitivity of irradiated tissue. The unit of measure used is the sievert (Sv).[9,24]

The effective equivalent dose in conventional radiographic examinations, comprising 3 maxillary periapical radiographs (5 µSv), 3 mandibular periapical radiographs to assess the bone tissue available in the mandibular symphysis (5 µSv), 1 upper occlusal radiograph (4 µSv), 1 panoramic radiograph (7 µSv), 1 posteroanterior cephalometric radiograph (7 µSv), 1 lateral cephalometric radiograph (7 µSv), results in a total of 42 µSv.[9,24] Using a Cone-Beam CT scanner such as the i-CAT, radiation exposure is approximately 30-100 µSv for examining both the maxilla and mandible, which represents a reduction of 1/6 in patient radiation exposure compared to a conventional medical CT scanner (helical). Cone-Beam CT radiation dose is similar to the radiation dose used in the periapical examination of the entire mouth, equivalent to approximately 4-15 times the dose of a panoramic X-ray.[9]

Moreover, compared to conventional radiography, the potential of CT to provide additional information is much higher. Additionally, with Cone-Beam CT, professionals can obtain reconstructions of all conventional dental radiographs in addition to the unique information provided by multiplanar and 3D reconstructions.[9]

As new knowledge is generated by three-dimensional views of the skull and face, Cone-Beam CT is expected to change concepts and shift paradigms, redefining goals and treatment plans in orthodontics. This would facilitate the diagnosis of maxillary atresia and maxillary behavior in terms of expansion procedures, thus allowing for quantification of the actual skeletal gains in dealing with two different activation protocols. CT will therefore contribute to diagnosis to the extent that it will be decisive in establishing the best protocol expansion to be used in treatment planning.[9]

DISCUSSION

The increase noted in upper arch transverse dimensions after rapid maxillary expansion (RME) is due mainly to orthopedic effects, implying a real gain in bone mass and dental arch perimeter, as illustrated in Figures 1 and 2. Besides providing an expected increase in dental arch width, the Haas expansion appliance provides high palatal expansion, which translates into a significant transverse increase in the deep region of the palate. Clear clinical evidence of separation of the maxillary processes is given through a gradual opening of the diastema between the maxillary central incisors, observed in Figure 3. After the third complete turn of the screw, the incisors are affected by rapid maxillary expansion. From this stage on, a direct relationship takes place between the magnitude of the open diastema and the amount of orthopedic effect induced by the expansion. It is therefore possible to perform a clinical interpretation of skeletal involvement during RME: The larger the diastema, the greater the induced orthopedic effect. After expansion screw stabilization the central incisors returned spontaneously to their original position. Control over this now purely orthodontic movement is linked to the memory of stretched gingival fibers, which rapidly move, first the crowns, then the roots, closer to each other.

Total maxillary occlusal x-rays are the routine diagnostic tool used in orthodontic practice to verify and document suture separation. Cone-Beam computed tomography enables more accurate result evaluation and improved quantification. One can observe a triangular, radiolucent area with its base facing the anterior nasal spine, a region where bone strength is reduced (Figs 2 and 3). At the same time that CT confirms the orthopedic splitting of the maxilla, it subsequently records midpalatal suture reorganization, which occurs during the retention phase, when the appliance is kept in the mouth (Fig 4). The fixed expander should only be replaced by a removable retention plate after complete tomographic restructuring, which takes on average 3-4 months.[29]

It seems indisputable that, even though the predominant effect is of an orthopedic nature, orthodontic effect, represented by the flaring of the posterior teeth and alveolar process, is an integral part of rapid maxillary expansion. It is known to practitioners who deal with orthopedic expansion that hand in hand with the gradual opening of the midpalatal suture, the force delivered by the expander causes periodontal ligament compression, lateral tipping of the alveolar process and subsequent flaring of the posterior teeth. These changes represent the orthodontic effect of RME. But before these forces induce classical orthodontic movement with osteoclastic histological changes in the periodontium, the maxillary bones are split due to orthopedic effects (Figs 2 and 3).

The ratio between orthopedic and orthodontic effects derived from rapid maxillary expansion depends mainly on bone strength, which increases with age. As a general rule, effects on the basal bone tend to be significant in children and minimal, or even non-existent, after the growth phase. As patient age increases, orthodontic effects will be increasingly more prevalent than orthopedic effects.[21]

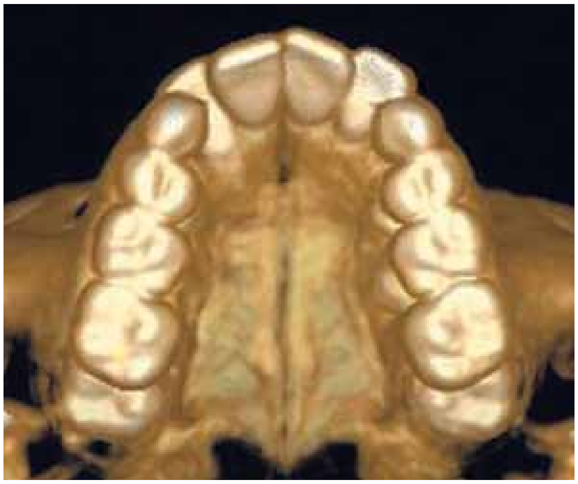

FIGURE 1 - Three-dimensional occlusal reconstruction of the maxilla from a CT scan, showing the closed midpalatal suture.

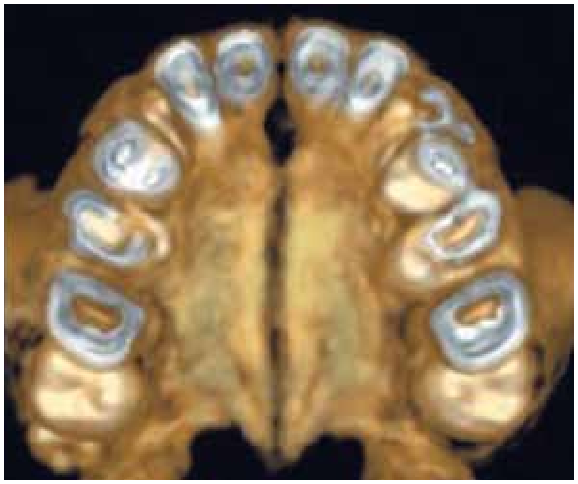

FIGURE 2 - Three-dimensional occlusal reconstruction of the maxilla from a CT scan, showing the open midpalatal suture.

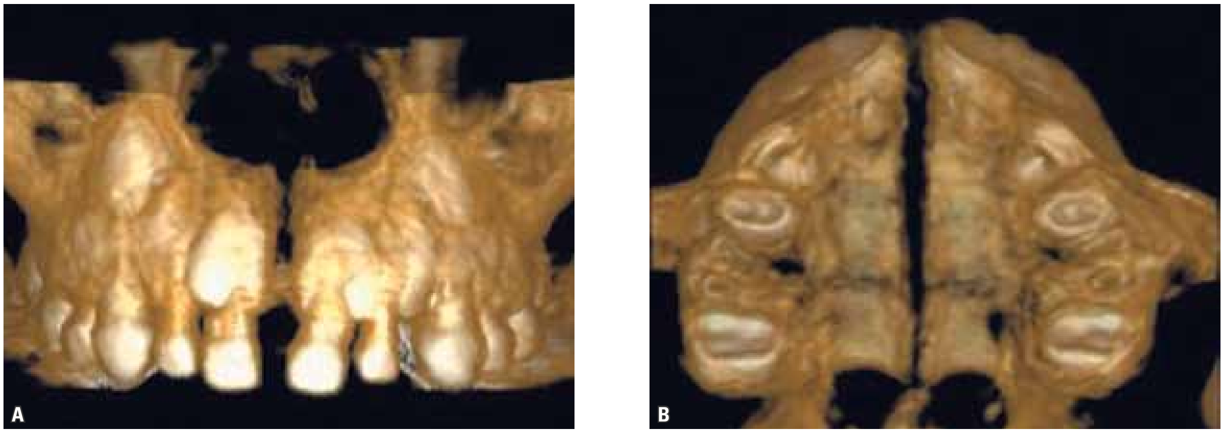

FIGURE 3 - Three-dimensional occlusal reconstruction of the maxilla from a CT scan, showing the open midpalatal suture: (**A**) posteroanterior view; (**B**) occlusal view.

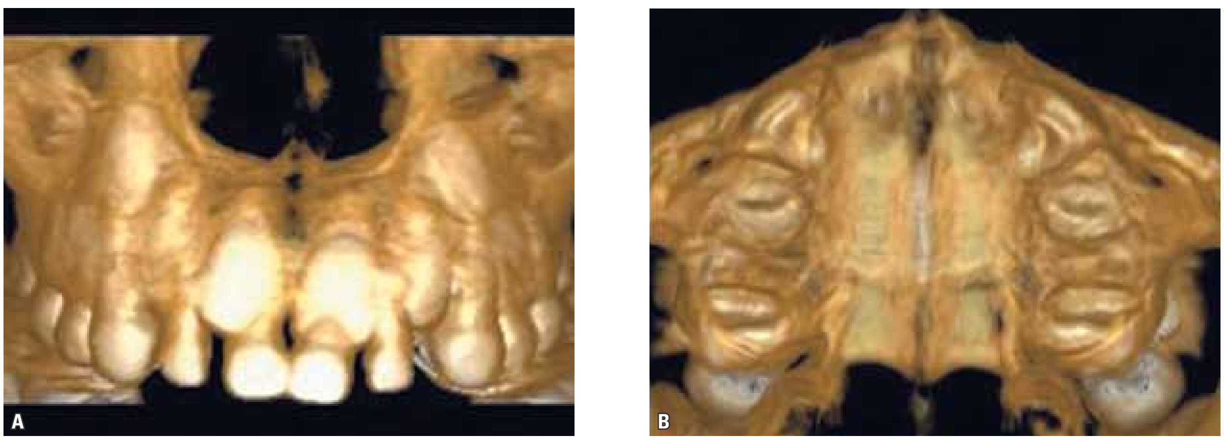

FIGURE 4 - Three-dimensional occlusal reconstruction of the maxilla from a CT scan, showing the suture reorganization process: (**A**) posteroanterior view; (**B**) occlusal view.

CONCLUSIONS

It could be argued that nowadays orthopedic maxillary expansion is part and parcel of a coherent therapeutic approach in orthodontic practice, provided that maxillary atresia is present. The lateral repositioning of the maxilla and increased basal bone, which can be accurately observed in Cone-Beam computed tomography confirms the marked morphological changes that occur in the upper arch and nasomaxillary structure.

In general, the decision to provide orthodontic treatment using palate-splitting mechanics will depend on the clinical experience of each orthodontist, the need for such procedure and the individual characteristics of each patient, such as age. These variables will establish the orthodontic planning and treatment best suited for each case.

Cone-Beam Computed Tomography is a groundbreaking diagnostic method in dentistry as it provides high dimensional accuracy of the facial structures and a reliable method for quantifying the behavior of the maxillary halves, dental tipping, bone formation at the suture in the three planes of space, as well as alveolar bone resorption and other consequences of palatal expansion.

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