Relapse and Stability of Surgically Assisted Rapid Maxillary Expansion: An Anatomic Biomechanical Study

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Purpose: This anatomic biomechanical study was undertaken to gain insight into the underlining mechanism of tipping of the maxillary segments during transverse expansion using tooth-borne and bone-borne distraction devices.

Materials and Methods: An anatomic biomechanical study was performed on 10 dentate human cadaver heads using tooth-borne and bone-borne distraction devices.

Results: The amount of tipping of the maxillary halves was greater in the tooth-borne group, but the difference was not significant. Four of the specimens demonstrated an asymmetrical widening of the maxilla.

Conclusions: Segmental tipping was seen in both study groups. In this anatomic model, tooth-borne distraction led to greater segmental tipping compared with bone-borne distraction. Keep in mind, however, that this anatomic model by no means depicts a patient situation, and any extrapolation from it must be done with great care. The fact that the tooth-borne group demonstrated greater tipping might reflect the general opinion that bone-borne distraction causes less segmental angulation than tooth-borne distraction. Some tipping was seen in the bone-borne group, suggesting that overcorrection to counteract relapse will be necessary with this treatment modality.

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In patients with transverse and sagittal maxillary hypoplasia of the midface, buccal cross-bites (unilateral and bilateral), anterior and posterior crowding, dental compensation (eg, as lingual tipping of mandibular posterior teeth), and buccal corridors may be noted clinically. The aim of treating this deformity is to obtain transverse occlusal stability, resulting in stable sagittal and vertical relationships.

Orthodontic correction of the transverse discrepancy is successful until closure of the midpalatal suture at approximately 14 to 15 years of age depending on the patient's gender. Once skeletal maturity has been reached, surgically assisted rapid maxillary expansion (SARME), in combination with a corticotomy, must be performed to release the areas of bony resistance, such as the midpalatal suture, zygomatic buttresses, and piriform aperture. This technique includes a buccal corticotomy and a median osteotomy. It appears to be predictable and can provide sufficient expansion as well as long-term stable results. It has several advantages, including bone apposition in the osteotomy site, reduced risk of dental version or extrusion compared with regular orthopedic care, and increased periodontal stability.

Traditionally, a tooth-borne orthodontic appliance called a Hyrax expander is placed preoperatively to expand the maxilla. Dental anchorage gives rise to several complications, including damage to the teeth,

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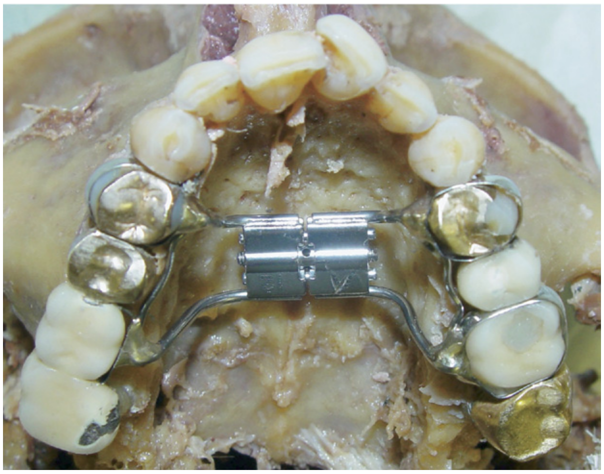

FIGURE 1. Photograph of the tooth-borne distractor (Hyrax) in situ on the anatomic specimen.

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possible loss of anchorage, periodontal membrane compression and buccal root resorption, cortical fenestration, and anchorage-tooth tipping and segmental tipping. Advantages of the Hyrax expander include its ability to be placed and removed in the orthodontic outpatient clinic without local anesthesia.

To help prevent the dental complications, several bone-borne devices (distractors) have been developed. These distractors are placed directly on the palatal bone during surgery. They are claimed to avoid several of the problems associated with the Hyrax expander including damage to the teeth, periodontal membrane compression and buccal root resorption, cortical fenestration, skeletal relapse, and anchorage-tooth tipping.[1-3] The major advantage of the bone-borne devices is that the forces are acting directly to the bone at the mechanically desired level, which prevents dental tipping and keeps segmental tipping to a minimum. Bone-borne devices have several disadvantages, including a risk of damaging the roots of the dentition during placement of the devices, risk of loosening of the module or the abutment plates, and the need to remove the distractor under local anesthesia in the outpatient clinic after the consolidation period.

Relapse, defined as the gradual recurrence over time of the abnormality for which distraction was performed, is widely recognized yet poorly described. There is no consensus in the searched literature regarding the cause and amount of relapse and whether or not overcorrection during the distraction phase is necessary.

One factor to be considered is that some relapse will occur due to the scar tissue contraction after distraction if sufficient time is not taken for consolidation. Three months is generally accepted as sufficient time to prevent this kind of relapse.

Another factor to consider is the mode of distraction. It has been suggested that the relapse is greater when a tooth-borne device is used. An explanation for this might be the tipping of the elements due to the tooth-borne fixation of the Hyrax expander. Another contributing factor may be the tipping of the maxillary segments instead of parallel expansion due to the different position of the tooth-borne and bone-borne distractors relative to the "center of resistance,"[5] the area where the maxillary halves are still connected to the skull after the corticotomy, the pterygoid region.

To the best of our knowledge, to date no basic anatomic study has been performed on this specific subject. This anatomic biomechanical study aimed to gain insight into the underlining mechanism of tipping of the maxillary segments after transverse expansion using tooth-borne and bone-borne distraction devices.

Materials and Methods

An anatomic biomechanical study was performed using 10 dentate human cadaver heads. The skulls were randomly selected into 2 groups of 5 skulls each, with 1 group using the tooth-borne distractor (Hyrax) and the other group using a bone-borne device (Rotterdam palatal distractor [RPD]).[6] All of the soft tissues were removed from the specimens, leaving only the bone intact. In the skulls of the tooth-borne group, dental casts were made, on which the Hyrax expanders were manufactured. A routine corticotomy (buccal and median osteotomy of the maxilla) was performed on each specimen, and either the Hyrax or RPD was placed (Figs 1, 2). The bone-borne

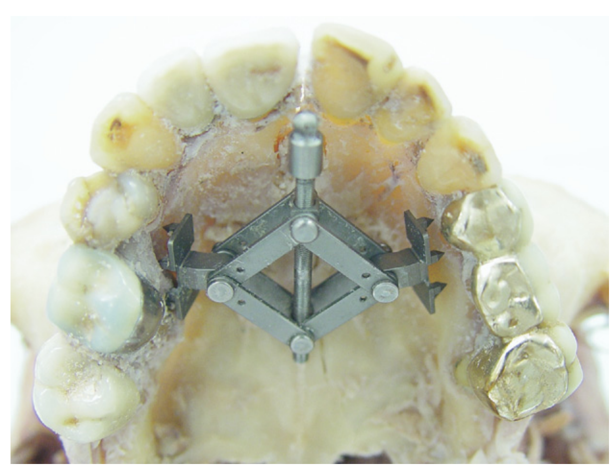

FIGURE 2. Photograph of the bone-borne distractor (RPD) in situ on the anatomic specimen.

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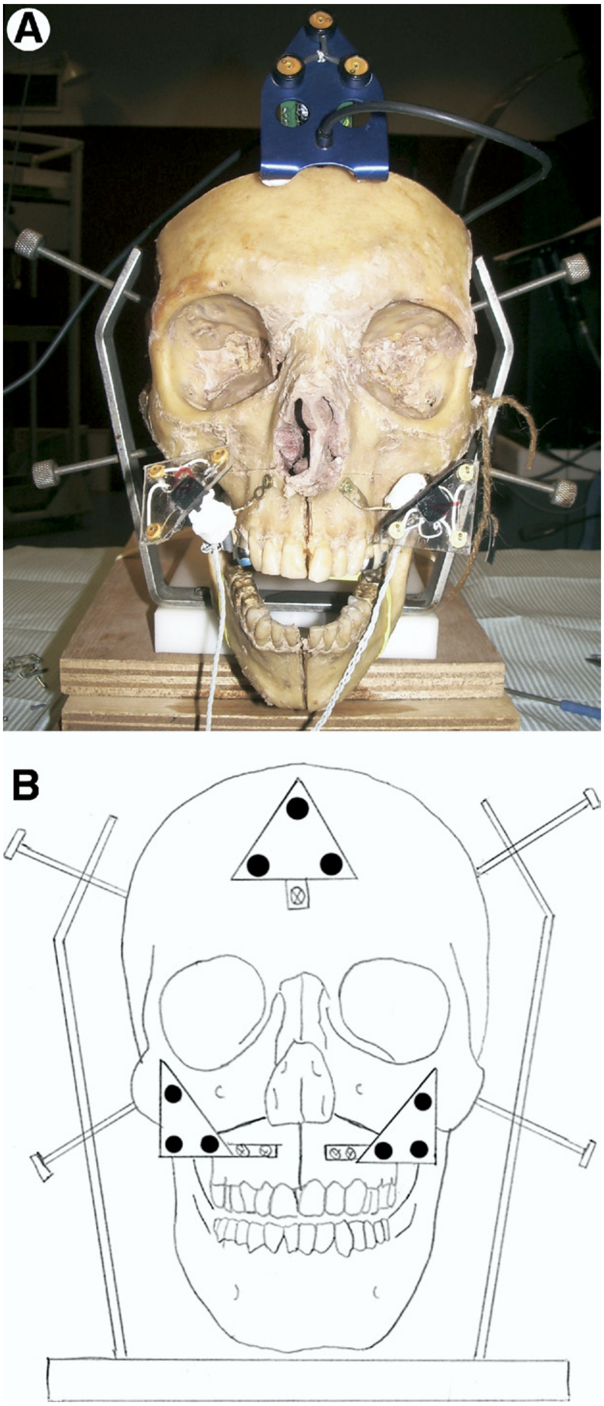

FIGURE 3. *A*, The experimental setup for measurement. The skull is fixed to the investigation table using a steel 4-pin anatomic specimen holder. Note the 3 sensor plates each containing 3 active markers. *B*, Schematic drawing of the experimental setup for measurement.

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RPD was placed on the palate as superiorly as possible. Each skull was fixed to the investigation table using a steel 4-pin anatomic specimen holder. There was no contact between the upper and the lower dentition. The same amount of distraction was acquired in both groups (1.5 cm).

During the distraction phase, the movement of the maxillary halves was registered using an opto-electronic system with active markers (Optrotrak 3020; Northern Digital Inc, Waterloo, Canada).[7] This device uses active markers that can be placed on the object of interest and is capable of measuring movement with a resolution of greater than 0.02 mm. Three small plastic plates were used, each with 3 markers positioned in a triangular configuration. These 3 markers made it possible to measure the displacement in distance and in angles (resolution, 0.05 degrees). The plates were connected with osteosynthesis screws to the bone. One of the plates was connected to the left maxillary half, and the other plate was connected to the right maxillary half. The third plate was connected to the frontal bone of the skull to measure any unwanted movement of the entire specimen due to manipulation (Fig. 3).

Results

The results of the angular displacement measurements are given in Table 1. Both maxillary halves have a horizontal and vertical outcome. The vertical result is the amount of rotation in the coronal plane, in other words, the amount of tipping of the maxillary half. The horizontal result is the rotation of the maxillary half in the axial plane. Table 2 shows the average vertical and horizontal rotations per group and the outcome of the statistical analysis (Student *t* test). The outcomes of the vertical and horizontal movements in both groups were not significant. Specimens 1 and 8 and, to a lesser degree, specimens 5 and 7, exhibited asymmetric widening of the maxilla.

Table 1. RESULTS OF THE OPTOTRAK MEASUREMENTS: VERTICAL AND HORIZONTAL ANGULAR DISPLACEMENT OF THE RIGHT AND LEFT MAXILLARY SEGMENTS (IN DEGREES)

Specimen	Right Vertical	Right Horizontal	Left Vertical	Left Horizontal
1 Hyrax	1.70	9.02	1.32	2.78
2 Hyrax	2.97	1.76	1.06	1.86
3 Hyrax	1.69	3.01	5.30	1.04
4 Hyrax	0.69	1.64	5.96	1.82
5 Hyrax	9.46	2.54	0.91	7.93
6 RPD	1.29	1.26	0.62	2.25
7 RPD	1.98	6.64	2.41	2.48
8 RPD	9.41	10.85	1.04	2.11
9 RPD	1.00	1.13	2.10	3.98
10 RPD	1.79	2.15	2.07	0.17

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Table 2. AVERAGE AMOUNT OF HORIZONTAL AND VERTICAL MOVEMENTS IN THE 2 GROUPS

Group	Average Vertical Movement, Degrees	Average Horizontal Movement, Degrees
Hyrax	5.42	5.73
RPD	3.32	5.54
P value; *t* test	.161 (NS)	.785 (NS)

Abbreviation: NS, not significant.

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Discussion

The major advantage of the bone-borne devices is claimed to derive from the fact that the forces are acting directly to the bone at the mechanically desired level.[4] Therefore, distraction by bone-borne devices would be expected to have a more parallel movement with less tipping of the maxillary halves compared with distraction by tooth-borne devices.

Few studies have reported relapse in SARME; relapse rate varies from 5% to 25%.[2,4,8-11] Pogrel et al[12] studied 12 adult patients, all of whom were still in orthodontic appliances 1 year after surgery and tooth-borne distraction, and found a relapse rate of only 11.8% at the maxillary first molar. Bays and Greco,[8] in a retrospective study of 19 adult patients after tooth-borne distraction who were out of orthodontic appliances for longer than 6 months, found relapse rates of 8.8% at the canines, 1% at the first premolar, and 7.7% at the first maxillary molar. The mean follow-up period in that study was 2.4 years. These authors concluded that SARME has excellent stability, and thus no overcorrection is necessary. Several authors have reported relapse using SARME in combination with a tooth-borne distractor, but have not quantified the amount of relapse.[13-15]

As for bone-borne distraction, Matteini and Mommaerts,[1] using the transpalatal distractor (TPD), and Zahl and Gerlach,[16] using the palatal distractor (PD), found overexpansion to be unnecessary because they detected no relapse on follow-up. These authors attributed the advocated lack of relapse to the fact that the forces of distraction are applied directly to the skeletal base.

As mentioned earlier some theorize that that distraction by bone-borne devices has a more parallel movement with less tipping of the maxillary halves compared with tooth-borne devices. Thus, it is important to place the bone-borne device as superiorly as possible to achieve optimal positioning and a vector of the distraction forces relative to the "center of resistance." If the assumption that tipping (either dental or segmental) causes relapse is correct, then there would be no need for overcorrection if the movement of the maxillary halves was perfectly parallel. In this study, segmental tipping occurred in both the tooth-borne and bone-borne groups, suggesting that overcorrection is needed to counteract the tipping-related relapse regardless of the device used. The tooth-borne group showed more tipping (although not significantly so), reflecting the general opinion that bone-borne distraction causes less segmental angulations than tooth-borne distraction.

Keep in mind that this anatomic model by no means depicts a patient situation, and any extrapolation from it must be done with great care. The distraction in this study was performed all at once. This is in contrast with the normal clinical situation in which distraction osteogenesis is performed gradually, thereby allowing the tissues the possibility to respond to the applied forces. The anatomic specimens were not able to respond to the different stresses applied, which possibly could have influenced the outcome between the different study groups and also possibly the degree of asymmetric widening.

In several clinical cases, the expansion of the maxilla was asymmetric. In these patients, 1 maxillary half moved more than the other or even solitarily, leaving the other side stationary, leading to an asymmetric end result. Our first impression was that the surgical mobilization was not performed evenly on both sides. In 1 case, we performed a second surgery in which both maxillary halves were again evenly mobilized; however, during the distraction phase, the same asymmetric widening occurred. An explanation for this finding could be that the different occlusal contact on each side was causing this problem. During the distraction phase of this anatomic study, asymmetric widening also occurred in 2 cases (Fig 4), speci-

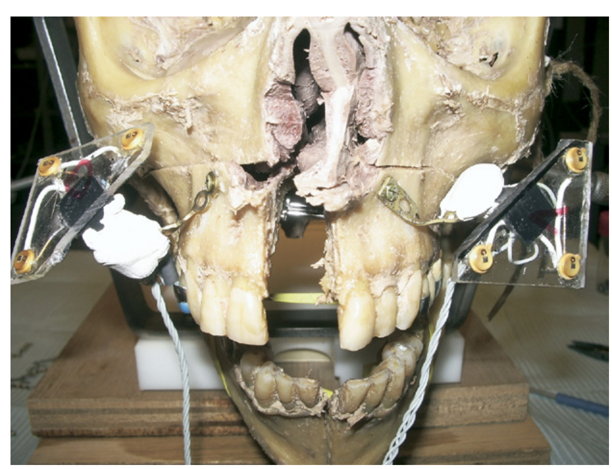

FIGURE 4. Photograph of the asymmetric expansion of the maxillary halves. Note that the right maxillary half has moved, whereas the left half is almost stationary.

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mens 1 and 8, and, to a lesser degree in specimens 5 and 7 (Table 1). The fact that asymmetric widening also occurred with no influence of the occlusion casts a different light on the former explanation, making it less plausible.

Based on what we learned from this study, another possible explanation might be that an equilibrium exists between the resistance of both maxillary halves. After the corticotomy, the maxillary halves are connected to the skull in the pterygoid region. This area and also probably the soft tissues (muscles, ligaments) will affect the amount of resistance on each side. If the difference in resistance between the 2 sides is excessive, then only the side with the least resistance will move, leaving the other side stationary.

Segmental tipping of the maxillary halves was seen in both study groups. In this anatomic model, tooth-borne distraction led to more segmental tipping compared with bone-borne distraction. One should be aware that this anatomic model by no means depicts a patient situation, and any extrapolation from it must be done with great abstention. The fact that the tooth-borne group showed more tipping might reflect the general opinion that bone-borne distraction causes less segmental angulations as tooth-borne distraction. There is also some tipping in the bone-borne group suggesting that overcorrection to counteract relapse would be necessary with this treatment modality.

Asymmetric maxillary expansion which is seen in the clinical situation was also encountered in this study model, suggesting that an imbalance in the equilibrium of the resisting forces in the maxillary segment might be the causative factor.

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