CASE REPORT

Adjusting Force Vectors During Maxillary Retraction with Miniscrew Anchorage

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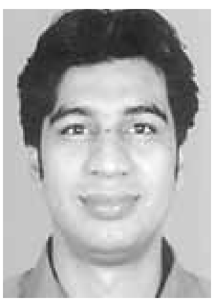
Whatever treatment method is used for maximum bodily retraction in extraction cases, the clinician's ability to control the mechanics will determine the outcome. One of the inherent limitations of orthodontics is the point of force application on the bracket, which is always at a distance from the center of resistance (CR) of the tooth or a consolidated section of teeth. To overcome this limitation and achieve the desired tooth movement, a counter-couple or -moment is required.

On the other hand, if the force vector can be designed to pass through the CR, the need for a counter-moment is reduced. This can now be accomplished with the use of miniscrews to anchor forces from hooks soldered to the archwire.[1-4] In addition to providing skeletal anchorage, such mechanotherapy provides a more reliable way to adjust the line of force for en masse retraction.

A problem still remains, however: determining the exact location of the CR of a tooth or segment of teeth.[5-7] The following case shows how force vectors may need to be modified based on a patient's individual response during treatment.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Diagnosis

A 21-year-old female presented with the chief complaint of protrusive upper and lower front teeth (Fig. 1). She had a brachycephalic, brachyfacial, convex profile with no divergence, competent lips, and a minor tongue-thrust habit. The upper and lower arches were symmetrical, with moderate spacing in the incisor regions, and the lower midline was shifted to the right. Molar and canine relationships were Class I on both sides, with an overjet and overbite of 1mm each.

Cephalometric analysis revealed an orthognathic maxilla and mandible, normal facial proportions, and Class I skeletal bases, with an ANB angle of 1° (Table 1). Convergent jaw bases indicated a horizontal growth pattern. Both the upper and lower incisors were severely proclined and protracted according to the Steiner analysis, with the upper incisors almost parallel to the facial axis. Bolton tooth ratios

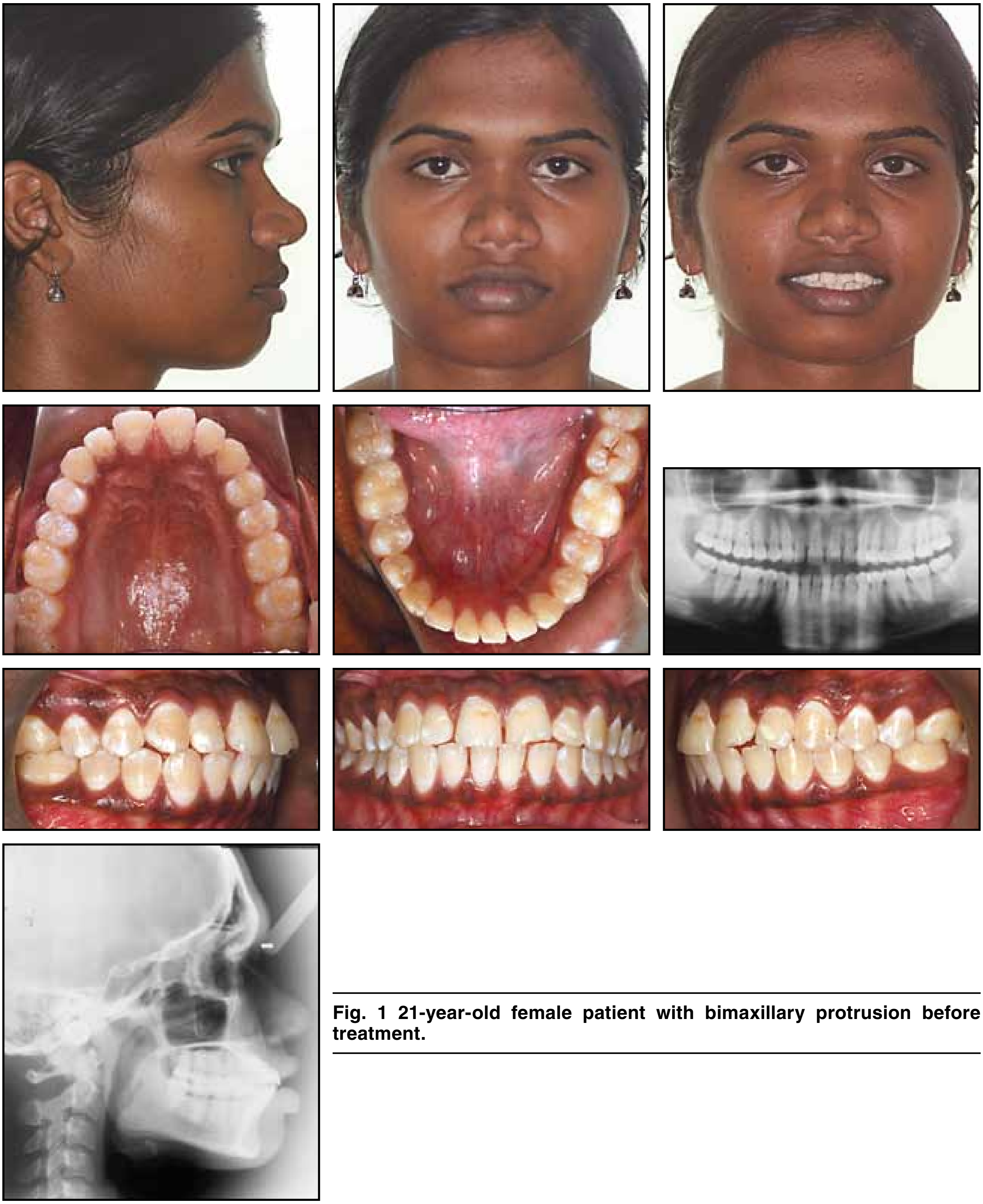

Fig. 1 21-year-old female patient with bimaxillary protrusion before treatment.

TABLE 1
CEPHALOMETRIC ANALYSIS

	Pretreatment	Post-Treatment
SNA	82.0°	81.0°
SNB	81.0°	81.0°
ANB	1.0°	0.0°
GoGn-SN	20.0°	20.0°
U1-NA	44.0°	39.0°
U1-FH	129.0°	124.0°
L1-NB	36.0°	25.0°
IMPA	109.0°	97.0°
Interincisal angle	101.0°	118.0°
Upper lip to E-line	0.0mm	–4.0mm
Lower lip to E-line	4.0mm	–1.5mm
Upper lip to S-line	2.0mm	0.0mm
Lower lip to S-line	6.0mm	1.0mm
Merrifield Z-angle	60.0°	75.0°
Nasolabial angle	65.0°	91.0°
Upper lip cant	36.0°	18.0°

were normal, but Carey's analysis and arch-perimeter analysis both showed an arch-perimeter excess of 1mm.

Treatment Plan

Treatment objectives were to level and align the arches and to maintain the posterior occlusion while retracting the upper and lower anterior teeth to achieve an esthetic profile. Extraction of the first premolars would be followed by en masse retraction of the upper arch using skeletal anchorage and lower anterior retraction with conventional mechanics.

Although the cephalometric analysis showed severe proclination of the upper and lower dentition compared to Steiner's values, we planned to treat the case in accordance with the patient's ethnic norms, which indicate an average interincisal angle of 119.7°.[8,9] Such proclination is common in low-angle patients,[10] but according to Ricketts, a low interincisal angle can provide a good plateau for articulation of the mandibular incisors against the maxillary incisors.[11] In Schudy's view, a small interincisal angle also minimizes the tendency of the incisors to upright with further mandibular growth.[12] In this case, to achieve our treatment objective, the upper incisors required only minimal tipping and further bodily retraction.

Treatment Progress

After .022" preadjusted brackets were bonded in both arches, initial leveling and alignment were initiated with .014" nickel titanium wires. Because only a modest amount of alignment was needed, this phase was completed with .0175" × .025" heat-activated nickel titanium and .019" × .025" stainless steel wires. Anterior spacing was consolidated with figure-8 ligatures. Since all fixed mechanotherapies are extrusive in nature and the bite was shallow to begin with, care was taken to minimize extrusion during treatment: no curve of Spee was added to the archwire, no interarch elastics were used, and the second molars were not bonded.

To anchor the substantial bodily retraction of the upper anterior region, we then placed miniscrews (1.6mm × 6mm Dual-Top Anchor System*) on both sides between the upper second premolars and first molars. Retraction hooks, positioned 7mm apical to the interproximal bone level, were soldered to the archwire between the upper lateral incisors and canines[5] (Fig. 2).

After three months of maxillary retraction, an anterior open bite was noted, suggesting that the retraction force vector was passing above the CR of the six anterior teeth and producing a counterclockwise moment.[3,4,13,14] Therefore, the height of the anterior hooks was reduced by 3mm, so that the force vector passed slightly below the CR, to correct the open bite while continuing the maxillary retraction (Figs. 3,4). When the upper incisors had been sufficiently retracted, the miniscrews were removed, allowing a slight mesialization of the upper molars for final detailing.

Results

After 21 months of treatment, all appliances were debonded (Fig. 5). Analysis of the ceph-

Fig. 2 Application of retraction forces to hooks 7mm above interproximal bone level.

Fig. 3 After appearance of anterior open bite following three months of retraction, archwire hooks were reduced by 3mm in height.

alometric superimpositions showed that the retraction of the maxillary anterior teeth was accomplished primarily by translation, with minimal tipping, whereas the lower anterior teeth were retracted by tipping alone (Table 1).

A small amount of anchorage loss occurred in the lower arch, but we felt this was insignificant because we still achieved acceptable facial balance in both hard and soft tissues. Skeletal anchorage was not used in the lower arch for three reasons: First, since the pretreatment axial inclination of the lower incisors was excessive (109° to the mandibular plane), a tipping movement was called for rather than bodily translation, which would have put more strain on the molar anchorage. Second, although considerable anchorage loss occurs during leveling and alignment with preadjusted edgewise appliances,[15] the arches in this case were well aligned to begin with, so that the anchorage demand was not high. Third, posterior anchorage control is not as critical in the lower arch due to the reduced tip and torque of the bracket prescription and the greater cortication of the mandible.[15]

Discussion

Theoretically, skeletal anchorage makes it possible to achieve any type of tooth movement without anchorage loss, provided the relationship between CR and the force vector is favorable.[14,16] Clinically, however, the picture is a little different. Three major factors are involved:

1. Anatomical constraints in positioning the skeletal anchors, the appliance, and the auxiliaries (in this case, anterior retraction hooks). The occlusogingival positioning of a miniscrew is limited by the width of the attached gingiva and buccal frenum. Similarly, the height of an anterior hook is limited by the depth of the vestibule and the mobile soft tissues in the anterior region. When it is not feasible to create the desired line of force in relation to CR, compensatory torque can be built into the archwire.[16,17]

2. Difficulty in determining moment-to-force ratios. The exact ratio at the target tooth or segment cannot be measured in most clinical situations unless a predictable appliance system, such as a segmented-arch technique,[16] is used.

3. Disagreement over the exact location of CR. The force is a

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physical property applied independent of human biology, whereas the CR can be affected by factors such as tooth morphology, alveolar bone morphology, and periodontal ligament thickness.[14,18,19] Even if uniform displacement of the periodontal ligament space were achieved by applying the proper mechanical force system to cause translation, the anisotropic properties of the ligament itself would make it unlikely that these stresses could be transmitted identically to the responsive cells and tissues.[20]

Attempts to locate the CR of a single tooth have produced varying results, and the CR for groups of teeth is even more difficult to pinpoint.[5,7,18,21,22] Vanden Bulcke and colleagues found that the vertical location of CR for the six maxillary anterior teeth is 7mm apical to the interproximal bone level.[5] According to Pedersen and colleagues, the CR is located 6.5mm apical to the bracket position.[21] A comparison of reports on the CR of the four upper incisors showed a range of 5-15mm from the bracket level of the upper central incisor.[7,14,18,19,22-24]

Other authors have used mathematical or physical models and finite-element modeling to determine the location of the centers of resistance and rotation.[7,25] Most of these models were simplified, however, and therefore did not adequately replicate true anatomical conditions. Cadavers have been used to test actual human teeth,[5,21] but the mechanical properties of the periodontal ligament in humans change substantially after death, and artifi-

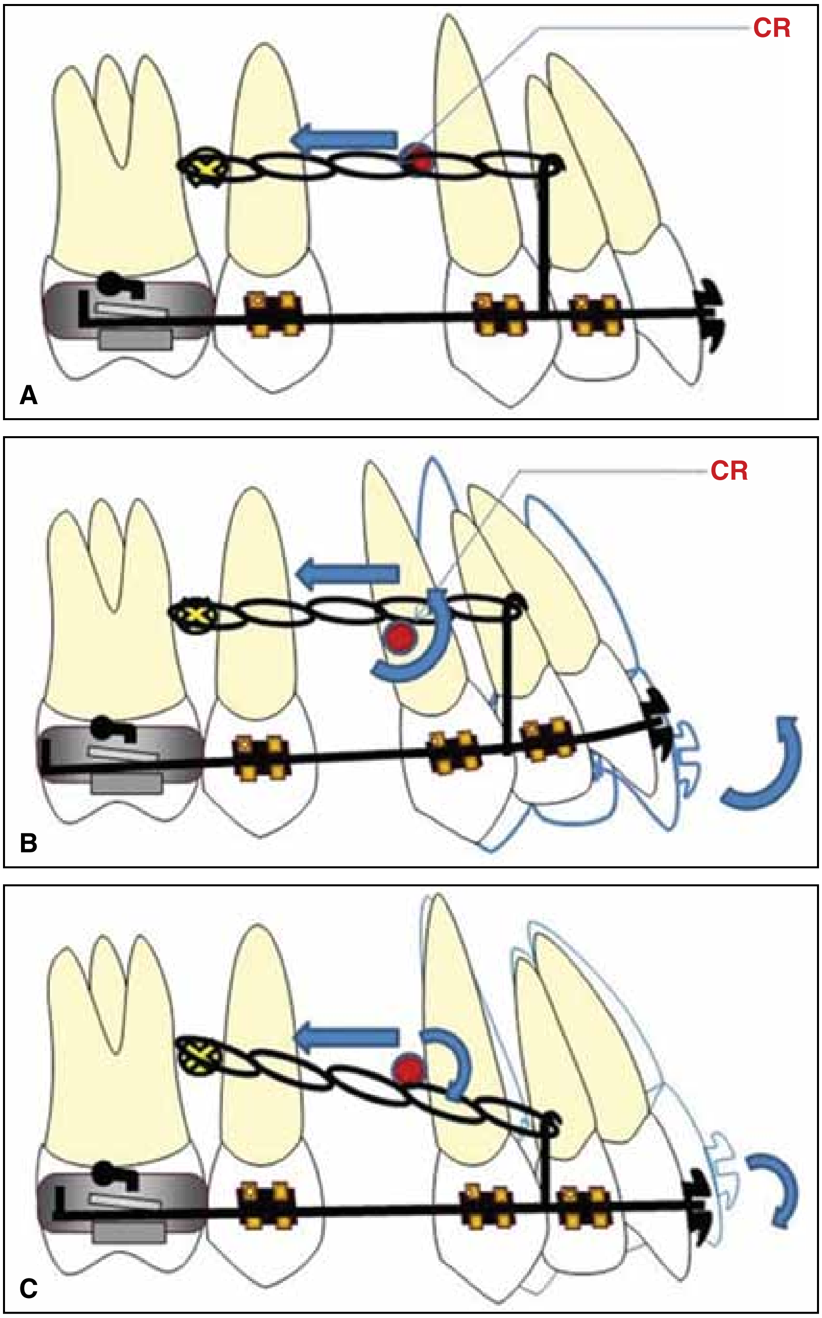

Fig. 4 A. For bodily retraction, line of force should pass through center of resistance (CR) of six anterior teeth—in this example, 7mm apical to crest of interproximal alveolar bone. B. Force vector passing above CR generates counterclockwise moment, leading to anterior open bite. C. Reducing height of hook by 3mm moves force vector below CR, allowing bite to be closed with slight clockwise moment and bodily retraction of anterior segment.

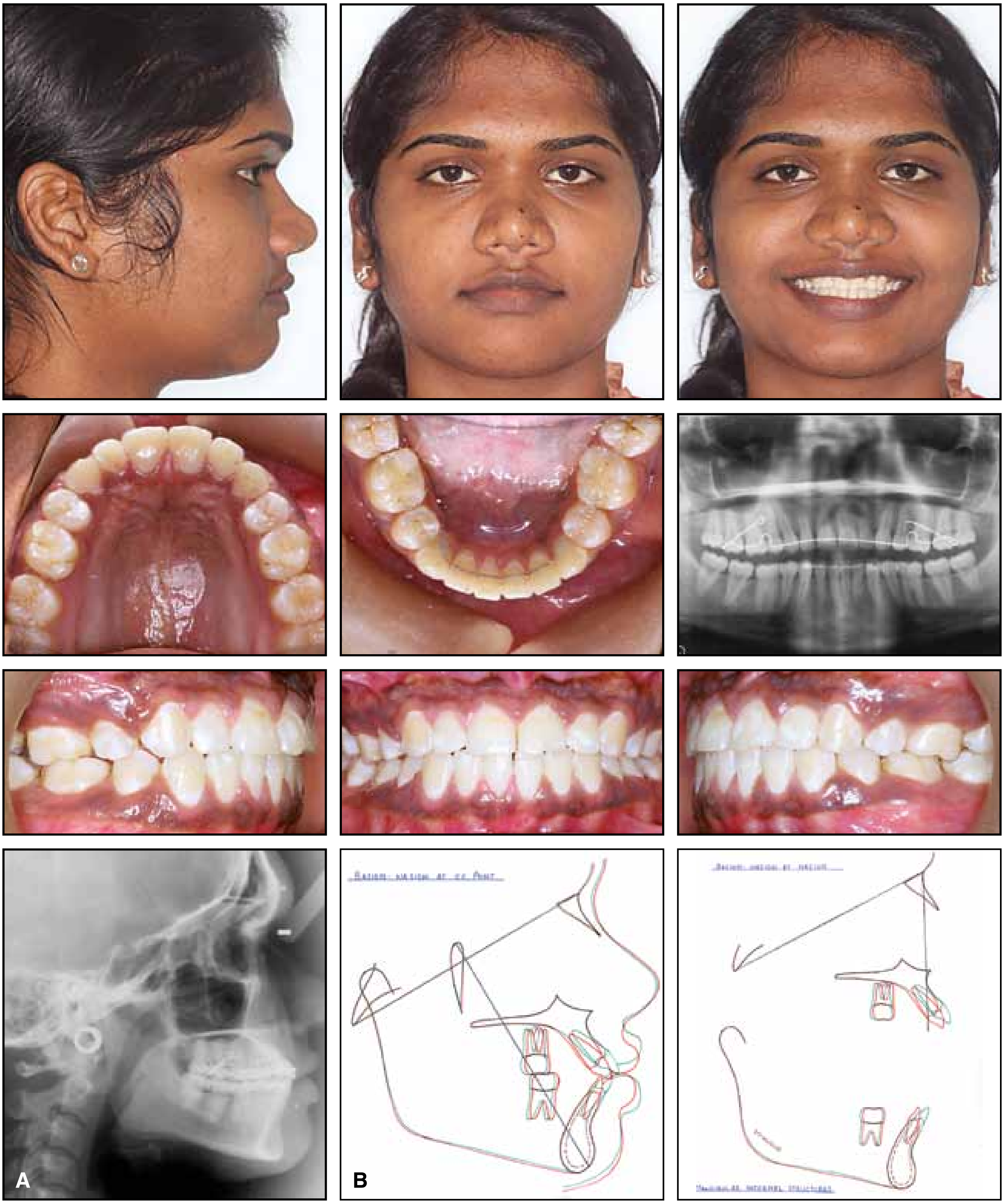

Fig. 5 A. Patient after 21 months of treatment. B. Superimposition of pretreatment (green) and post-treatment (red) cephalometric tracings.

cial materials such as silicone[5] cannot match the ligament precisely. In vivo measurements are needed to obtain more reliable results.

The CR has also been studied by measuring tooth displacements in living tissue with laser-holographic and strain-gauge techniques.[18] The former method is unreliable because even minute head movements of the subject can substantially reduce its accuracy. While more recent three-dimensional finite-element-model studies and in vivo measurements using magnetic sensors have improved the quality of available data,[14,22,23] these researchers still agree about the individual variability of CR, even demonstrating that CR can vary with the force direction on the same tooth.[23] The variety of reference points used in different studies and the difficulty involved in clinical observation of these points create further problems in accurately locating CR.[7,22]

Experimentally determined values of CR can provide only a starting point for planning the biomechanics of tooth movement; the actual location must be determined by clinical evaluation of the resulting tooth movements in each patient. As the case presented here shows, midtreatment adjustments are often needed to achieve the desired results.

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