Lip-to-incisor Relationship and Postorthodontic Long-term Stability of Cover-bite Treatment

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ABSTRACT

Objective: To investigate the impact of a persisting high lip line and other potential relapse-inducing factors on long-term stability of orthodontic correction of retroinclined maxillary central incisors.

Materials and Methods: Thirty-one cover-bite ("Deckbiss") patients with retroinclined maxillary central incisors and a deep frontal overbite were evaluated. The maxillary central incisor inclination was determined odontometrically with study models made pretreatment, posttreatment, and at a follow-up examination (mean posttherapeutic interval: 9.0 years). The lip-to-incisor relationship, the interincisal angle, and the anteroposterior maxillary central incisor position were measured on lateral cephalograms taken after active treatment.

Results: The relapse tendency of the orthodontic correction of the retroinclined maxillary central incisors displayed great interindividual variability with a range of posttherapeutic inclination change of $-6.75^\circ$ to $+8.00^\circ$. Multiple regression analysis revealed an increased tendency for relapse in patients with (1) a high posttherapeutic (dorsal) lip line level combined with the maxillary central incisor and lower lip contact only in the incisal crown area ($P < .01$) and (2) a marked therapeutically induced inclination change of the maxillary central incisors ($P < .05$). Interrelations between the relapse of the corrected maxillary central incisors and other evaluated parameters were not statistically significant.

Conclusions: For maximum treatment stability, the elimination of an excessive overlap of the upper incisors by the lower lip should be regarded as one of the most important therapeutic objectives when treating this malocclusion.

KEY WORDS: Cover-bite; Class II division 2; Relapse; Lip line; Upper incisor retroclination

INTRODUCTION

Cover-bite ("Deckbiss") refers to a dental malocclusion with extremely deep vertical overbite of the upper and lower incisors (Figure 1A) combined with a simultaneous retroclination of at least the upper central incisors.\textsuperscript{1} According to epidemiological studies, the prevalence of this malocclusion in the permanent dentition is around 7%.\textsuperscript{2}

According to clinical observations\textsuperscript{3,4} and retrospective studies,\textsuperscript{5–7} cover-bite shows a highly variable posttreatment stability. Factors considered important in the prevention of relapse include a physiological, posttherapeutic occlusion in the anterior dental segment;\textsuperscript{5,8,9} increased resting lip pressure; and a high lip line.\textsuperscript{10}

The aim of the present study was to investigate long-term stability of the therapeutic correction of retroinclined maxillary central incisors in cover-bite patients and to evaluate the significance of possible relapse-inducing factors. According to the German Radiation law, cephalometric studies for research purposes only are not allowed; therefore, cephalograms were not available from the end of the follow-up period. Consequently, an odontometric method had to be applied to measure the therapeutic and posttherapeutic maxillary central incisor inclination.

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LONG-TERM STABILITY OF COVER-BITE TREATMENT

MATERIALS AND METHODS

Study Group

A group of 31 former patients (17 female, 14 male) who had presented a cover-bite at the start of treatment were selected retrospectively from the records of our department. Inclusion criteria were (1) pretreatment retroinclined maxillary central incisors (≤98° relative to the anterior cranial baseline), (2) pretreatment frontal overbite ≥3 mm, (3) maxillary central incisors uprighted during orthodontic therapy, (4) the availability of a lateral cephalogram taken after completion of active mechanotherapy of sufficient quality to evaluate the posttreatment lip-to-incisor relationship, and (5) completion of active mechanotherapy at least 3 years before a follow-up examination.

These criteria were met by 113 of our former patients. We were able to contact 43 of them, and 31 agreed to participate in the clinical follow-up examination. The mean age of the patients at the start of treatment was 10.6 years (range: 7.0–33.9 years). The collective study group included both nonextraction (n = 25) and extraction (n = 6) cases.

Odontometric Analysis

Plaster casts made before treatment (T1), after active orthodontic treatment (T2), and after the follow-up examination (T4) were randomized and analyzed. Casts were not taken at T3, which corresponded to discontinuation of retention.

To measure the inclination of the maxillary central incisors, we trimmed the bases of the patient’s upper dental casts parallel to the occlusal plane and separated the casts at the midline. The median sides of both halves were ground further so that exactly half of each maxillary central incisor’s crown was removed in a mesiodistal dimension (Figure 2A). The axis of the crown was drawn through the incisal edge and through half the distance between the lingual and labial gingival sulci (or the lingual and labial enamel-cement borders, respectively, in case of gingival retractions) (Figure 2B). The crown inclination relative to the occlusal plane was measured with the help of a special device (Figure 2C).

Drawings of the crown inclination were performed three times each for the right and left maxillary central incisors. Model analysis included evaluation of the buccal and frontal occlusion.

Cephalometric Determination of Lip-line Parameters

The morphological relationships between the lips and the maxillary central incisors after active mechanotherapy were evaluated on the lateral cephalograms taken at T2. One fundamental problem in the determination of the lip-to-incisor relationship is that the contact between the upper lip and lower lip is generally not at a point but over an area (Figure 3). This was taken into account by determining both the most ventral and the most dorsal lip contact points and measuring the vertical distances between each of these points and the incisal edge of the most labially positioned maxillary central incisor (corresponding to the ventral and dorsal heights of the lip line). In addition, the lower lip level was measured to characterize the area of direct overlap between the maxillary central incisor and lower lip (Figure 3).

Additional posttreatment parameters evaluated on the T2 cephalograms included the interincisal angle and the perpendicular distance from the maxillary central incisor incisal edge to the nasion-pogonion line.
Figure 2. Odontometric method for determination of maxillary central inclinations relative to the occlusal plane (defined as the tip of the cusp and the most prominent cusp of the upper first molar). (A) Removal of half of the maxillary central incisor crown in mesiodistal dimension. (B) Drawing of the maxillary central incisor crown axis. (C) Measurement of maxillary central incisor crown inclination.

Figure 3. Parameters describing the morphological relationship between the maxillary central incisor and the lips on the lateral cephalograms: Ventral and dorsal lip line level (VentLipL, DorsLipL) measured as the vertical distance between the incisal edge (Is) and the most ventral and the most dorsal contact point of upper and lower lip (VentStm, DorsStm). The lower lip level (LowLipL) was determined as the vertical distance between the incisal edge and the most cranial contact point of maxillary central incisor and lower lip (LowLipCont). The constructed true horizontal plane (THP) served as reference line.11,12

Clinical Follow-up Examination and Evaluation of Treatment Records

Dental impressions were taken for the odontometric analysis at the clinical examination. In addition, the treatment records of the 31 patients were evaluated regarding tooth extractions during therapy, the type of retention appliance, the period the retention appliance was worn (T3 – T2), and the duration from the end of active treatment to the follow-up examination (ie, the length of the posttreatment interval, T4 – T2).

Statistical Analysis

The relapse of the corrected maxillary central incisors (change in incisor inclination T4 – T2) was subjected to multiple regression analysis by using SAS statistical software (SAS Institute Inc, Cary, NC). Extractions in the upper arch were quantified by defining an index (UExIn) that took into account the site of the extraction. An index defined for the kind of retention described the rigidity of the retention appliance (Re-ApIn). All parameters taken into account in the model calculations are shown in Table 1. Pearson correlation coefficients were calculated for relevant interrelations between model parameters.

The reproducibility of the odontometric determination of the maxillary central incisors’ inclination and for
Table 1. Parameters Included in the Calculation of the Multiple Regression Models Aimed at Explaining the Relapse in Upper Incisor Uprighting

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Parameter</th>
<th>Time Point or Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>VentLipL</td>
<td>Lip line level measured at ventral lip contact point</td>
<td>T2</td>
</tr>
<tr>
<td>DorsLipL</td>
<td>Lip line level measured at dorsal lip contact point</td>
<td>T2</td>
</tr>
<tr>
<td>LowLipL</td>
<td>Lower lip level at labial surface of upper central incisor</td>
<td>T2</td>
</tr>
<tr>
<td>IntInc</td>
<td>Interincisal angle</td>
<td>T2</td>
</tr>
<tr>
<td>U1-NPog</td>
<td>Perpendicular distance from upper central incisal edge to N-Pog line</td>
<td>T2</td>
</tr>
<tr>
<td>OvJet</td>
<td>Overjet</td>
<td>T2</td>
</tr>
<tr>
<td>OvBite</td>
<td>Overbite</td>
<td>T2</td>
</tr>
<tr>
<td>Occl 3b</td>
<td>Occlusion of the upper and lower canines</td>
<td>T2</td>
</tr>
<tr>
<td>Occl 6b</td>
<td>Occlusion of the upper and lower first molars</td>
<td>T2</td>
</tr>
<tr>
<td>U1Incl</td>
<td>Change in inclination of upper central incisors relative to occlusal plane</td>
<td>T2 – T1</td>
</tr>
<tr>
<td>UEInr</td>
<td>Index for maxillary extractions</td>
<td>T1 – T2</td>
</tr>
<tr>
<td>ReApInr</td>
<td>Index for type of retention appliance</td>
<td>T2 – T3</td>
</tr>
<tr>
<td>RetInt</td>
<td>Length of retention interval</td>
<td>T3 – T2</td>
</tr>
<tr>
<td>PTrInt</td>
<td>Length of posttreatment (follow-up) interval</td>
<td>T4 – T2</td>
</tr>
</tbody>
</table>

* T1 indicates before therapy; T2, after active mechanotherapy; T3, discontinuance of retention; and T4, at clinical follow-up examination.

b Given in cusp width.

c The farther to anterior the extraction site, the higher the index.
d The more rigid the appliance, the higher the index.

Table 2. Median Values and Ranges of Determined Odontometric and Cephalometric Parameters Before Therapy (T1), After Active Mechanotherapy (T2), and at the Clinical Follow-up Examination (T4)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>T1 Median</th>
<th>T1 Min</th>
<th>T1 Max</th>
<th>T2 Median</th>
<th>T2 Min</th>
<th>T2 Max</th>
<th>T4 Median</th>
<th>T4 Min</th>
<th>T4 Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>U1Incl, °</td>
<td>72.50</td>
<td>64.25</td>
<td>90.50</td>
<td>64.50</td>
<td>56.00</td>
<td>85.50</td>
<td>66.50</td>
<td>54.75</td>
<td>88.75</td>
</tr>
<tr>
<td>OvBite, mm</td>
<td>4.75</td>
<td>2.75</td>
<td>7.75</td>
<td>3.50</td>
<td>2.00</td>
<td>7.00</td>
<td>3.50</td>
<td>0.75</td>
<td>8.00</td>
</tr>
<tr>
<td>OvJet, mm</td>
<td>2.50</td>
<td>0</td>
<td>4.50</td>
<td>2.25</td>
<td>1.00</td>
<td>4.75</td>
<td>2.50</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Occl 3b</td>
<td>−0.31</td>
<td>−1.13</td>
<td>0.25</td>
<td>−0.23</td>
<td>−0.56</td>
<td>0</td>
<td>−0.23</td>
<td>−0.50</td>
<td>0</td>
</tr>
<tr>
<td>Occl 6b</td>
<td>−0.31</td>
<td>−1.00</td>
<td>0.13</td>
<td>0</td>
<td>−0.71</td>
<td>0.42</td>
<td>0.06</td>
<td>−0.63</td>
<td>0.19</td>
</tr>
<tr>
<td>VentLipL, mm</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>2.75</td>
<td>0</td>
<td>4.50</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>DorsLipL, mm</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>3.75</td>
<td>1.75</td>
<td>5.75</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>LowLipL, mm</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>3.25</td>
<td>1.25</td>
<td>5.00</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>IntInc, °</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>128.5</td>
<td>110.0</td>
<td>154.5</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>U1-NPog, mm</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>6.00</td>
<td>−0.50</td>
<td>12.00</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

* The odontometric parameters represent the average of the measurements on the right and left sides. For definitions of parameters, see Table 1.
b Given in cusp width. Negative value: distocclusion; positive value: mesiocclusion.

Results

Evaluation of Treatment Records

Extractions in the upper jaw (n = 6) concerned the upper first or second premolars only. For retention of the therapeutic result, removable plates (n = 13) were used in most patients, followed by vacuum-formed stents (n = 5), positioners or activators (n = 5), and bonded wire retainers (n = 1). Seven patients broke off retention within a few months after active treatment was finished.

The average duration (median value) of the retention period (T3 – T2) was 1.3 years (range: 0–15.2 years). The total duration of the posttherapeutic (follow-up) phase (T4 – T2) was 9.0 years (range: 3.4–15.2 years).

Model Cast Analysis

The median value of the maxillary central incisor inclination relative to the occlusal plane was 72.5° at T1, 64.5° at T2, and 66.5° at T4 (Table 2).

The corresponding changes during therapeutic and posttherapeutic intervals as well as their interindividual scatter are shown in box plot form in Figure 4A. Not all patients experienced a relapse, and most patients (those with a negative difference T4 – T2 in inclination) displayed further maxillary central incisor uprighting during the posttherapeutic observation period.

The median value for overbite (Figure 4B; Table 2) showed a tendency similar to the inclination values.
Buccal occlusion at time point T1 was $-0.31$ (range: $-1$ to $0.125$) cusp width distal (Table 2), indicating an average distoclusion (negative value) and a spectrum from severe distoclusion up to slight mesiocclusion in the initial study models. The median values of buccal occlusion at time points T2 and T4 were approximately neutral.

**Cephalometric Evaluation**

The cephalometric investigation (using the radiographs taken at T2) revealed a posttreatment lip line level (with reference to the incisal edge) of 2.75 mm measured at the ventral lip contact point and 3.75 mm measured at the dorsal lip contact point (Table 2). The most cranial maxillary central incisor and lower lip contact point was at an average distance of 3.25 mm from the incisal edge. The corresponding ranges of these parameters indicated relatively high interindividual variability.

**Statistical Analyses of Maxillary Central Incisor Inclination Relapse**

The relapse of the correction of the retroinclined maxillary central incisors showed a statistically significant interrelation with the amount of uprighting these teeth during therapy as well as the lip line level at time point T2 measured at both the dorsal and ventral lip contact points ($P < .05$ for all three parameters). Multiple regression analysis revealed that the percentage of relapse variability that could be explained by each of these parameters alone ranged between 12% and 15%. (As an example, the correlation between maxillary central incisor inclinational relapse and the dorsal lip-line level for each patient as well as the trend of the interrelation between these variables in the whole collective is shown in Figure 5.)

The simultaneous inclusion of the dorsal and ventral lip-line level in a regression model led to a redundancy of one of these two parameters (ie, their influence on maxillary central incisor inclinational relapse was interdependent). In contrast, additional consideration of the lower lip level at the labial crown surface considerably increased the percentage of explanation of maxillary central incisor inclinational relapse variability, though the lower lip level alone (ie, in a one-parametric model and the Pearson correlation test, respectively) did not show a statistical significant interrelation with the maxillary central incisor inclinational relapse. The combination of dorsal lip-line level ($\text{DorsLipL}_{(T2)}$) and lower lip level ($\text{LowLipL}_{(T2)}$) explained 31% of maxillary central incisor inclinational relapse variability (maxillary central incisor $\text{Incl}_{(T4 - T2)}$). Equation 1 was determined for this two-parametric model ($P < .01$ for both parameters).

\[
\text{Maxillary central incisor } \text{Incl}_{(T4 - T2)} = 4.01 \times \text{DorsLipL}_{(T2)} - 3.56 \times \text{LowLipL}_{(T2)} - 3.57
\]

**Figure 4.** Box plots: (A) Change in maxillary central inclinations (relative to occlusal plane) during therapeutic ($T2 - T1$) and posttherapeutic ($T4 - T2$) intervals, showing the 5th, 25th, 50th, 75th, and 95th percentiles. (B) Change in overbite during therapeutic ($T2 - T1$) and posttherapeutic ($T4 - T2$) intervals.

**Figure 5.** Correlation between the dorsal lip line level (horizontal axis) and the relapse of the therapeutical correction of the maxillary central incisor retroclination ($n = 31$).
The direction of the interrelations between the two model parameters and the relapse tendency, characterized by the individual coefficients preceding the respective variables, showed opposite polarity. This means that the maxillary central incisor inclinational relapse tendency was particularly high in cases of a high lip-line level at the dorsal lip contact point and, simultaneously, a relatively small overlap of the maxillary central incisor by the lower lip in the area of their incisal edge.

Additional inclusion of the therapeutic inclinational change of the maxillary central incisors (maxillary central incisor Incl(T2−T1)) in the regression model increased the proportion of relapse variability explained by the (three-parametric) model to 34% (equation 2). Although the interrelation between the therapeutic maxillary central incisor inclinational change and the maxillary central incisor inclinational relapse was statistically significant when analyzed in isolation, the corresponding P value in the three-parametric model was >.05, indicating an interdependence of the therapeutic inclinational change and one or both of the other two model parameters.

Maxillary central incisor Incl(T4−T2)
= 3.46 × DorsLipL(T2) − 3.08 × LowLipL(T2)
+ 0.14 × maxillary central incisor Incl(T2−T1)
− 4.04

By inclusion of additional parameters in the regression model, it was possible to further increase the explained proportion of relapse variability (to values >50%), but each of these models included one or several parameters that did not show a statistical significant interrelation with the maxillary central incisor inclinational relapse in both the corresponding regression model as well as in isolation (ie, in a one-parametric model and the Pearson correlation test, respectively).

Reproducibility of Odontometric and Cephalometric Measurements

Ninety-five percent of the repeated odontometric measurements of maxillary central incisor inclination were −3.56° to +3.57° from the corresponding mean value of all measurements. In comparison, the corresponding upper and lower limits for repeated cephalometric maxillary central incisor inclinational measurements relative to the anterior cranial baseline (determined in the context of a previous study14) were −3.27° and +3.87°.

DISCUSSION

The odontometric evaluation of the maxillary central incisor inclination was approximately in the same range when compared with a determination of this parameter on lateral cephalograms. Therefore, no negative impact on the results of the present study with respect to this measurement had to be expected.

The high average stability found in the present study for the therapeutic correction of retroinclined maxillary central incisors was in agreement with previous studies on treatment stability in Class II division 2 and cover-bite cases, respectively.5-7 Other concurrent findings with these previous investigations were the relatively high variability of relapse and the finding of patients with further posttherapeutic improvement of the initial malocclusion (ie, further maxillary central incisor uprighting as well as anterior bite opening in the retention period).

To identify those treatment or retention parameters that were significantly responsible for this high interindividual variability, we performed a multiple regression analysis with efforts to take into account all adequately quantifiable parameters potentially serving as relapse factors. The quantification of several parameters selected as input variables for multiple regression analysis (eg, type of retention appliance) was obviously subject to limitations. Moreover, some possibly relevant factors—other determinants of the amount of soft tissue pressure exerted against the maxillary central incisors (beside the lip line level), the treatment concept, and the applied mechanics or the patient compliance in the retention period—could not be considered in the present study. These aspects, together with the general limitations of accuracy of odontometric or cephalometric measurements, should be kept in mind when assessing the proportions of relapse variability explained by the individual parameters and the models described in equation 1 (31%) and equation 2 (34%). Indeed, these percentages suggest the importance of relapse-inducing factors that could not have been taken into account in this study.

The following parameters displayed a statistically significant interrelation with the relapse tendency of the corrected maxillary central incisor linguoversion: (1) parameters describing the morphological relationship between the lips and the maxillary central incisor after active mechanotherapy (in simplified terms, a high posttherapeutic lip line level) and (2) the extent to which the maxillary central incisor inclination was changed therapeutically. In terms of the respective direction of the statistically determined interrelations, the influence of these parameters on treatment stability is conclusive (ie, the higher the lip line level and the greater the proclination of maxillary central incisors in
the course of therapy, the greater the relapse tendency).

An interesting, and at a first view somewhat contradictory, finding was the relatively high percentage of relapse variability that could be explained by the combination of a high dorsal lip line level and simultaneously a small, incisally located area of direct overlap between the maxillary central incisors and the lower lip. In this respect, it is important to note that the maxillary incisor and lower lip overlap area showed this indirect proportional interrelation with the maxillary central incisor inclinational relapse only in combination with a particularly high dorsal lip line level. Furthermore, if considered in isolation (eg, in the correlation test), the overlap area was actually directly proportional to the relapse tendency, though statistically not significant.

One might speculate that in case of high dorsal lip line level and small, incisally located maxillary incisor and lower lip contact, the smooth contour of the lower lip is compromised by the encroaching contact from the incisal edge of the maxillary central incisors. As a result, a relatively great proportion of the lower lip mass supports itself just against those areas of the maxillary central incisor in which the exerted pressure is most effective regarding tipping these teeth back lingually. Accordingly, both factors determining the lingual tipping moment (pressure magnitude and distance from the center of resistance of the tooth) are maximized. The combination of high dorsal lip line level and small, incisally located maxillary central incisor and lower lip contact might be connected with a relatively proclined maxillary central incisor position after active treatment or a protruded lower lip. The first option might result from pronounced maxillary central incisor proclination during therapy and therefore might explain the interdependence of the model parameters found in the three-parametric regression model (equation 2).

Both a high lip-line level and a great amount of therapeutic maxillary central incisor uprighting were already identified in a previous cephalometric study as potential relapse factors for orthodontic treatment of cover-bite malocclusion.14 Actually, the results of this previous study can be regarded as complementary regarding the distinct durations of the posttherapeutic follow-up periods. An interesting finding regarding the results of the previous study and the present study was that the proportion of relapse variability explained by the lip-line level variability alone was much higher in the present study (with an average posttherapeutic interval of 9.0 years) when compared with the previous cephalometric study (with an average posttherapeutic interval of 2.0 years).

In contrast, the influence of the amount of therapeu-

tic maxillary central incisor inclinational correction on relapse variability showed a clear decrease with increasing time from active orthodontic therapy (ie, a reverse trend). This might be interpreted as an increasing importance of the lip line level as a relapse factor with increasing time distance from completion of active mechanotherapy probably explained by the continuing effect of increased lip pressure on the maxillary central incisors (in case of a high lip line level).

Taking the clinical relevance of our findings into account, not all factors found in causal relationship with the relapse tendency of the maxillary central incisor linguoversion can be influenced by therapeutic objectives or measures. In concrete terms, this applies to the extent of the therapeutically induced change in the maxillary central incisor inclinations irrespective of the pretherapeutic linguoversion of these teeth. The treatment objective is an inclination corresponding to the clinical reference value and certainly not just a partial correction of the linguoversion in the interests of a reduced relapse tendency. In contrast, elimination of a high posttherapeutic lip line level is certainly more readily considered as a therapeutic objective along with the simultaneous esthetic improvements in most cases.

Under these aspects, establishment of physiological relationships between maxillary incisors and lower lip must be seen as one of the most important treatment goals in patients with cover-bite or Class II division 2. Physiology roughly implies that the lower lip covers a maximum of 3 mm of the maxillary central incisors. This value is supported by information obtained through lip pressure measurements10 and also roughly indicated by the results of this study (Figure 5). With reference to the proven etiological interrelations, such a treatment strategy corresponds essentially to a causal therapeutic approach.

**CONCLUSIONS**

- The relapse tendency of orthodontic correction of the maxillary central incisor retroclination displayed great interindividual variability.
- An increased tendency to relapse was especially found in patients with a high posttherapeutic (dorsal) lip-line level and simultaneously with maxillary central incisor and lower lip contact only in the incisal area of these teeth, as well as in patients with a marked therapeutically induced change in maxillary central incisor inclination.
- In the interests of maximum treatment stability, the achievement of physiological relationships between upper incisors and lower lip should be regarded as one of the most important therapeutic objectives.
when treating cover-bite patients and maxillary central incisor retroclination.

REFERENCES