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Favourable dentoalveolar changes after lower premolar extractions for Class III camouflage with completely customized lingual appliances

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Abstract

Background The aim of the investigation was to evaluate if the inclination of the lower anterior teeth can be controlled reliably after lower premolar extraction for Class III camouflage treatment with completely customized lingual appliances (CCLAs). Treatment outcome was tested against the null hypothesis that lower premolar extractions for non-surgical camouflage treatment of a Class III malocclusion will lead to further compensation by retroclining mandibular incisors during CCLA treatment.

Methods This retrospective study included 25 patients (f/m 12/13; mean age 20.7 years, SD 9.5 years) with uni- or bilateral Class III molar relationship and a Wits value of ≤ -2 mm. In all consecutively debonded patients, lower premolars were extracted to correct the sagittal relationship with a non-surgical camouflage approach. Lateral head films prior to (T1) and at the end of lingual orthodontic treatment (T2) were used to evaluate skeletal and dentoalveolar effects. A paired t-test with alpha = 5% was used to define differences between the endpoints. The linear correlation between the inclination of the mandibular incisors at T1 and the achieved correction was measured with the Pearson correlation coefficient (PCC). A Schuirmann's TOST equivalence test was used to check if the final lower incisor inclination was within the defined norms.

Results The null hypothesis was rejected as the mean lower incisor inclination was improved by 1.8° despite lower premolar extractions (T1: 86.8°/ T2: 88.6°). There was a strong correlation (-0.75) between the lower incisor inclination at T1 and the achieved correction indicating a controlled correction towards the norm regardless of the initial incisor position. At T2, the interincisal angle as well as the lower incisor inclination were within the norm.

Conclusion Lower premolar extractions for non-surgical camouflage treatment of a Class III malocclusion will not lead to undesired retroclining of mandibular incisors during CCLA treatment even in severe cases.

Keywords Lingual orthodontics, Completely customized lingual appliance, Class III camouflage, Lower incisor inclination, Torque control

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Introduction

The correction of Class III malocclusions of moderate to severe extent in adolescent and adult patients can be performed in various ways [1]. When considering a surgical or a non-surgical approach, in particular, clinicians are frequently confronted with challenging decision making [2–5]. Orthodontic camouflage treatment of what in these cases usually involves a major skeletal discrepancy may have very different outcomes [6]. One treatment concept for Class III camouflage is the correction with intermaxillary elastics. Success of this most minimally invasive treatment option not only must rely heavily on patient compliance, but also results, as a rule, in counterclockwise rotation of the occlusal plane and the unwanted side effect of upper incisor intrusion [7]. In Class III malocclusion patients, the maxilla frequently is deficient in all three dimensions (sagittal, transversal, vertical), with the consequence that the display of the upper incisors when the patients are smiling is already reduced at the onset of treatment [8, 9]. A second concept for Class III camouflage is a treatment with extractions in all 4 quadrants. In both concepts, however, what impresses in the treatment outcome is the aesthetically displeasing, marked Class III compensation by visibly retroclined lower incisors [1–3, 5, 6, 10–12]. For this reason, most clinicians reject any treatment plan involving extractions only in the lower jaw which could be the third option for Class III camouflage. With only few investigations into this approach there are suggestions that retroclination of the incisors in the lower jaw, which are lingually tipped for compensation even pre-treatment, gets more marked, this also raising concern from a periodontal perspective [3, 7, 13–15]. Then, orthognathic surgery and not camouflage frequently is the only remaining alternative, despite all the known risks, of a mono- or bimaxillary surgical procedure [16–19]. In recent studies, completely customized lingual appliances (CCLAs) have been shown to provide reliable torque control [7, 20–23]. The basis for this is the high-precision bracket slots manufactured in a dedicated process using a five-axis high-speed milling system [20]. The torque of the brackets for the anterior teeth is determined in the process of preparing an individual target set-up and can be customized even further in the course of treatment by applying stainless steel wires with extra-torque [7, 21–23]. Therefore, the aim of this study was to investigate whether CCLAs can avoid lingual tipping of the anterior teeth in the lower jaw during Class III malocclusion camouflage treatment with mandibular premolar extraction.

We tested against the null hypothesis that lower premolar extractions for non-surgical camouflage treatment of a Class III malocclusion will lead to further compensation by retroclining mandibular incisors during CCLA treatment.

Material and methods

The approval for this retrospective cohort study was received from the ethical committee of the Hannover Medical School, Hannover, Germany (3151–2016). Inclusion criteria were adolescent or adult patients presenting a Wits value of ≤ -2 mm in combination with a Class III molar relationship on one or both sides which was corrected by uni- or bilateral lower premolar extraction without counterbalancing extractions in the maxilla. The third molars had to be present in the mandible and without displacement or visible pathology. Patients were consecutively treated in both arches with a CCLA (WIN, DW Lingual Systems, Bad Essen, Germany) in one orthodontic specialist practice (Bad Essen, Germany), and were debonded between 2015 and 2024 [24–29]. No patient was excluded from the consecutive sample for any reason (e.g. bad compliance, missing records, bad oral hygiene or missing appointments). All CCLA treatments were completed by 12 different orthodontic specialists or postgraduate students with high expertise in this field which were all following the same treatment protocol.

The camouflage treatment plan with lower premolar extractions on one or both sides was defined by an ideal target set-up. In particular, the interincisal angle was not meant to compensate the underlying class III skeletal pattern but was set-up to ideal values. No overcorrections were incorporated in the set-up as fixed orthodontic appliances in the hands of a well-trained practitioner can deliver precise three-dimensional control [30–32].

En masse space closure in the mandible was performed on 0.016”×0.024” ribbonwise stainless steel archwires with 13° of positive crown torque in the anterior segment from canine to canine (Fig. 1). This extra-torque could be upscaled to 21°, if necessary, after clinical judgement. Power chains were used for space closure mostly in a double cable approach (Fig. 1). Intermaxillary Class II or Class III elastics were prescribed if necessary to modulate anchorage. After debonding, all patients got a fixed retainer from premolar to premolar in the lower arch and from canine to canine in the upper arch. In most patients this was combined with a removable retention device for sagittal, vertical or transverse stabilization.

To check the null hypothesis, the following measurements were made on lateral head films before (T1) and after lingual orthodontic treatment (T2): Wits, ANB, occlusal plane to spina plane, interincisal angle, inclination of the mandibular incisors on the mandibular plane (Fig. 2). Furthermore, the positional change of the mandibular incisors in the alveolar process based on a

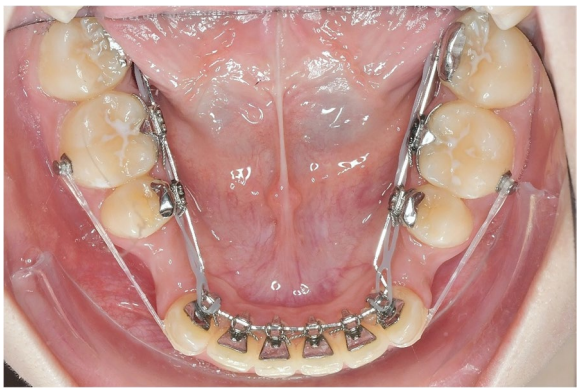

Fig. 1 All patients were treated with the standard archwire sequence for mandibular extraction cases: 0.012″ round SE-NiTi, 0.016″ × 0.022″ SE-NiTi, 0.016″ × 0.024″ Stainless Steel with 13° of lingual root torque from canine to canine, optional 0.016″ × 0.024″ Stainless Steel with 21° of lingual root torque from canine to canine and a final 0.018″ × 0.018″ Beta-Titanium for finishing. En masse retraction with root torque control (13° extra torque) on 0.016″ × 0.024″ ribbonwise stainless steel archwire with double cable mechanics. The buccal transparent chain is fixed onto the lingual archwire between canine and lateral incisor with a lasso. If necessary, intermaxillary elastics could modulate anchorage

structural superimposition of the mandible was determined by measuring the displacement of the centre of resistance of the mandibular incisors from T1 to T2 in mm parallel to the occlusal plane at T1 (Fig. 3) [33].

Statistical analysis

Intrarater reliability was evaluated using intraclass correlation coefficients (ICC). For this purpose, 10 patients were randomly selected and remeasured after at least 2 weeks by the main investigator (L.C.T.). ICC estimates were calculated based on a single measurement, absolute-agreement, 2-way mixed effects model. Interpretation of the correlation coefficients followed the cut-off limits of Koo and Li 2016 [34]. All data were summarized descriptively for each endpoint using mean, ± standard deviation (SD), median as well as maximum and minimum. The difference between T1 and T2 for the different endpoints was analyzed using a paired t-test. A p-value $p < 0.05$ was considered as statistically significant; no alpha correction was used. The linear correlation between the inclination of the mandibular incisors at T1 and the achieved correction was measured with the Pearson correlation coefficient (PCC). Additionally, the quality of the results (T2) was assessed for the endpoints interincisal angle and inclination of the mandibular incisors. To be able to evaluate if the results post treatment are not significantly different from the norm (130° for interincisal angle and 90° inclination of the mandibular incisors), a Schuirmann's TOST equivalence Test based on a one-sample t-Test with a one-sided alpha of 0.025 was used. The non-inferiority margins were selected in such a way that the results post treatment (T2) as well as the corresponding 95% Confidence Interval (CI) should not deviate more than ± 5° from the norm. All statistical analysis was conducted using the statistic software SAS v 9.4 (SAS Institute, Cary, NC, USA).

Results

25 Class III patients (f/m 12/13; mean age 20.7 years, SD 9.5 years) met the inclusion criteria. The baseline characteristics are summarized in Table 1. From the 25 included patients, 5 had unilateral and 20 had bilateral premolar extractions in the mandible. The total treatment time was on average 3.0 ± 0.7 years. Intrarater reliability was excellent for all variables (Table 2). The descriptive statistics are shown in Table 3. The average Wits value at T1 was -6.7 mm (SD 2.5 mm) with 13 patients presenting a Wits value < -7 mm. The Wits value improved on average by 1.7 mm (SD 2.0) and the improvement was statistically significant (Table 4). The clockwise rotation of the occlusal plane relative to the maxillary plane (mean 1.2°, SD 2.5) has neutralized part of the Wits improvement due to a statistically significant rotation of the reference plane (occlusal plane). The improvement of the ANB angle was statistically significant from -1.5° (SD 2.2) at T1 to 0.5° (SD 2.3) at T2 (Table 4). The interincisal angle was reduced from 130.4° (SD 7.8) at T1 to 128.2° (SD 5.5) at T2 indicating a decompensation. The mean lower incisor inclination was improved by 1.8° despite lower premolar extractions (T1: 86.8°, SD 7.4/ T2: 88.6°, SD 5.2). There was a strong correlation (-0.75) between the lower incisor inclination at T1 and the achieved correction indicating a controlled correction towards the norm regardless of the initial incisor position (Fig. 4). For the interincisal angle as well as for the lower incisor inclination it could be shown that the 95% CI limits stayed within the non-inferiority margins of ± 5° indicating a statistically significant equivalence (Table 5).

Intraoral photographs and lateral head films show the situations at T1 and T2 of all included Class III patients (Figs. 5 and 6). The results of the structural superimpositions of the mandible are displayed in Table 3. The centre of resistance of the mandibular incisors was moved on average 3.7 mm (SD 1.3 mm) lingually indicating a bodily tooth movement.

Discussion

Previous studies have assessed dentoalveolar changes in the lower incisor region in Class III camouflage treatment with or without extractions on lateral head films [1]. In all studies, a significant lingual tipping in the lower incisor region occurred, which could amount

Uia	upper incisor apex
Uie	upper incisor edge
Lia	lower incisor apex
Lie	lower Incisor edge
N	Nasion, the most anterior point of thefrontonasal suture
A	the deepest midline concavity on the anterior maxilla
B	the deepest midline concavity on the mandibular symphysis
Me	the intersection of the bony inferior symphysis with the inferior margin of the mandibular body
Go	the constructed point of the intersection of the ramus plane and the tangent to the body of the mandible
Ar	Articulare, a point on the posterior border of the ramus at the intersection with the basilar portion of the occipital bone
PNS	posterior nasal spine
ANS	anterior nasal spine
OCC	Occlusal plane

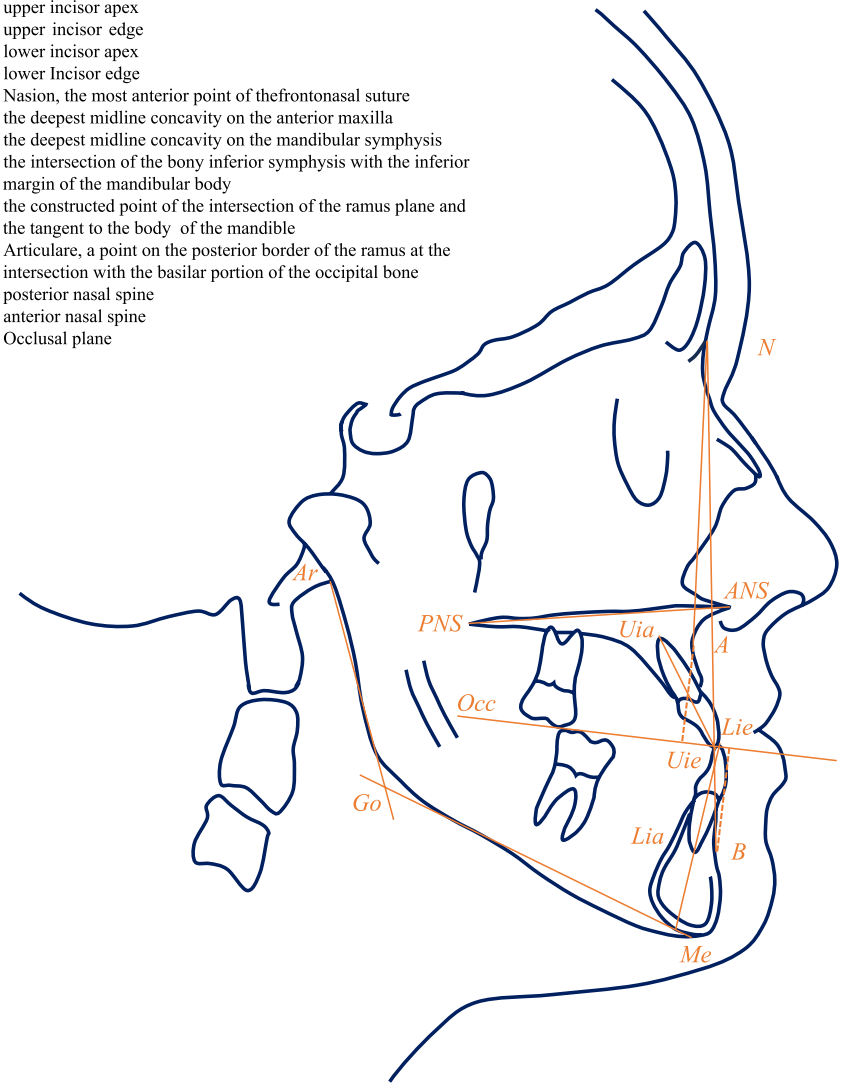

Fig. 2 Cephalometric measurements

to 10° or more [12]. Besides some case reports, only a few studies have evaluated the dentoalveolar changes in the lower anterior region after Class III camouflage treatment with premolar extractions in the mandible only [2–4, 35]. *Georgalis and Woods* reported a significant further retroclination of the lower anterior teeth which were already retroclined (mean lower incisor/MeGo: 84.3°) before Class III camouflage treatment with lower premolar extractions [2]. *Elham* et al. saw a mean lingual tipping of 8° in 30 patients treated with lower premolar extractions for Class III camouflage [3]. In the present study, the average inclination of the lower incisors improved from 86.8° at T1 to 88.6° at T2 despite lower premolar extractions (Table 3). Furthermore, the inclination changes during treatment correlated strongly with the initial situation, meaning that proclined incisors at T1 were uprighted, retroclined incisors at T1 were proclined, and the inclination of incisors which were well positioned at T1 was more or less unchanged (Fig. 4). In addition, the results of the mean values for the interincisal angle and the lower incisor inclination at T2 did not differ significantly from a margin of ± 5° around the norm (130° for interincisal angle and 90° for lower incisor/MeGo) as defined

Fig. 3 Structural superimposition of the mandible. The displacement of the center of resistance of the mandibular incisor is measured parallel to the occlusal plane

Table 1 Baseline Characteristics

Number of included patients	25
Male / Female	14 / 11
Extractions of two lower premolars: first/second/mixed	9/9/2
Unilateral Extraction of one lower premolar: first/second	2/3
Wits Male at T1 (mm) Mean, ± SD, Min/Max	-7,1, ± 2,5, -10,7/-2,1
Wits Female at T1 (mm) Mean, ± SD, Min/Max	-6,3, ± 2,5, -10,8/-3,4
Age at T1 (years) Mean, ± SD, Min/Max	20.7, ± 9.5, 12.6/40.2
Total treatment time (years) Mean, ± SD, Min/Max	3.0, ± 0.7, 1.8/4.4

by *Kubein et al.* and *Tweed* [36, 37] (Table 5). Therefore, the null hypothesis that lower premolar extractions for non-surgical camouflage treatment of a Class III malocclusion will lead to further compensation by retroclining mandibular incisors during CCLA treatment was rejected. Tooth movements that are that uncommon can be attributed to the low torque play of the archwires used during space closure: a 0.016" × 0.024" stainless steel archwire with a 13° extra-torque meant to compensate for the minor torque play in the anterior region totally. The excellent torque control of CCLAs has been demonstrated in numerous studies [7, 20–23, 30–32, 38–41].

Both the Wits value and the ANB angle were found to improve significantly in this study (Table 4). This may be interpreted as a skeletal correction, in line with comparable studies into Class III camouflage treatment [1–7]. At the same time, the significant clockwise rotation of the occlusal plane cancels out part of the Wits improvement (Table 4).

In terms of structural superimposition of the mandible, bodily movement towards lingual of the lower incisors, sometimes of considerable extent (max 7.1 mm/min 1.4 mm), stands out in all patients. As the lateral head films show, this leads to remarkable remodelling processes in the region of the lower anterior process. To follow up on the effects of this remodelling, the periodontal situation in particular was double-checked in the retention phase. In all the 25 patients no abnormalities were detected [42].

3.0 years of treatment on average (max 4.4 years / min 1.8 years) match with other studies into Class III camouflage treatment with extraction in the mandible only [2–4]. While this seems to be above average in duration, it can be considered reasonable upon a closer look: in four cases, the decision to extract in the mandible was made only after an unsuccessful attempt at no-extraction compensation because of lack of compliance in inserting the intermaxillary elastics. In 13 patients, lower wisdom teeth erupted in challenging positions during fixed lingual appliance treatment and had to be aligned actively. This kind of challenge was not found in patients with treatment durations of up to 2.5 years. In general, longer treatment times are more acceptable when lingual appliances are inserted, since both undesirable aesthetics in adult patients and susceptibility to white spot lesions in children and adolescents

Table 2 Description of the measurements and intrarater reliability

Measurement	Description	ICC
Wits T1 [mm]	Distance between perpendicular projections of points A and B on the occlusal plane	0.973
SPP-OP T1 [°]	The angle between occlusal plane and spina palatal plane	0.989
ANB T1 [°]	The ANB angle measures the anteroposterior relationship between the maxilla and the mandible	0.973
Interincisal angle T1 [°]	The angle between a line through long axis of lower incisor and a line through long axis of upper incisor	0.993
Lower 1/GoMe T1 [°]	The angle between a line through long axis of lower incisor and the mandibular plane	0.994
Lower 1 displacement [mm]	Displacement of the center of resistance of the lower incisor in the structural superposition of the mandible at T1 and T2	0.923

ICC < 0.5: poor reliability; 0.5 ≤ ICC < 0.75: moderate reliability; 0.75 ≤ ICC < 0.9: good reliability; ICC ≥ 0.9: excellent reliability

Table 3 Descriptive analysis of the linear and angular measurements

Linear and angular measurements	N	Mean	SD	Median	Minimum	Maximum
Wits at T1 in mm	25	-6.7	2.5	-7.1	-10.8	-2.1
Wits at T2 in mm	25	-5.4	2.6	-5.7	-9.3	-0.7
SPP-OP at T1 in °	25	9.1	5.5	10.5	-0.5	18.0
SPP-OP at T2 in °	25	10.3	5.5	11.0	0.5	19.0
ANB at T1 in °	25	-1.5	2.2	-1.0	-5.5	2.0
ANB at T2 in °	25	-0.5	2.3	0.0	-4.0	4.5
Interincisal angle at T1 in °	25	130.4	7.8	131.0	114.5	148.5
Interincisal angle at T2 in °	25	128.2	5.5	130.0	113.5	134.5
Lower 1/GoMe at T1 in °	25	86.8	7.4	86.0	73.0	99.5
Lower 1/GoMe at T2 in °	25	88.6	5.2	88.0	81.0	99.5
Lower 1 Cr displacement T1 to T2 in mm	25	3.7	1.3	3.6	1.4	7.1

Table 4 Paired t-Test for the difference (T2-T1)

Variable	N	Mean	SD	95% CI	Min	Max	*p*-value
Wits in mm	25	1.3	2.0	(0.50, 2.13)	-3.6	5.7	**0.003**
SPP-OP in °	25	1.2	2.5	(0.17, 2.23)	-3.5	7.0	**0.024**
ANB in °	25	0.9	1.0	(0.50, 1.34)	-1.5	2.5	**0.000**
Interincisal angle in °	25	-2.2	9.2	(-6.00, 1.60)	-18.5	12.5	0.243
Lower incisor/GoMe in °	25	1.9	7.2	(-1.12, 4.84)	-9.0	19.0	0.210

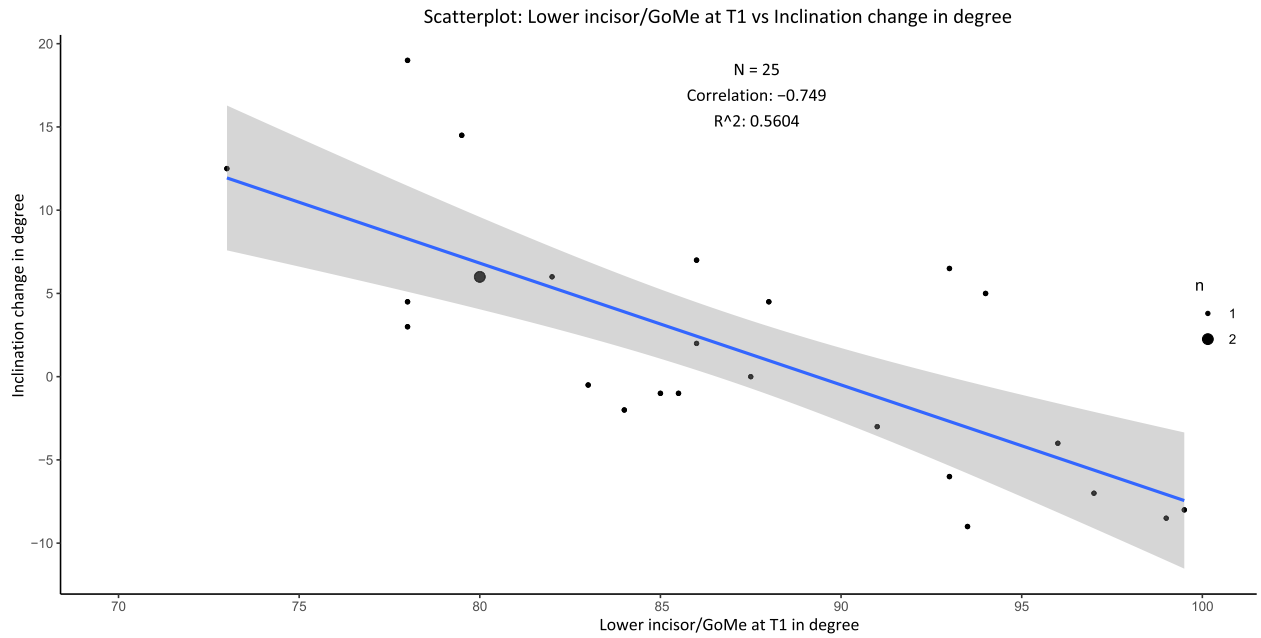

Fig. 4 Correlation lower incisor/GoMe at T1 versus correction achieved

Table 5 Schuirmann's TOST equivalence Test after treatment (T2) vs referenz value (130° or 90°)

Variable	mean	lower bound	95% lower CI	95% upper CI	upper bound	non-inferiority margin	*p*-value	Assessment: 95% CI within margin
Interincisal angle at T2 in °	128.2	125	125.9	130.5	135	5°	0.004	equivalent
Lower incisor/GoMe at T2 in °	88.62	85	86.48	90.76	95	5°	0.001	equivalent

are significantly less marked in lingual appliance treatments as compared to conventional labial bracket systems [43–46].

Camouflage without extractions or with 4 bicuspid extractions

Dentoalveolar camouflage treatment of Class III usually will correct the sagittal relationship to some extent using intermaxillary Class III elastics [47]. This will generally result in a counterclockwise rotation of the occlusal plane, in many cases with an aesthetically displeasing intrusion of the upper incisors. As opposed to this, the treatment approach presented herein supported residual space closure almost always by Class II elastics insertion, which yielded a significant clockwise rotation of the occlusal plane on average. In particular, in those cases, where the maxilla is not only sagitally deficient but also vertically, the extrusion of the maxillary incisors would seem favourable (Fig. 6m). In any case, the patient's being required to comply and wear the intermaxillary elastics is considerably less critical in the approach presented herein. For instance, also in the 4 patients that underwent a treatment plan revision, a Class I canine relationship could finally be achieved (Fig. 5j, o, u and w). In cases where Class III camouflage results in lingual inclination of the lower incisors, this can also lead to periodontal complications, as retroclination of the lower incisors with mesial basal relations increases the risk of more severe gingival recessions [14, 15].

Mono- or bimaxillary surgery

In a combined orthodontic and surgical approach, major changes in profile can be expected [1–3, 5, 47, 48]. Mainly in patients with Class III relationship who exhibit at the same time a normal or even retrognathic facial profile, individually assessing the limitations of what dentoalveolar compensation can achieve is recommended [48]. Along with the known risks of a mono- or bimaxillary procedure, effects on the airway and soft tissue issues, such as a double chin, should be discussed with the patient, in particular for mandibular set-back surgery [16, 17, 49–52]. Furthermore, one should keep in mind that, although surgery improves the patients' self-perception, not all of them would opt for surgery again [16]. Therefore, a very comprehensive preoperative patient education is mandatory, with the patient and not the practitioner giving the final "go ahead" after having clearly understood all the alternatives.

The magnitude of the Class III malocclusion has to be considered severe in most of the included patients, as 13 patients presented a Wits of < -7 mm at T1 [47]. In terms of the consideration of various treatment approaches for correcting Class III malocclusion, the results of this study underline that camouflage with lower bicuspid extractions is competitive. This is of particular interest in borderline cases or in patients who do not present a Class III profile.

Limitations

The retrospective nature of this study in terms of lack of randomization, selection bias, and less control over potential confounding variables is one limitation of this study. On the other hand, included patients were consecutively selected without exclusions for any reason, which minimises the risk of bias. Furthermore, the lack of a control group treated with vestibular fixed appliances can be explained by the fact that Class III camouflage with lower bicuspid extractions only is a relatively unusual treatment approach which in most of the cases leads to undesired severe lingual tipping of the lower incisors [1–3, 5, 6, 10–12]. The retrospective design is therefore ethically more acceptable and allows a deeper insight into clinical reality.

The fact that all patients were treated in one orthodontic specialists practice in Germany with extensive experience in lingual orthodontics, may limit the generalizability of the results. However, today many European and Asian universities have incorporated lingual teaching in their curricula as part of the orthodontic specialist education. The results of this investigation, which underline the reliable 3-dimensional control with CCLAs, may further motivate decision makers to focus on lingual orthodontics.

Fig. 5 Lateral intraoral view of all included patients at T1 (left) and T2 (right). Pictures of patients w and y were mirrored because only the lower premolar in the 3rd quadrant was extracted

Fig. 5 continued

Long term stability is an issue in every orthodontic case. Due to the innovative character of this study, long-term results can be evaluated for a small number of patients only. So far, after an average observation period of 28 months, the outcomes of the sagittal correction seem to be stable.

On top of the unusual tooth movements in the lower anterior segment, the existing bone in this region had to be remodelled to a large extent. So far, the clinical periodontal situation is without issues. Based on ethical considerations, no further control x-rays or CBCT scans for a better evaluation of bone remodelling during the retention period were prescribed.

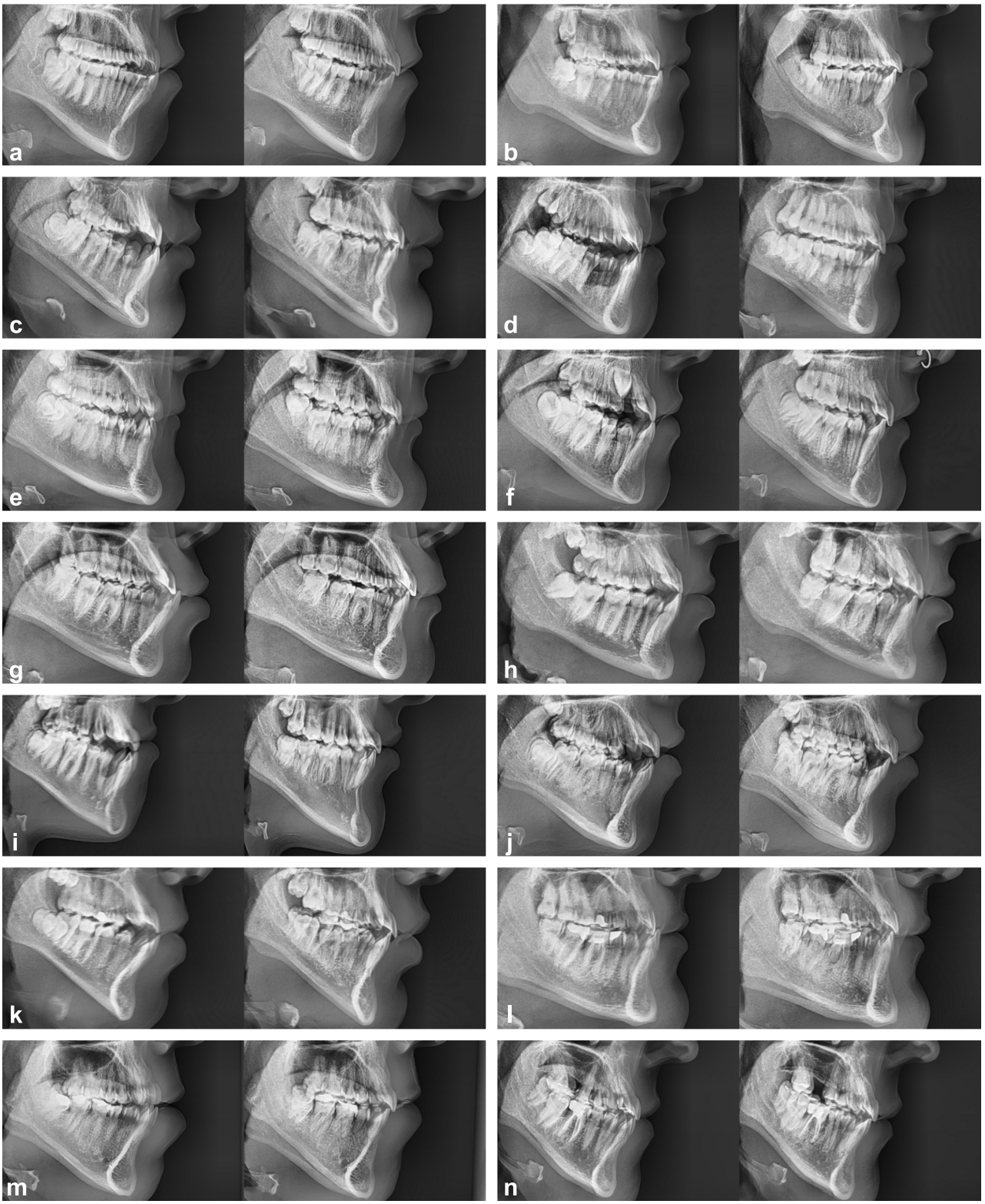

Fig. 6 Lateral head films showing the upper and lower jaws of all included patients at T1 (left) and T2 (right)

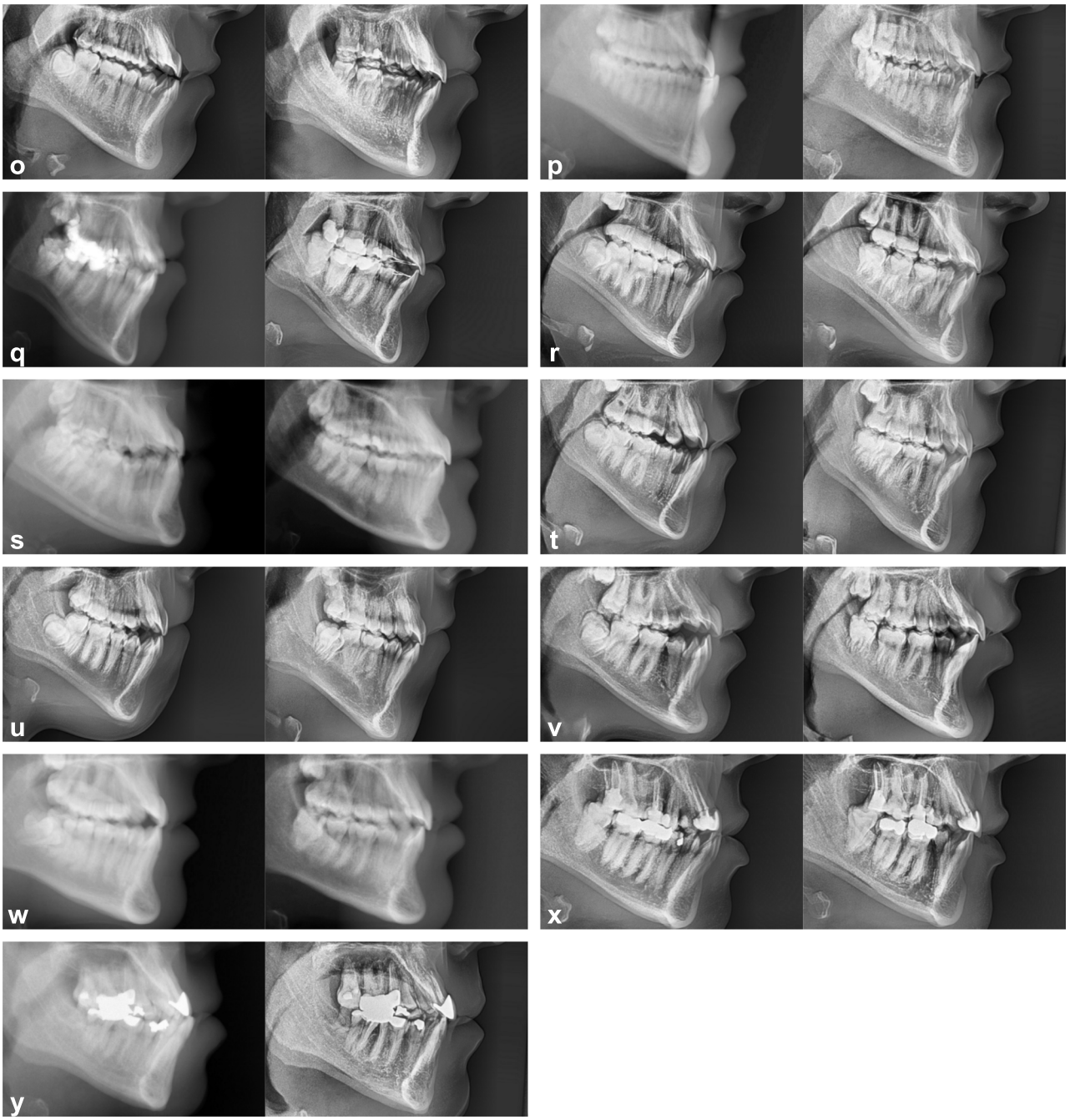

Fig. 6 continued

Conclusion

Lower premolar extractions for non-surgical camouflage treatment of a Class III malocclusion will not lead to undesired retroclining of mandibular incisors during CCLA treatment even in severe cases.

Authors' contributions

L.C.T. wrote the main manuscript text. L.C.T. made the measurements. J.Q.S. (lead) and L.C.T. provided the statistical evaluation. L.C.T. and Y.J. and L.B.-H. treated the patients and prepared the documents for the measurements. D.W. initiated the investigation and together with P.R. defined the conception of the method. All authors reviewed the manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Availability of data and materials
The data underlying this study can be shared upon reasonable request to the corresponding author.

Declarations

Ethics approval and consent to participate
This retrospective cohort study received approval from the ethical committee of the Hannover Medical School, Hannover, Germany (3151–2016).

Consent for publication
All patients signed a written consent form.

Competing interests
D. Wiechmann is the inventor of the WIN system.

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