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ORIGINAL ARTICLE

Compensation of skeletal Class III malocclusion by isolated extraction of mandibular teeth

Part 2: Skeletal, dentoalveolar and soft tissue parameters in comparison with nonextraction Class III therapies

Kompensation der skelettalen Klasse III mit isolierten Unterkieferextraktionen

Teil 2: Skelettale, dentoalveoläre und Weichgewebeparameter im Vergleich mit Klasse-III-Behandlung ohne Extraktion

Bernd Zimmer[1] · **Sarah Gaida**[2] · **Henning Dathe**[2]

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Abstract
Objectives To retrospectively compare two compensatory approaches taken in skeletal Class III patients during the main treatment stage, including a study group of multiband treatment plus isolated extraction of mandibular teeth and a control group of multiband treatment without extraction of teeth.
Patients and methods The extraction group included 22 (12 female, 10 male) patients receiving compensatory multiband treatment for a mean of 3.47 ± 1.14 years and 16.22 ± 1.92 years old at debonding. The nonextraction group included 24 (14 female, 10 male) patients undergoing multiband treatment for 2.76 ± 1.28 years and 15.38 ± 1.46 years old at debonding. Lateral cephalograms obtained at baseline and upon completion of active treatment were traced for skeletal, dentoalveolar, and soft tissue parameters. Welch and Wilcoxon tests were used to analyze intergroup differences (initial values, final values, initial-to-final changes) and within-group differences ($p < 0.05$).
Results Upon completion of active treatment, the only significant intergroup differences were noted for U1NA and L1ML. Significant within-group changes over the courses of treatment were seen for SNB, MLNL, U1NA, U1NL, L1NB, L1ML, H-angle, ULipEL, and LLipEL (extraction group) or for SNB, ANB, individual ANB, Wits appraisal, U1NA, U1NL, H-angle, Naslab-a, ULipEL, and LLipEL (nonextraction group). Parameters that changed by significantly different amounts in both groups included Wits appraisal, L1NB, L1ML, and LLipEL.
Conclusion The added value of isolated extraction therapy basically lies in increasing the potential for retruding the lower incisor inclinations, so that compensatory treatment becomes an option even in selected patients presenting with adverse occlusal situations that would otherwise require orthognathic surgery. Given the successful outcomes in both groups, which had been established by Peer Assessment Rating (PAR) scores, it was possible to define the skeletal, dentoalveolar, and soft tissue characteristics of successful treatment more precisely than before.

Keywords Class III malocclusion · Compensatory treatment · Extraction therapy · Dentoalveolar compensation · Orthodontics

Zusammenfassung
Ziele In der vorliegenden Arbeit sollten zwei kompensatorische Ansätze für die Hauptbehandlungszeit

Dr. Bernd Zimmer.

✉ Bernd Zimmer
BZimmerKFO@aol.com

[1] Orthodontic Specialist Practice, Teichstrasse 24, 34130 Kassel, Germany

[2] Department of Orthodontics, Georg-August University, Göttingen, Germany

skelettaler Klasse-III-Patienten verglichen werden. Dazu dienten eine Gruppe mit Multibandbehandlung plus isolierter Unterkieferzahnextraktion und eine Kontrollgruppe, bei der eine Multiband-Behandlung ohne Extraktion zum Einsatz kam.

Patienten und Methoden Die Extraktionsgruppe bestand aus 22 Patienten (12 weiblich, w, 10 männlich, m), die über im Mittel 3,47 ± 1,14 Jahre eine kompensatorische Multiband-Behandlung erhielten und zum Zeitpunkt des Debondings im Mittel 16,22 ± 1,92 Jahre alt waren. Die Gruppe ohne Extraktion bestand aus 24 (14 w, 10 m) Patienten, die sich für im Mittel 2,76 ± 1,28 Jahre einer Multiband-Behandlung unterzogen und bei Debonding im Mittel bzw. 15,38 ± 1,46 Jahre alt waren. Die vor Behandlungsbeginn und nach Beendigung der aktiven Behandlungsphase erstellten Fernröntgenseitbilder wurden zur Erhebung von skelettalen, dentoalveolären und Weichgewebeparametern durchgezeichnet. Zur Analyse von Inter- (Werte vor Beginn und nach Beendigung der aktiven Behandlung, Veränderungen im Intervall) und Intragruppenunterschieden ($p < 0{,}05$) dienten der Welch- und der Wilcoxon-Test.

Ergebnisse Nach Beendigung der aktiven Behandlungsphase wurden signifikante Unterschiede zwischen den Gruppen lediglich für U1NA und L1ML beobachtet. Signifikante Intragruppenveränderungen im Laufe der Behandlung zeigten sich für SNB, MLNL, U1NA, U1NL, L1NB, L1ML, H-Winkel, ULipEL und LLipEL (Extraktionsgruppe) bzw. für SNB, ANB, individuelle ANB, Wits-Appraisal, U1NA, U1NL, H-Winkel, Naslab-a, ULipEL und LLipEL (Nichtextraktionsgruppe). Zu den Parametern, die sich in beiden Gruppen in signifikant unterschiedlichem Ausmaß veränderten, zählten Wits-Appraisal, L1NB, L1ML und LLipEL.

Schlussfolgerungen Der zusätzliche Wert einer isolierten Extraktionsbehandlung liegt darin begründet, dass sie das Potenzial für die Bewegung der Schneidezahninklination nach lingual erhöht. Damit kann eine kompensatorische Behandlung auch für ausgewählte Patienten mit einer ungünstigen Okklusionslage, bei denen andernfalls eine chirurgische orthognathe Intervention erforderlich wäre, zu einer Therapieoption werden. Angesichts der mittels PAR (Peer Assessment Rating)-Indizes als erfolgreich eingestuften Therapie-Outcomes in beiden Gruppen war es möglich, skelettale, dentoalveoläre und Weichgewebeparameter einer erfolgreichen Behandlung genauer als bisher zu definieren.

Schlüsselwörter Klasse-III-Malokklusion · Kompensatorische Behandlung · Extraktionsbehandlung · Dentoalveoläre Kompensation · Kieferorthopädie

Introduction

Ideal compensatory treatment of skeletal Class III cases may be defined as successful outcomes of mainly orthopedic treatment with attenuation of the mesial tendency [2, 3, 37, 48] and normalization of key occlusal parameters like overjet and molar relationship [9, 27, 36]. If indicated, such therapies may be supplemented by conventional multiband treatment, aimed at resolving residual dental issues, during the main orthodontic stage [46, 51]. Yet these therapies do not always succeed as desired [6, 15, 16, 29, 36]. Not all of these patients have the level of compliance required for extraoral orthopedic appliances [6]. Others will undergo treatment belatedly and, indeed, may have reached their growth peak by the time of presentation. Even if timely treatment and good compliance are ensured, an ideal outcome may still be unattainable [3, 16, 41, 45] due to the magnitude of the mesial tendency or to concomitant factors [12, 23, 25, 27, 39]. Furthermore, late or additional therapies may be required because of late growth spurts [28, 40, 45] or due to the high risk of relapse inherent in Class III anomalies [6, 15, 41].

As a consequence, effective treatment strategies are required to ensure that dental compensation will remain satisfactory (by dentoalveolar, occlusal, functional and esthetic standards, and in terms of stability) beyond the early treatment stage, i.e., beyond the point of posterior support by permanent teeth being fully established [14, 29, 36, 39]. Several compensatory approaches are documented for skeletal Class III in the main treatment stage, including headgear to the mandibular dentition [5, 6], the multiloop edgewise archwire (MEAW) technique [19, 21, 35, 47], skeletal anchorage [1, 4, 13, 19, 20, 31, 42], and isolated extraction of mandibular teeth [22, 34, 52]. Our first study in this series [53] demonstrated that isolated extraction of mandibular teeth for compensatory treatment [10, 32, 34] is routinely capable of yielding satisfactory occlusal relationships that will remain acceptably stable even over longitudinal observation. Of the indicators available to evaluate these occlusal relationships, Peer Assessment Rating (PAR) scores [33, 50] offer better validity than singular parameters like overjet [14, 30, 45], overjet/overbite [5, 29], or overjet/molar relationship [3, 18].

The first study in this series [53] was devoted to the occlusal findings associated with mandibular extraction therapy and to their stability. Its promising results encouraged us to design this second investigation into skeletal, dentoalveolar, and soft tissue parameters in

comparison with conventional nonextraction cases. The objective of this study design was twofold: to gain specific insights into the differences between both treatment strategies and to define, in greater detail than known from the existing literature, the nature of successful compensatory therapies in skeletal Class III patients.

Patients and methods

Patients

The extraction group of this retrospective study was derived from 25 Class III patients who had undergone compensatory treatment—including isolated extraction of mandibular teeth—between 1995 and 2004. Of these Caucasian patients, 22 (12 female and 10 male) were included while 3 were excluded because of unavailable or deficient cephalograms. The nonextraction group comprised 24 (female 14, male 10) consecutively completed cases of compensatory treatment using a modified straight-wire appliance and intermaxillary elastics. Both groups exhibited mild-to-moderate sagittal basal Class III tendencies in the initial cephalograms, associated with mean vertical basal relationships that exhibited an open tendency. In both groups, the upper incisors were mildly protruded and the lower incisors moderately retruded.

In the extraction group, the initial cephalograms were obtained at a mean age of 11.69 ± 2.26 years. Standard compensatory treatment was initiated by inserting an MB appliance at 12.75 ± 1.62 years. Extraction therapy was initiated 1.08 ± 0.92 years later. By the time of debonding, the patients were 16.22 ± 1.92 years old, for a total mean duration of orthodontic compensatory treatment of 3.47 ± 1.14 years. The final cephalograms were obtained 4.53 ± 1.88 years after the initial cephalograms, and the mean PAR score at debonding was 4.58 ± 3.85. In the nonextraction group, the mean duration of treatment was 2.76 ± 1.28 years, the mean age at debonding 15.38 ± 1.46 years, and the mean PAR score at debonding 4.92 ± 3.79. All patients in the extraction group presented with relevant occlusal problems at the time of extraction, including negative overjet, end-to-end bite, molar and/or canine class III relationships, anterior and/or posterior open bite, and transverse discrepancies. The decisions to extract were due to the existing deficiencies and their severity (i.e., no standard modalities of compensatory treatment were available to eliminate the deficiency). For a detailed listing of the inclusion criteria, the reader is referred to the first part of this study [53].

Treatment approach

The concept of compensatory follow-up treatment—aimed at avoiding orthognathic surgery to correct the skeletal discrepancy—prominently includes extraction of lower second premolars or first molars in an effort to redefine the occlusal relationship by controlled space closure. Some of the goals pursued by space creation via removal of these teeth include distalization of the incisors to establish a normal overjet; distalization of the canines and first premolars to establish a Class I canine relationship and premolar normal occlusion; mesialization of the first molars (=removal of the second premolars) to establish a Class III molar relationship, or distalization of the second premolars (=removal of the first molars) to create a Class I molar relationship; and bite deepening in the anterior and posterior segments. Also, fewer mandibular teeth should make it possible to reduce the mandibular arch width (which is commonly increased in Class III cases) for additional transverse adjustment. For more detailed information on the treatment concept using isolated extraction of mandibular teeth, the reader is referred to the first part of this study [53].

Parameters measured

Our assessments included six skeletal parameters (SNA, SNB, ANB, individualized ANB, Wits, MLNL), four dentoalveolar parameters (upper incisor inclination relative to NA/NL and lower incisor inclination relative to NB/ML), and four parameters of soft tissue morphology (Holdaway angle, nasolabial angle, upper lip relative to esthetic line, and lower lip relative to esthetic line).

Statistical analysis

Table 1 lists the results for method error, determined by the principal investigator scanning and analyzing 12 randomly selected cephalograms twice with an interval of ≥2 weeks, then applying the Dahlberg formula $MF = \sqrt{\Sigma d^2/2n}$, where n was 12 and d the difference between the repeated measurements. The error was within the range of previous measurements performed by other authors [17]. Then the presence of a normal data distribution was verified using the Shapiro–Wilk test. On this basis, Welch and Wilcoxon tests were used for intergroup (extraction versus nonextraction, unconnected samples) comparison of the initial and final data, and of the changes between both times. The same procedure was followed for within-group (connected samples) analysis of these changes effected over the course of active treatment. The rationale of this double testing by applying one parametric (Welch) and one nonparametric test (Wilcoxon) was to optimize the statistical validity of

Tab. 1 Parameters and method error
Tab. 1 Parameter und Methodenfehler

Parameter	Abbreviation used	Expressed in	Error
Skeletal			
SNA angle	SNA	°	0.74
SNB angle	SNB	°	0.42
ANB angle	ANB	°	0.53
Individualized ANB angle	indANB	°	0.61
Wits appraisal	Wits	mm	0.79
Mandibular line to nasal line	MLNL	°	0.91
Dentoalveolar			
Upper incisor inclination to NA	U1NA	°	0.83
Upper incisor inclination to NL	U1NL	°	0.75
Lower incisor inclination to NB	L1NB	°	0.9
Lower incisor inclination to ML	L1ML	°	0.72
Soft tissue			
Holdaway angle	H-angle	°	0.44
Nasolabial angle	Naslab-a	°	0.81
Upper lip to esthetic line	UlipEL	mm	0.67
Lower lip to esthetic line	LlipEL	mm	0.71

the results, as similar results obtained by multiple testing may be assumed to be especially reliable. Differences were considered significant at $p \leq 0.05$. As null hypotheses, we assumed (1) no intergroup differences in initial values, final values, or changes between both times, and (2) no within-group differences between initial and final values.

Results

Intergroup comparison of initial situations

Based on the mean ANB angles, individualized ANB angles, and Wits appraisal, the pretreatment findings were characterized by mild-to-moderate Class III relationships in both patient groups (Table 2). Wits appraisal was the only skeletal parameter to show a significant intergroup difference ($p < 0.05$). Both groups were found to show mildly to moderately compensatory incisor inclinations, to the extent that the upper incisors were mildly protruded relative to both NA and NL. The lower incisors were retrusively inclined relative to the mandibular line. Relative to NB, the lower incisors were found to be significantly more retruded in the nonextraction group (18.61° versus 23.79°; $p < 0.01$). The soft tissue parameters confirmed the generally prognathic appearance. The values for Holdaway angle were near the bottom of the normal range (defined, in the presence of a normal data distribution, as deviations of $\leq$1 SD from the mean value of an average sample). Significant intergroup differences were found for lip position relative to the esthetic line, with more retruded positions of both lips in the nonextraction group (both $p < 0.01$). The mean values for nasolabial angle exceeded the normal range in both groups.

Intergroup comparison of final situations

The skeletal parameters seen in the final cephalograms were uniformly within the range of Class III relationships in both groups (mean ANB: −0.03° or −0.89°; mean individual ANB: −4.31° or −4.08°; Wits appraisal: −3.70 or −3.27 mm; Table 3). In both patient groups, the upper and lower incisor inclinations were compensatory regardless of the reference plane. Upper incisor inclinations, with NA as reference plane, were significantly more protruded in the nonextraction group ($p < 0.05$; Welch test only). The lower incisor inclinations also revealed a significant difference ($p < 0.01$; Wilcoxon test only). This latter difference reflected more retruded positions in the extraction group and was apparent only against the mandibular base (not against NB). No significant intergroup differences were found for any of the four soft tissue parameters at the end of active treatment. Their mean values (except those for nasolabial angle) deviated from normal (e.g., those for upper lip to esthetic line), and some of them clearly so. Mean Holdaway angle was closer to the normal range in the extraction group than in the nonextraction group.

Intergroup comparison of initial-to-final changes

Both groups revealed skeletal trends in the same direction, with decreasing regular and individualized ANB angles (Table 4). Wits appraisal followed this trend by showing a decrease in the nonextraction group. This trend was

Tab. 2 Intergroup comparison of initial situations (before active treatment)
Tab. 2 Intergruppen-Vergleich der Situationen vor Beginn der aktiven Behandlung

	Extraction group	Nonextraction group	p (Welch or Wilcoxon test)			
			Welch		Wilcoxon	
SNA (°)	81.09 ± 4.47	80.33 ± 3.28	0.517	n.s.	0.652	n.s.
SNB (°)	80.26 ± 3.75	80.09 ± 2.82	0.859	n.s.	0.921	n.s.
ANB (°)	0.79 ± 2.41	0.24 ± 1.22	0.340	n.s.	0.312	n.s.
indANB (°)	−3.65 ± 1.67	−3.19 ± 1.11	0.289	n.s.	0.276	n.s.
Wits (mm)	−4.41 ± 3.52	−2.01 ± 2.69	0.014	*	0.022	*
MLNL (°)	27.64 ± 5.69	26.28 ± 6.25	0.445	n.s.	0.422	n.s.
U1NA (°)	25.75 ± 7.38	25.87 ± 6.52	0.957	n.s.	0.939	n.s.
U1NL (°)	115.02 ± 8.24	112.17 ± 6.59	0.206	n.s.	0.244	n.s.
L1NB (°)	23.79 ± 7.21	18.61 ± 5.47	0.010	**	0.005	**
L1ML (°)	87.71 ± 8.06	86.28 ± 7.72	0.544	n.s.	0.367	n.s.
H-angle (°)	7.54 ± 4.69	5.65 ± 3.45	0.143	n.s.	0.114	n.s.
Naslab-a (°)	111.37 ± 10.32	112.22 ± 11.58	0.799	n.s.	0.572	n.s.
UlipEL (mm)	−5.20 ± 3.06	−7.70 ± 2.50	0.006	**	0.005	**
LlipEL (mm)	−1.80 ± 2.69	−4.52 ± 2.66	0.002	**	0.001	**

* $p < 0.05$, ** $p < 0.01$

Tab. 3 Intergroup comparison of final situations (after active treatment)
Tab. 3 Intergruppen-Vergleich der Situationen nach Beendigung der aktiven Behandlung

	Extraction group	Nonextraction group	p (Welch or Wilcoxon test)			
			Welch		Wilcoxon	
SNA (°)	81.55 ± 3.90	80.14 ± 2.57	0.161	n.s.	0.198	n.s.
SNB (°)	81.55 ± 3.45	81.02 ± 2.26	0.542	n.s.	0.361	n.s.
ANB (°)	−0.03 ± 1.71	−0.89 ± 1.64	0.089	n.s.	0.146	n.s.
indANB (°)	−4.31 ± 1.20	−4.08 ± 1.06	0.487	n.s.	0.692	n.s.
Wits (mm)	−3.70 ± 3.26	−3.27 ± 2.64	0.628	n.s.	0.758	n.s.
MLNL (°)	26.03 ± 6.55	25.81 ± 7.19	0.914	n.s.	0.843	n.s.
U1NA (°)	29.93 ± 5.77	34.18 ± 7.46	0.036	*	0.060	n.s.
U1NL (°)	119.70 ± 7.35	120.03 ± 7.92	0.885	n.s.	0.965	n.s.
L1NB (°)	19.23 ± 6.51	19.61 ± 5.56	0.835	n.s.	0.676	n.s.
L1ML (°)	83.42 ± 8.70	87.07 ± 6.19	0.112	n.s.	0.01	**
H-angle (°)	5.98 ± 4.19	3.92 ± 3.48	0.087	n.s.	0.078	n.s.
Naslab-a (°)	108.89 ± 9.66	108.83 ± 9.68	0.984	n.s.	0.836	n.s.
UlipEL (mm)	−8.76 ± 3.36	−9.71 ± 2.63	0.307	n.s.	0.325	n.s.
LlipEL (mm)	−5.06 ± 3.35	−5.93 ± 2.56	0.346	n.s.	0.388	n.s.

* $p < 0.05$, ** $p < 0.01$

reversed in the extraction group, where Wits appraisal indicated an attenuation of the Class III relationships. This intergroup difference was significant ($p < 0.05$; Wilcoxon test only). Upper incisor inclination was, again, found to increase in the same directions in both groups regardless of reference planes—namely by means of 4.18° (extraction group) versus 8.31° (nonextraction group) relative to NA and 4.69° versus 7.86° relative to NL (Fig. 1). Lower incisor inclination, by contrast, changed in significantly different directions in both groups—namely by means of −4.55° versus +1.00° in the extraction group relative to NB and by −4.29° versus +0.79° relative to ML (Fig. 2). While the soft tissue parameters of Holdaway angle and 'upper lip to esthetic line' decreased in both groups, the only significant intergroup difference in this regard was noted for 'lower lip to esthetic line', changing by a mean of −3.46 mm in the extraction group versus by −1.31 mm in the nonextraction group ($p < 0.05$).

Within-group comparison of initial-to-final changes

In the extraction group, parameters that significantly increased over the courses of treatment included SNB angle and upper incisor inclination relative to both NA and NL

Tab. 4 Intergroup comparison of changes during active treatment (differences of final versus initial values)
Tab. 4 Intergruppen-Vergleich von Veränderungen während der aktiven Behandlung (Differenzen finale vs. initiale Werte)

	Extraction group	Nonextraction group	*p* (Welch or Wilcoxon test)			
			Welch		Wilcoxon	
ΔSNA (°)	+0.45 ± 2.06	−0.19 ± 2.07	0.295	n.s.	0.214	n.s.
ΔSNB (°)	+1.29 ± 2.11	+0.93 ± 2.19	0.576	n.s.	0.455	n.s.
ΔANB (°)	−0.82 ± 2.26	−1.12 ± 1.19	0.574	n.s.	0.333	n.s.
ΔindANB (°)	−0.66 ± 1.57	−0.88 ± 1.01	0.579	n.s.	0.461	n.s.
ΔWits (mm)	+0.72 ± 4.49	−1.26 ± 2.72	0.083	n.s.	0.045	*
ΔMLNL (°)	−1.61 ± 3.41	−0.47 ± 3.33	0.260	n.s.	0.281	n.s.
ΔU1NA (°)	+4.18 ± 9.20	+8.31 ± 6.81	0.094	n.s.	0.144	n.s.
ΔU1NL (°)	+4.69 ± 8.59	+7.86 ± 7.54	0.191	n.s.	0.410	n.s.
ΔL1NB (°)	−4.55 ± 7.75	+1.00 ± 6.02	0.010	**	0.004	**
ΔL1ML (°)	−4.29 ± 8.22	+0.79 ± 6.01	0.023	*	0.013	*
ΔH-angle (°)	−1.85 ± 3.00	−1.72 ± 2.90	0.888	n.s.	0.845	n.s.
ΔNaslab-a (°)	−2.50 ± 10.16	−4.29 ± 8.76	0.551	n.s.	0.549	n.s.
ΔUlipEL (mm)	−3.76 ± 3.53	−2.10 ± 2.54	0.093	n.s.	0.124	n.s.
ΔLlipEL (mm)	−3.46 ± 3.61	−1.31 ± 2.84	0.042	*	0.046	*

* $p < 0.05$, ** $p < 0.01$

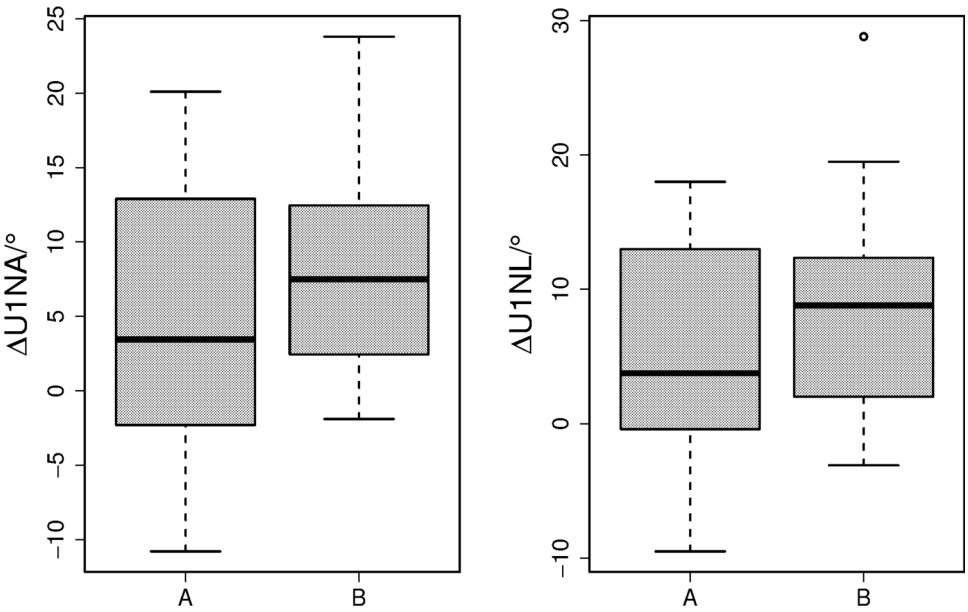

Fig. 1 Changes in upper incisor inclination relative to NA and NL (ΔU1NA/ΔU1NL) in the extraction group (**a**) and in the nonextraction group (**b**). Significant intergroup difference for ΔU1NA ($p < 0.05$; Welch test only)
Abb. 1 Veränderungen der Inklination der oberen Schneidezähne relativ zu NA und NL (ΔU1NA/ΔU1NL) in der Extraktionsgruppe (**a**) und der Nichtextraktionsgruppe (**b**). Signifikante Intergruppenunterschiede: ΔU1NA ($p < 0{,}05$; nur Welch-Test)

(Table 5). Significant decreases were noted for MLNL, lower incisor inclination relative to both NB and ML, Holdaway angle, as well as upper and lower lip distance to esthetic line. In the nonextraction group, we noted significant increases in SNB angle (Welch test only) and upper incisor inclination relative to both NA and NL. Significant decreases in the nonextraction group included ANB angle, individual ANB angle, Wits appraisal, Holdaway angle, nasolabial angle, and the distances of both lips to the esthetic line.

Discussion

The goal of this retrospective study was to analyze a method of optimizing conservative Class III treatment by isolated extraction of mandibular teeth as compared to conventional camouflage therapy. It turned out that both groups were comparable, at the beginning of treatment, not only in age and gender but also with regard to skeletal parameters like ANB, individual ANB, or MLNL. The only

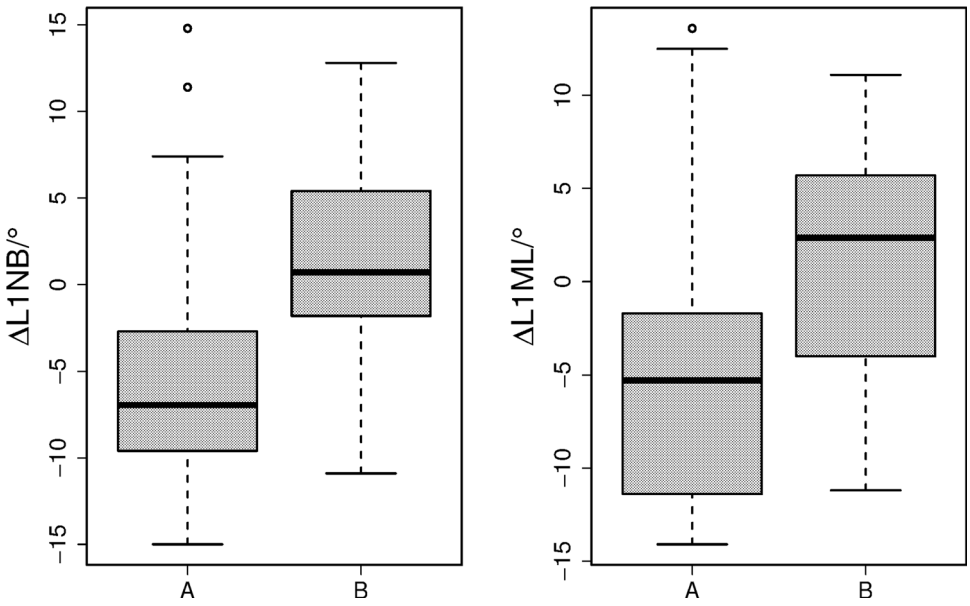

Fig. 2 Changes in lower-incisor inclination relative to NB and ML (ΔL1NB/ΔL1ML) in the extraction group (**a**) and in the nonextraction group (**b**). Significant intergroup difference for ΔL1ML ($p < 0.01$; Wilcoxon test only)
Abb. 2 Veränderungen der Inklination der unteren Schneidezähne relativ zu NB und ML (ΔL1NB/ΔL1ML) in der Extraktionsgruppe (**a**) und der Nichtextraktionsgruppe (**b**). Signifikante Intergruppenunterschiede: ΔL1ML ($p < 0{,}01$; nur Wilcoxon-Test)

Tab. 5 Within-group comparison of changes during active treatment (differences of final versus initial values)
Tab. 5 Intragruppen-Vergleich von Veränderungen während der aktiven Behandlung (Differenzen finale vs. initiale Werte)

	Extraction group				Nonextraction group			
	Welch		Wilcoxon		Welch		Wilcoxon	
ΔSNA (°)	0.312	n.s.	0.356	n.s.	0.654	n.s.	0.383	n.s.
ΔSNB (°)	0.009	**	0.014	*	0.048	*	0.063	n.s.
ΔANB (°)	0.104	n.s.	0.168	n.s.	1.2×10^{-4}	***	5.5×10^{-4}	***
ΔindANB (°)	0.060	n.s.	0.091	n.s.	2.8×10^{-4}	***	6.9×10^{-4}	***
ΔWits (mm)	0.462	n.s.	0.463	n.s.	0.033	*	0.045*	n.s.
ΔMLNL (°)	0.039	*	0.036	*	0.500	n.s.	0.346	n.s.
ΔU1NA (°)	0.045	*	0.058	n.s.	4.3×10^{-6}	***	3.6×10^{-5}	***
ΔU1NL (°)	0.018	*	0.031	*	3.6×10^{-5}	***	1.6×10^{-4}	***
ΔL1NB (°)	0.012	*	0.023	*	0.426	n.s.	0.432	n.s.
ΔL1ML (°)	0.023	*	0.022	*	0.527	n.s.	0.553	n.s.
ΔH-angle (°)	0.013	*	0.029	*	0.013	*	0.016	*
ΔNaslab-a (°)	0.284	n.s.	0.296	n.s.	0.036	*	0.050	n.s.
ΔUlipEL (mm)	1.3×10^{-4}	***	7.8×10^{-4}	***	0.001	***	0.002	**
ΔLlipEL (mm)	4.0×10^{-4}	***	7.1×10^{-4}	***	0.048	*	0.050	*

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

exception was Wits appraisal, which was significantly lower in the extraction group at baseline. Some authors [14, 36, 39, 44] have considered this parameter (which indicates the sagittal relationship relative to the occlusal plane) as key to differentiating therapeutic options. Against this background, our significant intergroup finding for Wits appraisal suggests that the spectrum of indications for compensatory therapies can be successfully increased by including, rather than excluding, isolated extraction of mandibular teeth as an option.

In both groups, the parameters of SNB angle and upper incisor inclination (relative to both NA and NL) increased significantly during treatment. While the changes in SNB angle indicate a residual growth effect that has repeatedly been reported in previous studies [8, 11], the increases in upper incisor protrusion are very likely a therapeutic effect of compensatory treatment [26, 43]. Significant decreases in ANB, individualized ANB, and Wits appraisal were findings specific to the nonextraction group. All three findings are consistent with the anticipated growth trend [8, 11], so that their presence in the nonextraction group is less surprising than their absence in the extraction group (where Wits appraisal was even found to increase). Neither should these differences be overestimated, however, considering that they were rather small in absolute terms (by 0.3° for ANB, by 0.2° for individualized ANB, and by 2 mm for Wits appraisal).

Troy et al. [43] reported that compensatory incisor positions were common in Class III patients before and after both camouflage and surgical therapies, which was true of the upper incisors in 35−40 % of cases even after orthognathic surgery. Kim et al. [26], distinguishing between skeletal vertical relationships, observed that compensatory upper incisor positions are key to establishing a regular overjet. Battagel and Orton [5] and Yoshida 2006 et al. [49] reported increases in upper incisor inclination by 8° and 4.4°, respectively, during compensatory treatment of patients. Our data are in keeping with those studies, in that the basic compensatory effect in our nonextraction group, too, was one of protrusion of the upper incisors by similar amounts (which were twice as large as in the extraction group). This finding represents one of two essential intergroup differences of our study at the end of treatment (both of which concerned parameters of incisor inclination) and may be explained by the potentially inclination-reducing effect of the Class II elastics that were used in the extraction group.

Our finding of significant lower incisor retrusion due to isolated extraction therapy was desirable from a compensatory viewpoint. This effect was consistent with the mean inclination decrease of the lower incisors by −8.1° after bialveolar extraction therapy reported by Battagel and Orton [5]. In contrast to their result of a mandibular inclination decrease by −4.7° after headgear application, our nonextraction group of patients still exhibited a mildly protrusive effect after treatment. This significant difference in lower incisor inclination represents our second finding of a significant intergroup difference at the end of treatment. It follows that the compensatory potential of the lower incisors is of paramount importance—which is consistent with reports by Ko et al. [27], Tseng et al. [44], and Schuster et al. [36], all of whom have regarded lower incisor inclination as a predictor of successful compensatory treatment.

It should be emphasized that compensatory incisor inclinations, to the extent described here, are required for successful outcomes of camouflage treatment. Even after orthognathic surgery in one or both jaws, an ideal ANB angle of 1−5° was achieved in only 40 % of cases, with 46 % still showing compensatory incisor positions [24]. Regardless of the question what incisor inclinations may be morphologically ideal, and how this idealness could be defined, the only justification to regard compensatory positions as deficient would be to associate them with tangible disadvantages in terms of resorption, mobility, or recession. Dental effects of this kind were not apparent in our patients but should be systematically evaluated in future studies.

Stability is another important consideration related to compensatory incisor positions. Our longitudinal observations have disclosed relatively small occlusal changes after isolated extraction of mandibular teeth [53]. While this observation is, for now, merely supported by case reports [38], it would radically differ from the relapse rate after nonextraction therapies of approximately 50 % reported by Battagel [6]. Other authors share this view that compensatory therapies carry a high risk of relapse [15, 45]. There are two likely explanations for the high stability in our patients [53]. First, the extraction therapies took place late during the main treatment stage, with residual growth already reduced. Second, the postextraction excess of space routinely offered a higher potential for compensatory tooth movement than other approaches, so that therapies could be completed, where appropriate, even on a slightly increased overjet to prevent relapse.

Regarding the soft tissue parameters, we found significantly more retral positions of both lips in the nonextraction group at baseline. By the end of active treatment, no more relevant intergroup differences were seen for any of the soft tissue parameters. This development may be explained by significantly greater retrusion of the lower lip from the esthetic line after the extraction therapies. It should be noted that, regardless of extraction therapy, the mean Class III soft tissue morphology after compensatory treatment was not characterized as much by the nasolabial as by the Holdaway angle and by the upper and lower lip positions. This result supports the view held by Benyahia et al. [7] that the Holdaway angle has great potential in detecting Class III patients requiring surgery, even when used on its own. Thus soft tissue findings like a prominent nose or chin are, more likely than not, an unfavorable departure point for compensatory therapy, as they imply a retral appearance of the upper and lower lip.

By the same token, a full lip profile is conducive to straightening the lower facial third, thus being, more likely than not, favorable for compensatory Class III treatment. As a consequence, the preexisting soft tissue morphology of a patient should be acceptable or good for clinicians to make a final decision in favor of compensatory treatment, no matter which approach is selected. The soft tissue changes we found scarcely differed from those after various procedures of orthognathic surgery reported by Ghassemi et al. [17], given nasolabial angle changes of −2.5° or −4.3° in our patients as compared to −2° or −3° after maxillary advancement or bimaxillary procedures. Any reduction of an initially increased angle in this context should be rated as a favorable effect on soft tissue morphology. The distances from lower lip to esthetic line also decreased by −0.4 to −2 mm after three different surgical procedures [17], although the present study revealed larger reductions by −3.4 or −1.3 mm after compensatory treatment.

Upon completion of active treatment, no significant intergroup differences were apparent from any of the skeletal or soft tissue changes we observed in both groups.

Significant dentoalveolar findings between both groups included more upper incisor protrusion relative to NA in the nonextraction group and less lower incisor inclination relative to ML in the extraction group. The fact, however, that both differences were significant in merely one of the two tests applied (i.e., Welch or Wilcoxon, but not both) suggests that the true significance of both findings was weak. Overall, therefore, both treatment groups were associated with comparably satisfactory outcomes by occlusal, skeletal, and soft tissue standards. The added value of isolated extraction therapy lies in increasing the potential for retruding the lower incisor inclinations, so that compensatory treatment becomes an option even in selected patients presenting with adverse occlusal situations that would otherwise require orthognathic surgery.

Our results indicate a number of critical requirements for successful outcomes of compensatory Class III therapy. First of all, the decision to extract teeth should be made as late as possible in the main treatment stage, thus, minimizing the risk of significant residual growth yet to occur. The patient-specific compensatory potential in the upper dental arch should have been fully exploited, or should be reliably assessable, prior to initiating extraction therapy in the mandible. Taking into consideration retrusion of the lower incisors as an essential implication of mandibular extraction therapy, there is a need to make sure that this inclination change will be acceptable by all odontological standards. The required switch from Class III to Class II elastics in this context may be considered safe with regard to inhibiting or promoting skeletal effects. Mandibular extraction therapy will create an opportunity to complete compensatory therapies in the presence of a mildly increased overjet. If significant residual growth is yet to be expected, precautions should be taken in the form of early retention planning.

Conclusion

Our data on compensatory Class III therapies with or without extraction of mandibular teeth indicate that reducing the number of mandibular teeth prepares the ground for potentially useful changes in the lower dental arch. These changes—notably retrusion of the lower incisors—may be required to establish an ideal occlusal relationship in specific patients, thus, eliminating the need for orthognathic surgery in selected cases.

Compliance with ethical guidelines

Conflict of interest Bernd Zimmer, Sarah Gaida, and Henning Dathe state that there are no conflicts of interest.
The accompanying manuscript does not include studies on humans or animals.

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