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Stability of treatment for anterior open-bite malocclusion: A meta-analysis

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Introduction: Anterior open-bite (AOB) treatment is considered challenging because of difficulties in determining and addressing etiologic factors and the potential for relapse in the vertical dimension after treatment. In this review, we compiled evidence on the long-term stability of the major therapeutic interventions for correcting AOB. Our objective was to review and compile evidence for the stability of surgical and nonsurgical therapies for AOB malocclusion. Our data sources were PubMed, EMBASE, Cochrane Library, limited gray literature search, and hand searching. **Methods:** A search was performed of the electronic health literature on the stability of AOB after treatment. Hand searching of major orthodontic journals and limited gray literature searching was also performed, and all pertinent abstracts were reviewed for inclusion. Full articles were retrieved for abstracts or titles that met the initial inclusion criteria or lacked sufficient detail for immediate exclusion. Studies accepted for analysis were reviewed and their relevant data retrieved for pooling. The long-term stability estimates were pooled into nonsurgical and surgical groups, and summary statistics were generated. **Results:** One hundred five abstracts met the initial search criteria, and 21 articles were included in final analyses. Rejected articles failed to exhibit follow-up times of 12 months or more, did not include measurements of overbite (OB), or did not meet inclusion criteria. All included articles were divided into a surgical group (SX) with a mean age of 23.3 years and a nonsurgical group (NSX) with a mean age of 16.4 years. All studies were case series. Random-effects statistical models were used to pool the mean OB measures before and after treatment and also at the long-term follow-up. The pretreatment adjusted means of OB were –2.8 mm for the SX and –2.5 mm for the NSX. AOB closures up to +1.6 mm (SX) and +1.4 mm (NSX) were achieved. Relapse in the SX group during the mean 3.5 years of follow-up reduced the OB to +1.3 mm; the NSX group relapsed to +0.8 mm in the mean 3.2 years of follow-up. Pooled results indicated reasonable stability of both the SX (82%) and NSX (75%) treatments of AOB measured by positive OB at 12 or more months after the treatment interventions. **Conclusions:** In the included case series publications, success of both the SX and NSX treatments of AOB appeared to be greater than 75%. Because the SX and the NSX were examined in different studies and applied to different clinical populations, no direct assessment of comparative effectiveness was possible. The pooled results should be viewed with caution because of the lack of within-study control groups and the variability among studies. (Am J Orthod Dentofacial Orthop 2011;139:154-69)

Anterior open-bite (AOB) is historically considered a challenging malocclusion to treat, and its correction is prone to relapse.[1-3] The etiology is complex, potentially involving skeletal, dental, respiratory, neurologic, or habitual factors.[1,3-6] Open-bite treatment is usually targeted at obtaining a positive amount of overlap of the maxillary and mandibular incisors. Relapse or instability refers to the tendency for the AOB to recur after treatment; this can result in a decrease in incisor overlap or a frank return of interincisal space (negative overlap).

There is no consensus as to the optimal therapy for AOB. It might be treated dentally by moving the teeth in the alveolar bone and soft-tissue housing with

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Table I. Search strategies and results returned

Database	Key words	Results*	Selected	% of 21 total selected abstracts
PubMed	(open bite OR openbite) AND (recurr* OR treatment outcome OR follow-up studies OR stability OR instabil* OR retreat* OR relaps*)	389	21	100%
EMBASE	(open bite OR openbite) AND (recurr* OR treatment outcome OR follow-up studies OR stability OR instabil* OR retreat* OR relaps*)	73	4	19%
Cochrane Library	(open bite or openbite):ti,ab,kw AND (recurr* OR treatment outcome OR follow-up studies OR stability OR instabil* OR retreat* OR relaps*):ti,ab,kw	18	2	10%

*428 distinct articles remained after removal of duplicates; 21 were selected for inclusion.

interarch orthodontic mechanics. Behavior-modifying appliances might be indicated when digit sucking or intercincisal tongue posture is identified. Attempts to gain stability of therapy have led to the evolution of dentoalveolar and surgical interventions. New techniques can involve minimally invasive osseous implant anchorage or extensive maxillomandibular repositioning surgery.[7]

A systematic review and a meta-analysis seek to use existing evidence to produce an unbiased summary estimate of a quantifiable effect. A meta-analysis looks at the average effects of size and direction, precision, and the extent of differences between studies that can be explained by chance (heterogeneity). Even when the state of evidence is low or ambiguous, the technique provides a summary of current knowledge and can offer insight to direct future research.

Although there are many articles on the treatment of AOB in the orthodontic and surgical literature, most look only at the postintervention effects. Because of the propensity for relapse after any orthodontic treatment, it is important to look beyond the immediate posttreatment time point to assess long-term stability.[8,9] Relapse after AOB treatment has been attributed to tongue posture, growth pattern, treatment parameters, and surgical fragment instability.[10-12] Most skilled practitioners can obtain positive overlap of the teeth with orthodontic or surgical interventions, but retaining the vertical correction can be challenging once the appliances are removed.

The a priori objective of this study was to assess the scientific literature and compile the current state of the evidence for stability of surgical and nonsurgical therapies for AOB malocclusion.

MATERIAL AND METHODS

Electronic searching was performed to identify all eligible studies for inclusion in the review and meta-analysis, according to criteria described below. A health sciences librarian was consulted, and wide electronic searches in PubMed (1949-May 2009), EMBASE (1988-May 2009), and the Cochrane Library were performed to return the greatest number of hits. Keywords used are shown in Table I. All languages were searched, and pertinent articles were translated and reviewed.

Inclusion criteria for the final selection were (1) human subjects, (2) stability of outcome assessed at the posttreatment follow-up ≥1 year, (3) negative overbite (OB) or open-bite preintervention as defined by vertical measures, and (4) corrective therapy for open-bite malocclusion adequately described.

The exclusion criteria were (1) case reports with ≤5 subjects, (2) editorials or opinion or philosophy articles with no new data, (3) subjects with other craniofacial pathologies or anomalies potentially influencing stability or complicating treatment (syndromes, periodontal disease, cleft lip or palate, trauma), and (4) mixed measures of open bite (combining horizontal and vertical measures).

Two orthodontic experts (G.M.C. and J.C.) independently reviewed the list of titles and abstracts for inclusion. All articles that appeared to meet the inclusion criteria were reviewed, and differences were resolved by consensus. Hand searching was performed in the major journals in the field: *American Journal of Orthodontics and Dentofacial Orthopedics* and *Angle Orthodontist*. Hand searching of reference lists was also performed on included studies. A limited search of the gray literature (unpublished) was performed by using the University of Washington's library of orthodontic theses. Articles with the same data set were combined and the most recent article reported. The last search was performed in April 2009.

No study with a long-term follow-up had a control group to demonstrate the efficacy of the intervention. All studies meeting the inclusion criteria were follow-up studies of a series of patients who received 1 form of treatment (surgical or nonsurgical) and therefore did not allow inferences about the comparative effectiveness of alternative treatments or comparisons with no treatment. Sample sizes were low, with 1 exception.[13] Most studies did not describe their methodology for

Table II. Methodologic quality assessment of included studies

	Study design					*Study conduct*
Study	*Population described (2)*	*Selection criteria (2)*	*Sample size (2)*	*Controls used (2)*	*Follow-up definition & length (2)*	*Dropouts mentioned (1)*
Akkaya[103]	1	1	1	0	1	0
Arpornmaeklong and Heggie[15]	2	1	2	0	2	0
Denison et al[33]	1	1	2	1	1	0
Ding et al[29]	1	1	1	0	2	0
Espeland et al[16]	2	2	2	0	2	0
Fischer et al[26]	1	1	2	0	2	0
Hoppenreijs et al[13]	2	1	2	0	2	0
Huang et al[12]	2	1	2	1	2	0
Janson et al[28]	2	1	2	1	2	0
Kahnberg et al[22]	1	1	1	0	1	1
Katsaros and Berg[21]	1	1	1	1	1	1
Kim et al[24]	2	1	2	0	1	1
Kucukkeles et al[23]	1	1	1	0	1	0
Lawry et al[18]	1	1	1	0	1	0
Lo[104]	2	1	2	1	2	0
McCance et al[20]	1	1	1	0	1	0
Moldez et al[25]	1	1	1	1	2	0
Nelson et al[19]	2	0	1	0	1	0
Remmers et al[30]	2	2	2	0	2	0
Sugawara et al[7]	1	1	1	0	1	0
Swinnen et al[27]	2	2	2	1	2	0
Average score						

selecting subjects, and most did not address dropouts. A methodologic quality-assessment list was developed after the study of Nguyen et al[14] by analyzing study design, study content, statistical analysis, and conclusions (Table II). Each study was scored by the same 2 investigators, and discrepancies were resolved by discussion and consensus. The maximum quality score possible was 20.

Data collection forms and electronic spreadsheets were used for data abstraction. There were some variations in the methodology used to measure OB. Of the 16 studies included, 14 measured OB on cephalometric radiographs either perpendicular to the occlusal plane (10 studies) or from S' to N (7° down from sella-nasion) (2 studies), and along the nasion-menton line (2 studies). Two articles used direct measurements on dental casts or patients to quantify OB. Three surgical articles did not report postintervention estimates or variances for OB.[13,15,16] These data were calculated from reported change scores between study time points and the variance of the reported change used.

Despite the lack of high-level evidence, summarizing the available data with a forest plot has value. Mean OB data at each time point were pooled by using a random-effects model. Chi-square tests of homogeneity and the I^2 statistic were computed to evaluate the heterogeneity of the included studies. The random-effects model partly accounted for the heterogeneity among the articles when estimating the precision of summary estimates by allowing for a distribution of the true parameter being estimated among studies, rather than assuming only 1 true parameter value; 95% CI values were calculated to indicate the precision of the pooled means.

A secondary analysis looked at dichotomous success as a percentage of stable subjects at the long-term follow-up. The percentages of reported patients with positive overlap at the longest follow-up point were calculated.

RESULTS

The search strategy returned 428 potential articles for inclusion. Table I outlines the search results, the number of studies selected for inclusion from each database, and the percentage contribution to the included articles.

No studies were identified with control or comparison groups so that standardized mean-difference statistics could be developed. Consequently, a meta-analysis using effect size as described by the Cochrane Collaboration[17] could not be performed. Sixteen case-series

Table II. Continued

Study conduct		Statistical analysis			Conclusion	
Measurement defined (2)	*Reliability/ error testing (1)*	*Appropriate statistics (1)*	*Confounders analyzed (2)*	*Presentation of data (2)*	*Reasonable conclusion for study power (1)*	*Total (20 possible)*
0	1	0	0	1	1	7
2	1	0	0	1	0	11
2	1	1	0	1	1	12
2	1	1	0	0	1	10
2	1	1	0	1	1	14
1	1	1	0	1	1	11
2	1	1	2	1	1	15
2	1	1	0	0	1	13
2	1	1	1	2	1	16
1	0	0	0	2	0	8
2	1	1	0	2	1	13
0	1	0	0	2	0	10
1	1	0	0	2	0	8
0	1	0	0	1	1	7
2	1	1	0	1	1	14
0	1	0	0	2	1	8
1	1	1	0	1	0	10
2	0	1	0	1	1	9
2	1	1	0	2	1	15
2	0	0	0	2	1	9
2	1	0	0	1	1	14
						11.1

studies identified in the search had reports allowing extraction of mean OB data for the preintervention condition (T1), the posttreatment result after therapeutic intervention (T2), and long-term stability follow-up (T3).[7,13,15,16,18-30] These data were pooled to enable the primary evaluation of long-term surgical and nonsurgical open-bite treatment outcomes. Figure 1 is the flow diagram outlining the process leading to the included articles. Table III lists articles considered for inclusion but later rejected and the reasons for exclusion.

Quality scores for the studies meeting the inclusion criteria were relatively low and as a whole averaged 10.3 quality points of a possible 20. Most articles had shortcomings in the reporting of subject selection methods and dropouts, the analysis of confounders, and the lack of controls or comparison groups. Table II lists the quality scores for the articles included in the primary and secondary analyses.

The intervention to close AOB was the primary discriminator used to divide the included articles into the 2 samples. Subjects in the surgical group all had maxillary impaction surgery, with 7 studies reporting mandibular surgery as well. Nearly all patients in the surgical studies had presurgical orthodontic treatment, with the largest study reporting that 64 of 267 patients had no orthodontic treatment before surgery. The subjects in the nonsurgery group all had fixed appliance therapy with or without appliances for anteroposterior correction (headgear or functional appliances). Five of the nonsurgical studies explicitly stated that vertical elastics were used to close the bite, 3 articles included patients with extractions, and 2 stated a recommendation for speech or myofunctional therapy.

The mean and standard deviation for the subjects' ages in the surgical studies were 23.3 ± 1.6 years. This postadolescent age was not unexpected, since orthognathic surgery is not routinely performed on skeletally immature patients, and adults with open bite are more likely to have surgery recommended. The mean age of the nonsurgical group was 16.4 ± 4.9 years, more typical of most orthodontic patients. Three studies in the nonsurgical group did include adults, so this sample was not entirely composed of growing subjects. This fact is partly adjusted for in examining median age, which was the same as the mean age in the surgical group at 23.3 years, but only 13.5 years for the nonsurgical group. Both surgical and nonsurgical samples were predominantly female at 71.7% and 75.4%, respectively. Seven of the 11 surgical studies reported presurgical cephalometric values, rather than pretreatment values.

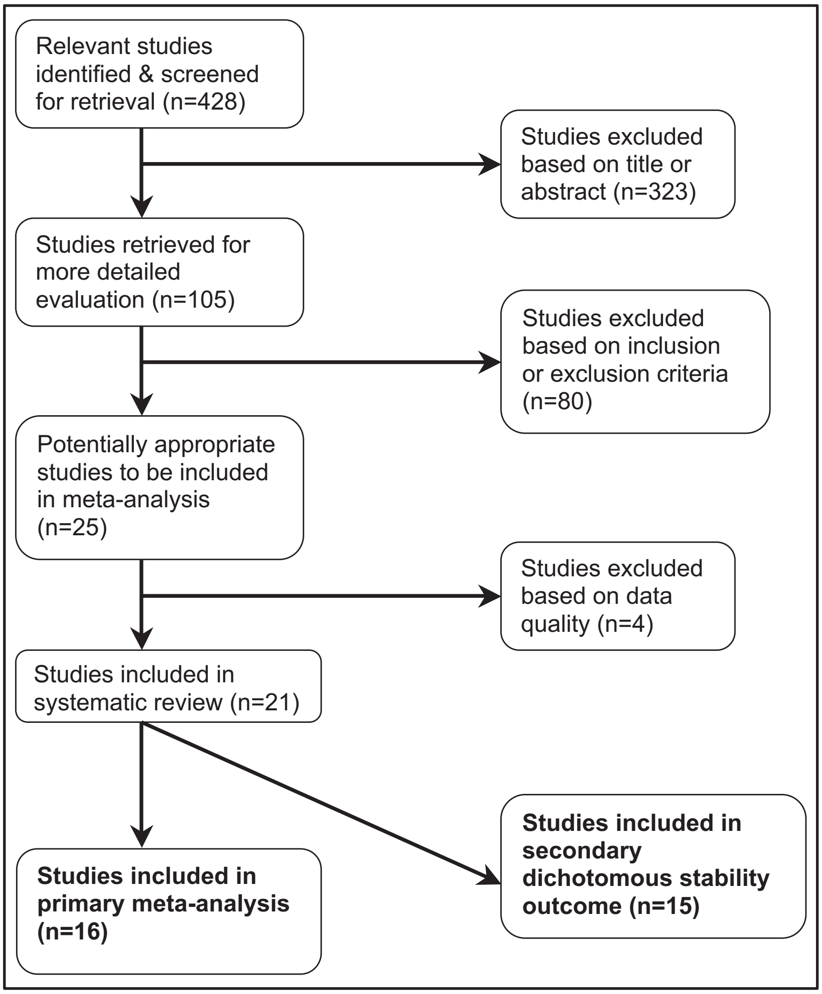

Fig 1. Flow diagram.

The mandibular plane angle (SN-MP) was examined as an indication of case difficulty. Average presurgical SN-MP for the surgical studies was 42.9°; pretreatment SN-MP for the nonsurgical studies was 39.2°. Both values were higher than the general population average, indicating challenging treatment.[31]

Tables IV and V outline data abstracted from studies included in the primary analysis.

Figures 2 through 7 display mean OB data and variance from the included studies, as well as the random-effects pooled means for each time point. T1 refers to OB data before the treatment intervention of interest, T2 was the posttreatment OB, and T3 was the long-term (at least 1 year posttreatment) follow-up OB. These plots show the graphic point estimates of the included studies, the size of which varies with the weight assigned with the random-effects model. Error bars depict the 95% CI limits for each study, and a random-effects summary point estimate is shown, pooling all included studies. I^2 tests of homogeneity indicated that the level of heterogeneity was high, ranging from 81% to 91%.

Six surgical and 4 nonsurgical studies from the primary analysis also reported dichotomous stability. Three additional surgical and 2 nonsurgical studies meeting the inclusion criteria also reported dichotomous stability. A secondary analysis looking at the pooled mean percentages of stable patients at follow-up was performed on the 9 surgical and 6 nonsurgical studies. No adjustment for study size was attempted. Mean stability values were 82% for patients receiving surgical treatment and 75% for patients receiving only orthodontic therapy. Means and median mandibular plane angles for the secondary outcomes were calculated; these values were nearly identical to the mean values calculated for the primary outcomes, indicating similar levels of pretreatment

Table III. Studies considered for inclusion but later rejected

Author and year	*Limitations*	*Author and year*	*Limitations*
Aarnes[37] 1974	2	Kiliaridis et al[38] 1990	1
Bailey et al[39] 1994	2	Klocke et al[40] 2002	3
Bazzucchi et al[41] 1999	1	Kloosterman[42] 1985	2
Beane[43] 1999	1, 2	Kuroda et al[44] 2007	1
Beckmann and Segner[45] 2002	2	Kuster and Ingervall[46] 1992	1
Bell et al[47] 1977	2	Lello[48] 1987	2
Bennett et al[49] 1999	1	Lentini-Oliveira et al[50] 2007	1, 2
Bishara and Chu[51] 1992	1, 2	Lopez-Gavito et al[32] 1985	3
Champagne[52] 1992	1, 2	Lugstein and Mossbock[53] 1988	2
Cinsar et al[54] 2007	1	MacIntosh[55] 1981	2
Cozza et al[56] 2007	1	Martis[57] 1980	2
Cozza et al[58] 2006	1	McSherry et al[59] 1997	2
Cozza et al[60] 2005	1, 2	Meral and Yuksel[61] 2003	1
Dattilo et al[62] 1985	2	Meyer-Marcotty et al[63] 2007	1
De Frietas et al[64] 2004	4	Ng et al[11] 2008	1, 2
Dellinger[65] 1996	2	Nwoku[66] 1974	2
Emshoff et al[67] 2003	2	Oliveira and Bloomquist[68] 1997	2
Epker and Fish[2] 1977	2	Pedrin et al[69] 2006	1
Erbay et al[70] 1995	1	Proffit et al[71] 2000	2
Ermel et al[72] 1999	2	Reitzik et al[73] 1990	2
Frankel and Frankel[74] 1983	2	Reyneke and Ferritti[75] 2007	2
Goncalves et al[76] 2008	2	Rittersma[77] 1981	2
Gottlieb et al[78] 2006	1, 2	Schmidt and Sailer[79] 1991	2
Greebe and Tuinzing[80] 1987	2	Schrems and Schrems-Adam[81] 1982	2
Hayward[82] 1978	2	Seres and Kocsis[83] 2008	1
Hoppenreijs et al[84] 2001	4	Shpack et al[85] 2006	3
Hoppenreijs et al[86] 1996	2, 4	Spens[87] 1981	2
Iannetti et al[88] 2007	2	Steiner and Gebauer[89] 1985	3
Iscan et al[90] 2002	1	Stella et al[91] 1986	2
Janson et al[92] 2008	1	Teuscher et al[93] 1983	2
Janson et al[94] 2003	4	Torres et al[95] 2006	1
Johanson et al[96] 1979	2	Turvey et al[97] 1976	2
Joos et al[98] 1984	2	Turvey et al[99] 1988	2
Justus[100] 1976	2		
Justus[101] 2001	2		
Kahnberg and Widmark[102] 1988	2		

1, No long-term follow-up reported; *2*, no or incomplete report of OB measure or data; *3*, mixed measure of OB; *4*, sample reused in another study.

case difficulty. Tables VI and VII give the dichotomous stability and mandibular plane angle data of the 15 studies with long-term success data.

DISCUSSION

The results of this meta-analysis must be regarded with caution. The level of evidence on long-term outcomes of AOB patients was low, and the studies included in this review were predominantly descriptive. High heterogeneity indicates that a range of treatment effects and long-term outcomes of open-bite therapy can be expected. Point estimate summaries should therefore be interpreted with care. Nevertheless, this uncontrolled sample represents the best evidence to date and could serve as a starting point for future studies with more rigorous designs.

Previous retrospective studies reported differing rates of open-bite relapse.[31-33] Small sample sizes and varying definitions of open bite might have contributed to these conclusions. This aggregation of the published data reports more favorable results for patients treated either surgically or nonsurgically. Even though the reported summary statistics do not exclude subjects with unsuccessful therapy (ie, those with no incisor overlap at T2), there is still reasonably good long-term stability of therapy for AOB malocclusions.

With the exception of age, preintervention condition was remarkably similar for the included surgical and nonsurgical studies. Factors other than open-bite

Table IV. Characteristics of surgical studies

Study	T1 (n)	Female (%)	Age (y) at T1	SD age (y)	T1 SN-MP (°)	SD T1 SN-MP	T1 OB mean (mm)	T1 SD	T2 OB mean (mm)
Lawry et al[18]	19	68.4	21.40		35.0	5.1	−2.53*	1.50	1.89
McCance et al[20] Class II	10	NR			46.9	3.9	−4.60*	4.90	−1.60
McCance et al[20] Class III	11	NR			43.4	7.2	−6.30*	3.80	3.10
Kahnberg et al[22]	19	57.9	23.30				−4.90*	2.30	1.40
Hoppenreijs et al[13]	259	78.7	23.60				−1.24*	2.48	1.86†
Arpornmaeklong and Heggie[15] Mx surgical only	17	76.5	21.40		42.5	7.6	−1.70*	1.20	0.90†
Fischer et al[26]	58	69.0	23.00		45.7	7.2	−0.80	2.80	1.30
Moldez et al[25] Mx impaction	13	84.6			46.8	5.5	−2.20	2.10	2.00
Moldez et al[25] Mx rotation	10	70.0			44.5	7.2	−3.80	1.70	2.20
Ding et al[29]	10	80.0	24.42		41.4	5.2	−3.20	2.10	1.60
Espeland et al[16]	40	60.0	25.80	9.50	39.9	7.1	−2.60*	1.70	1.50†
Sum/average	466	71.7	23.27	1.58	42.9		−3.08	1.68	1.47
Median		70.0	23.30		43.4		−2.60		1.60

NR, Not reported; *F/U*, follow-up; *Mx*, maxillary; *BSSO*, bilateral sagittal split osteotomy.
*Only presurgical OB available; preorthodontic values not reported; †Calculated means and SD from change scores.

Table V. Characteristics of nonsurgical studies

Study	T1 (n)	Female (%)	Age (y) at T1	SD age (y)	T1 SN-MP (°)	SD T1 SN-MP	T1 OB mean (mm)	T1 SD	T2 OB mean (mm)
Nelson and Nelson[19]	23	73.9	19.90				−2.60	1.20	1.40
Katsaros and Berg[21]	20	85.0	11.80	2.50	39.0	5.8	−1.90	1.80	1.20
Kucukkeles et al[23]	17	70.6	19.35		40.5	5.8	−4.05	2.92	1.75
Kim et al[24] growing	29	72.4	13.50	1.92	37.7	4.6	−2.27	2.10	1.41
Kim et al[24] nongrowing	26	80.8	26.08	2.25	39.7	6.5	−2.23	2.10	1.90
Sugawara et al[7]	9	77.8	19.30		40.1	2.1	−2.80	1.80	2.10
Janson et al[28] nonextraction	21	76.2	12.40		36.9	5.7	−1.75	0.66	1.43
Janson et al[28] ext	31	74.2	13.22		39.1	4.2	−2.73	1.80	1.09
Remmers et al[30]	52	67.3	12.40	2.70	40.9	6.1	−3.20	1.90	0.40
Sum/average	228	75.4	16.44	4.93	39.2		−2.61	0.70	1.41
Median		74.2	13.50		39.4		−2.60		1.41

NR, Not reported; *F/U*, follow-up.

severity might play an important role in the decision to treat with orthognathic surgery, although we could not delineate them in this study. Considerable heterogeneity in initial open-bite presentation was evident in the surgical group of studies, and many of these did not report OB conditions before presurgical orthodontic treatment.[13,15,16,18,20,22] Even so, the 3 largest surgical studies reported initial conditions similar to or less than those reported in the included nonsurgical studies.[13,16,26] Both types of therapy produced approximately 4 mm of closure to a positive overlap on average, indicating the success of treatment. Relapse occurred in both samples at the T3 follow-up over 3 years later—0.3 mm in the surgical group and 0.6 mm in the nonsurgical group. Since

Table IV. Continued

T2 SD	T3 F/U time (y)	T3 OB mean (mm)	T3 SD	Open bite measured	Intervention	Surgical fixation
1.83	1.54	2.71	0.98	Cephalogram, possibly parallel occlusal plane	Maxillary impaction ± BSSO, fixed appliances	Wire, rigid
1.90	1.00	−1.70	1.90	Cephalogram, possibly parallel occlusal plane	Maxillary impaction ± BSSO, fixed appliances	Wire, rigid
1.90	1.00	2.40	1.20			
0.60	1.50	1.10	1.00	Clinical measurement in mouth or casts	Maxillary impaction, fixed appliances	Wire, rigid
2.74[†]	5.75	1.24	1.45	Cephalogram, parallel to S'-N	Maxillary impaction ± BSSO, fixed appliances in 76%	Wire, rigid
1.80[†]	2.00	0.90	1.80	Cephalogram, parallel to occlusal plane	Maxillary impaction ± BSSO, fixed appliances	Rigid
1.10	2.00	0.80	1.40	NR, possibly parallel occlusal plane	Maxillary impaction ± BSSO, fixed appliances	Wire, rigid
0.90	5.00	1.10	0.90	Cephalogram, parallel to occlusal plane	Maxillary impaction ± BSSO, fixed appliances	Wire, rigid
0.70	5.00	1.70	0.80			
0.68	15.00	1.50	0.90	Cephalogram, parallel to occlusal plane	Maxillary impaction ± BSSO, fixed appliances	Wire, rigid
3.60[†]	3.00	1.10	1.20	Cephalogram, parallel to S'-N	Maxillary impaction, fixed appliances	Rigid
1.17	3.89	1.17	1.13			
		1.10				

Table V. Continued

T2 SD	T3 F/U time (y)	T3 OB mean	T3 SD	Open bite measured	Intervention
1.20	2.00	−0.10	1.60	Vertical average distance between 4 incisors	Fixed appliances, elastics, possibly speech therapy
2.00	2.00	1.20	1.80	Cephalogram, perpendicular to Na-Me line	Fixed appliances, functionals, extractions
1.16	1.00	0.50	1.76	Cephalogram, parallel to occlusal plane	Fixed appliances, elastics, reverse curve of Spee archwires
0.75	2.00	1.18	1.01	NR, possibly parallel occlusal plane	Fixed appliances, elastics, reverse curve of Spee archwires
0.57	2.00	1.55	1.09		
0.80	1.00	1.20	0.80	Cephalogram, parallel to occlusal plane	Fixed appliances, miniplate anchors
0.50	5.22	0.07	0.62	Cephalogram, parallel to occlusal plane	Fixed appliances, elastics
0.94	8.35	1.02	1.62		Fixed appliances, elastics, extractions
1.10	5.00	0.20	1.80	Cephalogram, perpendicular to Na-Me line	Fixed appliances, elastics, headgear, functionals, extractions
0.50	3.17	0.76	0.60		
		1.02			

the nonsurgical group included growing subjects, some of the increased relapse might be explained by vertical growth.

The mean OB data failed to tell us how many patients maintained their correction over the long term. Our secondary analysis indicated that the included studies had reasonable success at maintaining positive OB. Furthermore, although the included surgical studies had marginally better percentages of stability, this might not be clinically significant, particularly when some surgical patients with open bite at the presurgical stage might not have had an open bite before their preparatory orthodontic treatment. Because the included studies lacked controls, selection bias was possible.

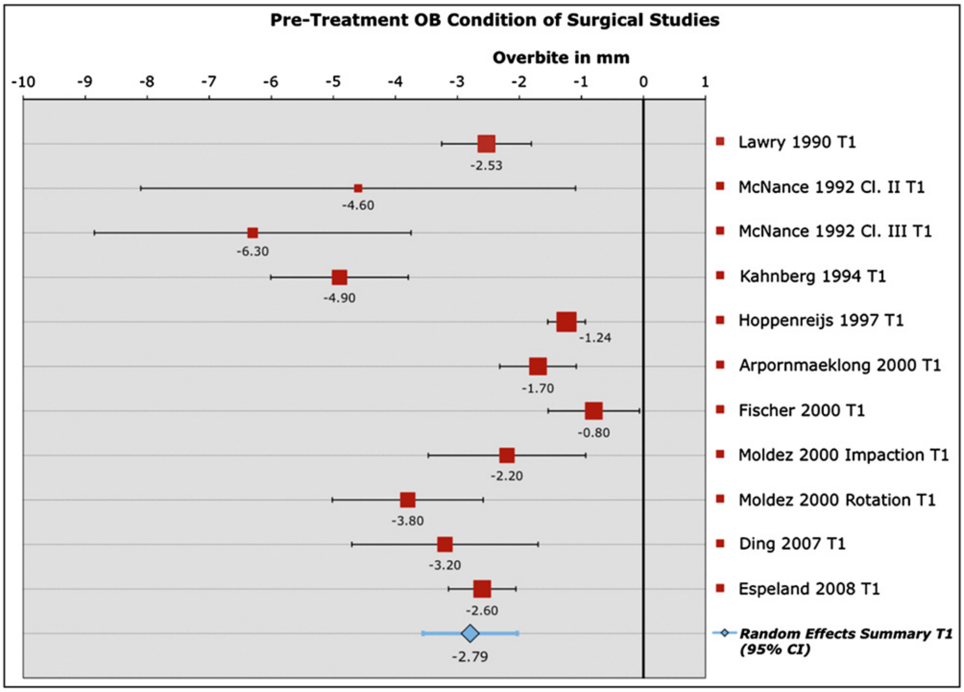

Fig 2. Pretreatment OB of surgical studies.

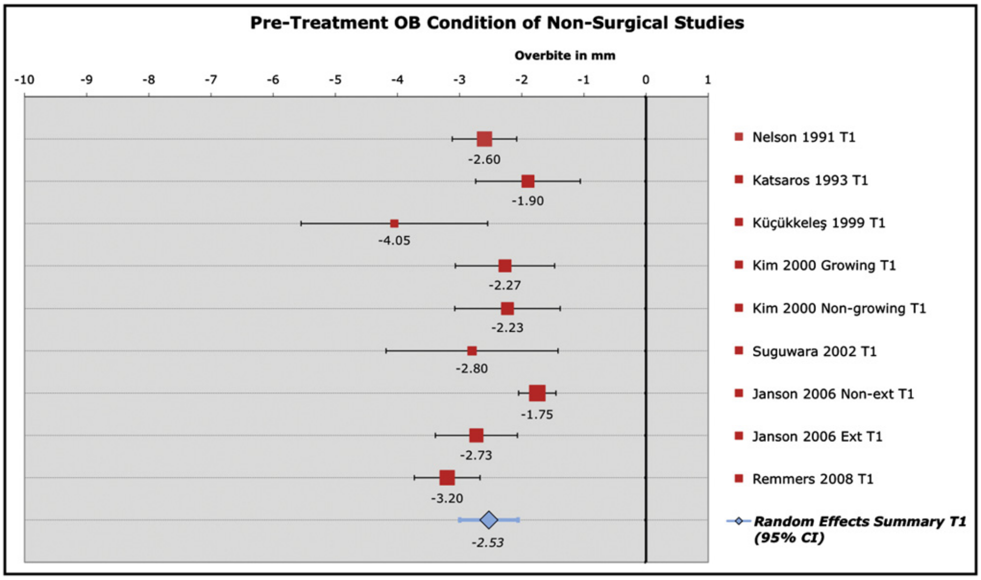

Fig 3. Pretreatment OB of nonsurgical studies.

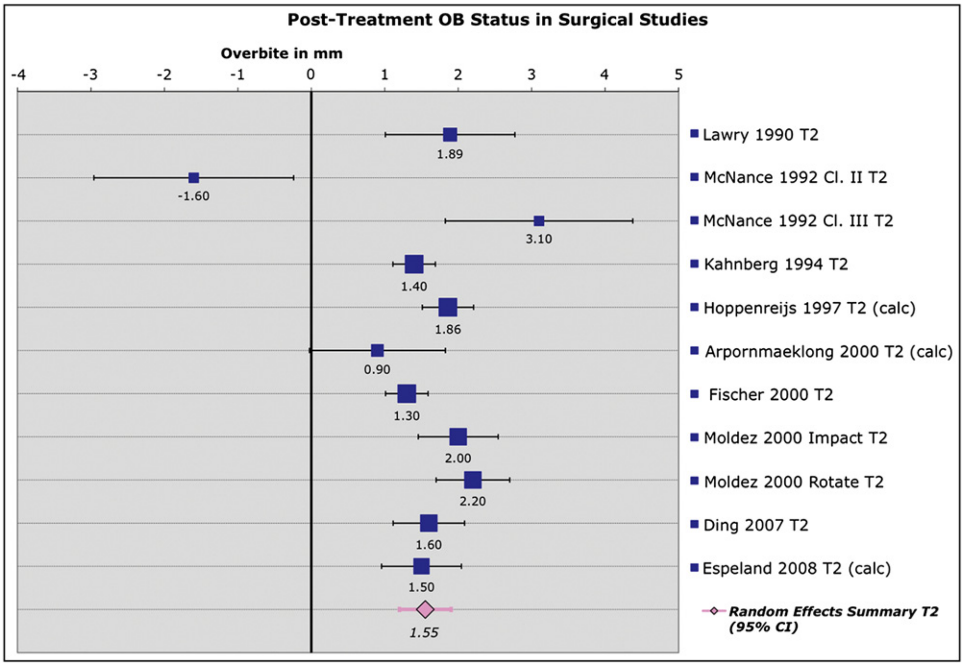

Fig 4. Posttreatment OB of surgical studies.

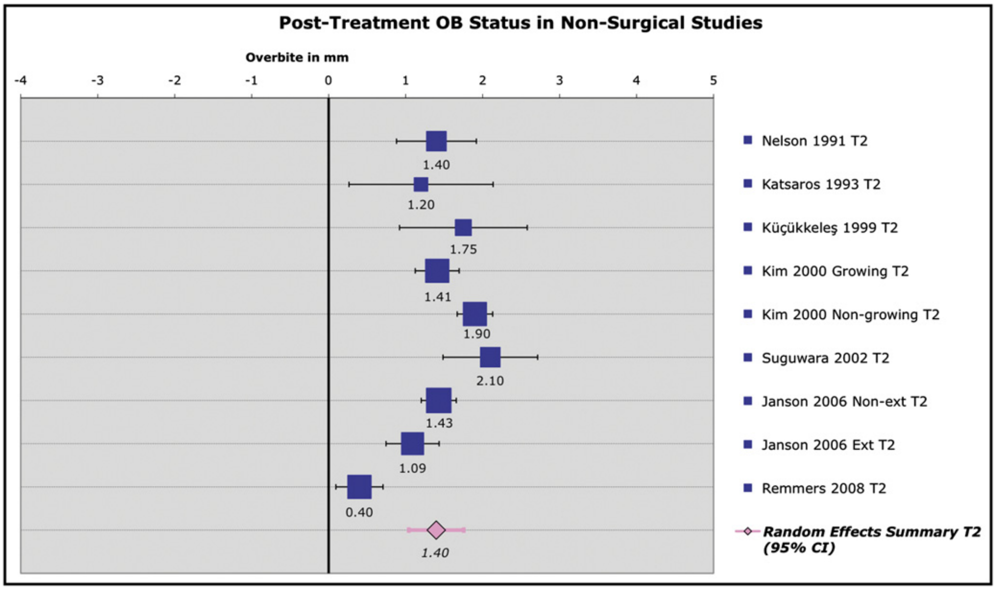

Fig 5. Posttreatment OB of nonsurgical studies.

Fig 6. Long-term follow-up OB of surgical studies.

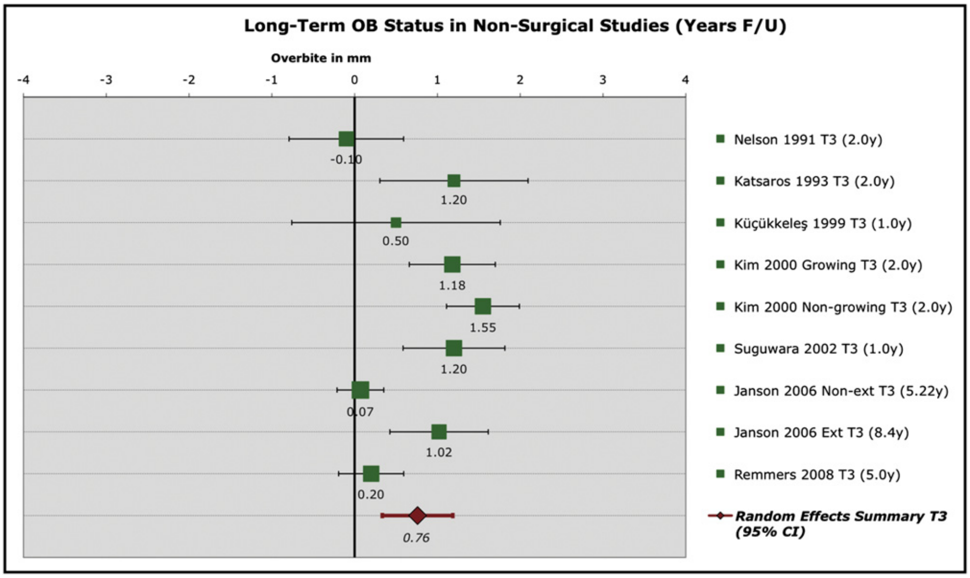

Fig 7. Long-term follow-up OB of nonsurgical studies.

Table VI. Dichotomous long-term stability outcomes of surgical studies

Study	F/U (y)	Relapsed at F/U	Positive OB at F/U	Patients stable at F/U (%)	SN-MP angle (°)
Denison et al[33]	3	12	16	57.1	NR
Ding et al[29]	15	1	9	90.0	41.4
Espeland et al[16]	3	5	35	87.5	39.9
Fischer et al[26]	2	17	41	70.7	45.7
Hoppenreijs et al[13]	5.75	50	212	81.0	NR
Lawry et al[18]	1.54	0	19	100.0	35.0
Lo[104]	5.83	10	30	75.0	NR
Moldez et al[25]	5	2	21	91.3	45.7*
Swinnen et al[27]	1	5	44	88.0	NR
Nine-study average	4.68			82.0	42.2

NR, Not reported; *F/U*, follow-up.
*Impaction and rotation groups averaged.

Table VII. Dichotomous long-term stability outcomes of nonsurgical studies

Study	F/U (y)	Relapsed at F/U	Positive OB at F/U	Patients stable at F/U (%)	SN-MP angle (°)
Akkaya[103]	2	7	3	30.0	41.1
Huang et al[12] growing	5.67	3	23	88.5	37.4
Huang et al[12] nongrowing	3.42	0	7	100.0	41.9
Janson et al[28] nonextraction	5.22	8	13	61.9	36.9
Janson et al[28] extraction	8.35	8	23	74.2	39.1
Katsaros and Berg[21]	2	4	14	77.8	39.0
Kim et al[20] growing	2	1	17	94.4	37.7*
Kim et al[20] nongrowing	2	1	9	90.0	39.7*
Remmers et al[30]	5	23	29	55.8	40.9
Six-study average	3.96			75.0	39.3

F/U, follow-up.
*SN-MP was calculated by adding 7° to reported SN-FH.

Challenges with closing an AOB and concerns over long-term stability of this treatment have led to the routine recommendation of combined surgical and orthodontic therapy for nongrowing patients. Orthognathic surgery is often indicated for many nongrowing patients, particularly for esthetic need, considerable open bite, or skeletal problems in multiple planes of space. The results of this study indicate that there is some vertical relapse associated with surgical treatment, possibly because of increased facial height and extrusion of the maxillary molars. It is unknown whether these patients would have fared similarly if their open-bite problems had been addressed with only orthodontic treatment, since uncontrolled studies provide no direct proof for this comparison. This examination of the state of the evidence suggests that many patients with mild to moderate open bites were successfully treated with less invasive and less costly nonsurgical orthodontics without notable compromises in long-term stability. For the adolescent subjects treated nonsurgically, it was difficult to determine whether the open-bite relapse was due to poor growth patterns, residual habits, or rebound of tooth positions. However, because of the relatively good record of success of orthodontic therapy, there seems little need to consider more invasive and costly surgical options for treatment in this group.

There were several limitations to this analysis, mostly due to the low level of evidence of the included studies. Significant gaps in our knowledge need exploration. Of particular interest is clinical decision-making for borderline patients, such as older adolescents with AOB or adults with mild to moderate open bite. Should we recommend conventional orthodontic therapy, assuming equal long-term stability outcomes, or should we suggest delaying treatment until growth is complete and addressing the open bite surgically? Although there is no question that younger patients can benefit from interventions aimed at decreasing the severity of AOB, higher-quality evidence from controlled trials is needed to definitively answer how best to deal with these borderline patients. Temporary skeletal anchorage,[34] corticotomy,[35] or orthognathic surgery performed in the mandible[36] have been advocated as viable treatment alternatives for AOB. More evidence is needed to establish the efficacy and stability of these methods.

CONCLUSIONS

There is no high-level controlled evidence for the therapeutic efficacy or stability of AOB treatment for either the surgical or the nonsurgical technique. An analysis of case-series studies with long-term follow-ups of at least 1 year indicated that both surgical and nonsurgical treatments can close open bites and are prone to some relapse. Stability with either treatment modality is greater than 75%. The assumption that nonsurgical treatment of AOB is much less stable might be unfounded, but higher-level controlled studies must be performed to confirm this.

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APPENDIX

METHODOLOGIC CRITERIA (MAXIMAL POINTS) AND EXPLANATIONS

1. Study design
   - Population described (2)—points awarded if the population was adequately described and descriptive statistics were provided.
   - Selection criteria (2)—points awarded if the inclusion and exclusion criteria were explained, and bias-reduction methods were implemented (consecutive selection).

- Sample size (2)—maximum points were awarded if sample was more than 25 subjects.
- Follow-up definition and length (2)—points awarded for clear description of initiation and amount of follow-up time and how the statistics were computed.

2. Study conduct

- Dropouts mentioned (1)—point awarded for acknowledgment of dropouts.
- Measurement defined (2)—points awarded for clear description of OB measurement.
- Reliability and error testing (1)—point awarded for statistical examination of errors.

3. Statistical analysis

- Appropriate statistics (1)—point awarded for correct and judicious use of statistical tests and avoidance of type 1 error.
- Confounders analyzed (2)—points awarded for mention of adjustment for confounding variables.
- Presentation of data (2)—points awarded for clear presentation of data, point estimates, variances, changes scores, and individual data listings.

4. Conclusions

- Reasonable conclusion for study power (1)—point awarded for reasonable statement of study meaning in light of limitations.