Long-Term Stability of Anterior Open-Bite Therapy: A Review

Greg J. Huang

This article reviews the orthodontic literature with respect to long-term stability after orthodontic or combined orthodontic-surgical treatment of anterior open bite. Efforts were made to review the studies in a manner that allowed comparison of treatment success as well as the subsequent stability. The existing literature suggests that approximately 80% of anterior open-bite subjects will have positive overlap at the latest follow-up, whether they undergo only orthodontic therapy or a combination of orthodontic-surgical therapy. However, orthodontic therapies appear to have slightly lower treatment success but better stability than surgical therapy. In other words, fewer subjects achieve positive incisor overlap with orthodontic therapy alone, but almost all that do maintain it. The level of evidence provided by the current literature is not conclusive because many surgical and nonsurgical open-bite studies are characterized by small samples and the potential for selection bias. Thus, well-designed studies are necessary to improve our knowledge of the etiology, therapies, and stability of anterior open bite. (Semin Orthod 2002;8:162-172.) *Copyright 2002, Elsevier Science (USA). All rights reserved.*

A ll orthodontists have been faced with the difficult task of treating patients with anterior open-bite and the subsequent challenge of retention. The orthodontic literature has numerous case reports and studies reporting good results at the end of treatment. These are helpful, but the success of open-bite therapy is ultimately measured by long-term stability. Thus, the purpose of this article is three-fold: (1) to identify and review studies that address the long-term stability of anterior open-bite therapy, (2) to compare the long-term stability reported by the nonsurgical and surgical studies, and (3) to critically assess the level of evidence presented by these studies with suggestions for future research.

To identify studies, PubMed was searched by using combinations of the key words stability,

orthodontics, and either openbite, open-bite, or open bite. Additionally, reference lists from the open-bite literature were searched to identify citations not retrieved by PubMed. Of the hundreds of open-bite articles published in the English language, 21 were identified that specifically investigated stability. Among these, six investigated orthodontic therapy, whereas 15 investigated combined orthodontic and surgical therapy. Studies that did not specifically address anterior open bite were excluded, as were those that had less than five subjects.

Studies Assessing Orthodontic Therapies

One of the earliest orthodontic studies was a retrospective case series, comparing a sample of 13 relapsed open-bite subjects with a sample of 13 relapsed deep-bite subjects.[1] All subjects had fixed appliances, and overbite was measured as the distance between the upper and lower incisor tips perpendicular to the occlusal plane. In this study, open-bite relapse was associated with

an increase in posterior maxillary facial height, resulting in downward rotation of the mandible.

Fränkel and Fränkel[2] investigated a functional approach to the treatment of skeletal open bite.[2] (This study did not specifically address stability, but because it followed subjects for approximately 8 years, it was included.) In a cohort study, 30 subjects treated with functional regulators and lip-seal exercises were compared with 11 untreated subjects. Subjects were selected based on a hyperdivergent skeletal pattern, as well as clinical observation of lip incompetence and postural weakness of the orofacial muscles. The treated subjects were followed from a mean age of 7 until a mean age of 15, with the last follow-up at least 4 years postretention. The corresponding means for the untreated group were 8 and 16 years. The treated subjects had significant closure of the mandibular plane and gonial angles during the study period. However, the mean pretreatment characteristics of the two groups were not reported so it is difficult to assess whether the treated and untreated subjects were comparable before the start of the study. Additionally, although the normalization of the skeletal characteristics in the treated subjects was impressive, no overbite values were reported, making it difficult to assess whether the open bites were successfully closed and stable.

Lopez-Gavito et al[3] evaluated stability of orthodontic treatment (fixed appliances and headgear) in subjects at least 9 years and 6 months after the discontinuation of retention devices. Subjects were selected from the postretention files of the University of Washington based on the availability of records. In this retrospective case series, Lopez-Gavito et al reported that 35% of their sample relapsed, as defined by a cephalometric distance >3 mm from the tip of the lower incisor to the nearest hard tissue (tooth or palate) measured along the long axis of the lower incisor. Although these results suggest a high relapse rate, anteroposterior skeletal change may have influenced this distance in the absence of vertical changes. In fact, a subsequent master's thesis, using this same sample but a different method of measuring overbite (distance between upper and lower incisor tips measured relative to the nasion-menton line), found that all of these subjects had positive overlap at the postretention period, although 60% of these

subjects did not have incisal contact.[4] Thus, the relapse rate varied considerably depending on the method chosen to measure overbite.

Another study of orthodontic interventions assessed the impact of tongue cribs.[5] In this study, subjects were selected based on a negative pretreatment overbite; the use of a tongue crib; and the availability of records at the pretreatment, posttreatment, and at least 1-year posttreatment times. This retrospective case series identified 26 adolescent (growing) patients and 7 adult (nongrowing) patients. The mean pretreatment overbite, which was measured relative to the nasion-menton line, was −2.8. The overall success rate for achieving a positive overbite was 88%, and of these successful subjects, none relapsed to negative overbite during the posttreatment period. Although the stability of the successfully treated cases was impressive, a criticism of this study was the potential for selection bias.

In a retrospective case series, Katsaros and Berg[6] assessed the stability of 20 subjects treated with fixed (n = 19) or functional (n = 1) appliances at least one year after discontinuation of retention. Selection of the sample was based on the existence of a pretreatment open bite, assessed on plaster casts, and the availability of records at the pretreatment, posttreatment, and postretention periods. Cephalometric measurements were also taken, with overbite measured perpendicular to the nasion-menton line. This sample exhibited typical open-bite characteristics, with a mean pretreatment openbite of −1.9 mm. Success, based on incisal contact measured on plaster casts in habitual occlusion or in a forward position, was achieved in 15 of the 20 subjects (75%). None of the successfully treated subjects had negative overbite at the postretention period. Again, the stability of successful cases is impressive, but limitations include the potential for selection bias, as well as a definition of success that depends on the articulation of models rather than a cephalometric measurement.

Kim et al[7] reported that the multiloop edgewise arch-wire technique is a stable method for orthodontic correction of open bites. In a recent study, 55 open-bite subjects treated with the multiloop edgewise arch-wire technique technique were identified, with 27 of these having final records at the 2-year follow-up period. The investigators divided their sample into growing

and nongrowing groups. Among the growing subjects with complete records (n = 17), all achieved a positive overbite at the end of treatment, and one (6%) relapsed to negative overbite at the 2-year follow-up. Among the nongrowing subjects with complete records (n = 10), all achieved a positive overbite at the end of treatment, and one (10%) relapsed to negative overbite at the 2-year follow-up. Thus, the overall relapse rate was 7% (2/27). These results are encouraging but could be influenced by selection bias and a considerable loss to follow-up.

We can learn several things from these studies (Table 1). First, there are relatively few studies that evaluate the long-term stability of orthodontic therapies. Second, the sample sizes for these studies are not large. Third, definitions for open bite differ, as well as methods to assess success and stability. In an effort to compare these studies, the following conventions were used. Subjects were required to have an open bite (specifically, no incisal overlap) before treatment. Treatment success was defined as the achievement of positive overlap at the end of therapy, and stability was defined as the maintenance of positive overlap at the last follow-up period. The overall success rate was the product of the percentage of treatment success and the percentage of stable cases at the last follow-up. For example, if a study reported 80% treatment success and 90% stability, the overall success would be 72%. By using these conventions, the overall success of orthodontic therapies is between 75% and 93%, which seems quite good (Table 2). However, several other factors should also be considered.

First, were the open bites of these subjects likely to improve without therapy? Some studies have reported from 40% to 80% spontaneous closure of untreated open-bite subjects.[8,9] However, their conclusions were based on cross-sectional data using subjects as young as 6 to 8 years old. At that age, open-bite malocclusions are difficult to define because of the normal transition of incisors. Most orthodontists would probably agree that open bites persisting into the late mixed dentition rarely close without intervention. This view is supported by the National Health and Nutrition Estimates Survey III data, which reports the prevalence of openbite to be 3.6% in 8-11 year-olds, 3.5% in 12-17 year-olds, and 3.3% in 18-50 year-olds.[10] Additionally,

some believe skeletal open bites are less likely than dental open bites to spontaneously improve. Thus, given the lack of controls, pretreatment characteristics are useful in assessing the severity and nature of the open-bite subjects, which, in turn, may provide information on the likelihood of spontaneous correction. The open-bite subjects in the previous studies all had steep mandibular planes and moderate open bites, with the exception of Lopez-Gavito et al's subjects. (Although the mean open bite they reported was −5 mm, the mean overbite was 0.3 mm if measured relative to the nasion-menton line.) Additionally, all of the subjects were probably in permanent dentition, except for the adolescent crib therapy group. Thus, the majority of the subjects in the studies mentioned previously had permanent dentitions, significant open bites, and skeletal components, and would not be expected to improve without therapy.

The second issue that should be addressed is sample selection. Although selecting subjects based on the availability of records might seem unbiased, we must keep in mind that having models and radiographs at various time points requires some degree of cooperation from patients and that willingness to participate in these recall visits may differ among successfully and unsuccessfully treated patients. Additionally, the likelihood of recalling successful and unsuccessful cases may differ as well as the effort placed into recalling these subjects. If successfully treated subjects are more likely to be recalled by orthodontists and they are also more likely to participate in recalls, an overly optimistic estimate of stability will be reported. Thus, every effort should be made to identify either a random sampling of subjects or all consecutively treated subjects. In either case, it is also useful to know how many subjects were treated with a particular therapy and what percentage was recalled for the study.

In summary, the orthodontic therapies do not always result in positive overlap of the incisors at the end of treatment. However, for subjects who achieve a positive overlap, the stability of the open-bite correction seems to be quite good. Although other nonsurgical therapies have been prescribed, such as myofunctional therapy, posterior bite blocks, magnets, and chin cups, no studies assessing the long-term stability of those therapies could be located. As with many orth-

Table 1. Studies Assessing Orthodontic and Combined Orthodonic/Surgical Therapies

	Year	Design	Sample	Pre-TX Age (y-mo)	Overbite Measure	Intervention	Pre-TX OB	Pre-TX MP
Orthodontic studies								
Nemeth and Isaacson[1]	1974	Case Series	13 Relapsed cases	13-0 (at post-TX)	Occlusal Plane	FA (+HG?)	NR	NR
Fränkel and Fränkel[2]	1983	Cohort	30 Treated	Followed age 7 to 15	NR	Functional regulator/ Lip exercises	NR	NR
			11 Untreated	Followed age 8 to 16	NR	No treatment	NR	NR
Lopez-Gavito et al[3]	1985	Case Series	41 Adolescents	12-6 (median)	Long-axis MN incisor	FA + HG	−5.1 (.3)*	39.8
Huang et al[5]	1990	Case Series	26 Adolescents	9-7	Nasion-menton	Crib (+FA + HG)	−2.9	37.4
			7 Adults	20-10	Nasion-menton	Crib + FA (+HG)	−2.7	41.5
Katsaros and Berg[6]	1993	Case Series	20 Adolescents	11-8	From casts	19 w/FA, 1 w/Functional	−1.9	39
Kim et al[7]	2000	Case Series	17 Adolescents	13-5	NR	MEAW	−2.3	30.7 (to FH)
			10 Adults	26-1	NR	MEAW	−2.2	32.7 (to FH)
Combined orthodontic/surgical studies							Pre-op OB	Pre-op MP
Turvey et al[11]	1976	Case series	9	Range: 14-27	NR	MX impaction (+MN surgery + FA)	NR	NR
Denison et al[12]	1989	Cohort	28 openbite	24-0 (median)	Nasion-menton	MX impaction + FA	NR	NR
			24 overlap	27-0 (median)	Nasion-menton	MX impaction + FA	NR	NR
			14 contact	32-2 (median)	Nasion-menton	MX impaction + FA	NR	NR
Reitzik et al[13]	1990	Consecutive	16 of 20	NR	NR	Reverse-L osteotomy + FA	NR	NR
Haymond et al[14]	1991	Case series	38	26-4	Nasion-menton	MX impaction + FA (+MN surgery)	NR	NR
McCance et al[15]	1992	Case series	21	NR	NR	Bimaxillary surgery + FA	−5.5	37.6 (to PP)
Oliviera and Bloomquist[16]	1997	Case series	10	NR	NR	BSSO + FA	NR	39.7
Ermel et al[17]	1997	Consecutive	20 of 44	26-0	NR	MX impaction + FA (+MN surgery)	NR	37.5
Hoppenreijs et al[18]	1997	Cohort	267	26-6	Occlusal plane	MX impaction (+MN surgery + FA)	−1.24	37.6 (to PP)
Hoppenreijs et al[18]	1998	Cohort	130	23.1	Occlusal plane	MX impaction (+MN surgery + FA)	NR	NR
Lo and Shapiro[20]	1998	Cohort	19 extrusion	19-2	Nasion-menton	MX impaction + FA (+MN surgery)	−1.7	NR
			21 no extrusion	26-7	Nasion-menton	MX impaction + FA (+MN surgery)	−2	NR
Arpornmaeklong and Heggie[21]	2000	Case series	17	21-4	Occlusal plane	MX impaction + FA	−1.7	35.5 (to FH)
			10	22-0	Occlusal plane	Bimaxillary surgery + FA	−1.4	33.8 (to FH)
Proffit et al[22]	2000	Case series	28	21.8	True vertical	MX impaction + FA	>2 mm open	NR
			26	24.5	True vertical	Bimaxillary surgery + FA	>2 mm open	NR
Moldez et al[23]	2000	Cohort	13	NR	Occlusal plane	MX impaction + MN surgery + FA	−1.7	46.7
			10	NR	Occlusal plane	MX rotation + MN surgery + FA	−3.2	44.4
			11	NR	Occlusal plane	Bimaxillary surgery + FA	−0.1	38.8
Fischer et al[24]	2000	Consecutive	58 of 58	23-0 at surgery	NR	Bimaxillary surgery + FA	−0.9	46.2
Swinnen et al[25]	2001	Consecutive	38 of 38	~20	Relative to S'-N	LeFort I intrusion (+MN surgery + FA)	−0.6	NR
			11 of 11	~20	Relative to S'-N	LeFort I extrusion (+MN surgery + FA)	−1.9	NR

NOTE. Interventions in parentheses were performed for some subjects.
Abbreviations: Pre-TX, pretreatment; OB, overbite; MP, mandibular plane relative to sella-nasion; FA, fixed appliances; HG, headgear; FH, Frankfort horizontal; MX, maxillary; MN, mandibular; PP, palatal plane; S'-N, sella-nasion construct; NR, not reported; pre-op, preoperative.
*If measured relative to nasion-menton.

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Table 2. Assessment of Treatment Success, Stability, and Overall Success

Study	Mean Follow-up (y-m)	Follow-up Range	Fixation	TX Success (%)	Stable (%)	Overall Success (%)	Open-Bite Confirmation
Orthodontic studies							
Lopez-Gavito et al[3]	11-6 post-retention*	9-6 to 18-0	NA	93	100	93	15 subjects, no pre-TX overlap on cephs
Huang et al[5]	5-3 post-ortho	1-0 to 14-0	NA	88	100	88	33 subjects, no pre-TX overlap on cephs
Katsaros and Berg[6]	≥1 year post-retention	1-0 to 19-6	NA	75	100	75	20 subjects, no pre-TX overlap on casts
Kim et al[7]	2-8 post-ortho	2-0 to ?	NA	100	93	93	27 subjects, no pre-TX overlap on cephs
Combined orthodontic/surgical studies (TX success assumed to be 100% for these studies)							
Denison et al[12]	3-0 post-ortho*	1-0 to 11-9	NR	100	79	79	28 subjects, no pre-TX overlap on cephs
Reitzik et al[13]	≥1 year post-op	1-0 to 7-2	Rigid	100	100	100	16 subjects, pre-TX openbite not reported
Haymond et al[14]	≥1 year post-op	1-0 to 5-0	Rigid	100	84	84	38 subjects, no pre-op overlap on cephs
Ermel et al[17]	7-3 post-retention	1-0 to 15-0	Rigid	100	88	88	20 subjects, pre-TX openbite not reported
Hoppenreijs et al[18]	5-9 post-op	1-8 to 17-6	Mixed	100	81	81	267 subjects (168 confirmed with no pre-TX overlap on cephs)
Lo and Shapiro[20]	5-10 post-ortho	2-0 to ?	NR	100	75	75	40 subjects, no pre-TX overlap on cephs
Proffit et al†[22]	5-4 post-op	2-6 to 13-7	Mixed	100	88	88	54 subjects with >2 mm pre-TX openbite
Moldez et al[23]	≥5 year post-ortho	5-0 to ?	Mixed	100	91	91	23 subjects, clinical diagnoses of pre-TX openbite
Fischer et al‡[24]	≥2 year post-op	2-0 to ?	Mixed	100	71	71	58 subjects, clinical diagnoses of pre-TX openbite
Swinnen et al[25]	1-0 post-op	1-0 to 1-2	Rigid	100	89	89	49 subjects, no pre-TX overlap on cephs

Abbreviations: NA, not applicable; NR, not reported.
*Median values.
†Stable defined as <2 mm decrease in overbite.
‡Reported range of pre-TX openbite from −7.9 to +5.8.

odontic studies, the limitations of the studies reviewed earlier are small sample sizes, selection bias, loss to follow-up, and a lack of untreated controls.

Studies Assessing Combined Orthodontic-Surgical Therapies

Surprisingly, there are considerably more studies assessing stability of open bite with combined orthodontic-surgical therapy. One of the earliest studies of stability after surgical correction of open bites focused on tongue function and speech changes.[11] This retrospective case series classified nine subjects into simple (canine to canine), compound (premolar to premolar), and infantile (extending posterior to premolars) open bites, and a variety of maxillary and mandibular surgeries were performed. They re-

ported that six of nine subjects had excellent stability (no appreciable dental or skeletal movement was detected), two had fair stability (detectable movement but no effect on the corrected overbite), and one had poor stability (a reopening of the bite). These results are difficult to evaluate because the definitions of open-bite stability are not quantitatively defined.

Denison et al[12] used a cohort design to compare vertical stability in 66 subjects who had maxillary LeFort I osteotomies. These subjects were selected from the practices of various faculty members of the University of Washington Department of Orthodontics, Seattle, WA. Overbite was measured relative to the nasion-menton line, and records were available at pretreatment, posttreatment, and at least 1 year posttreatment. The subjects were divided into three groups: (1) an open-bite group (no incisal overlap, n = 28),

(2) an incisal overlap group (positive overbite but no contact of incisors, as assessed on the cephalometric headfilm (ceph), n = 24), and (3) an incisal contact group (as assessed on the ceph, n = 14). All subjects had maxillary superior repositioning surgery and were followed for a minimum of 1 year after the completion of orthodontic treatment. Although the incisal contact and incisal overlap subjects did not show any significant changes in overbite during the posttreatment period, 43% of the open-bite subjects had significant increases in facial height, eruption of maxillary molars, and decreases in overbite during the posttreatment phase. In 21% of the open-bite subjects, the overbite relapsed to a negative value.

Reitzik et al[13] reported on a mandibular procedure for open-bite correction—the reverse-L osteotomy with rigid fixation. Of 20 consecutively treated cases, the records of 16 were available at the preoperative, postoperative, and ≥1-year postoperative time periods. The surgical procedure resulted in a mean closure of 9° for the gonial angle and 4.3° for the mandibular plane angle. At 1 year postoperative, the gonial angle had relapsed 0.3° and the mandibular plane angle 0.6°. The investigators also reported that incisal contact had been maintained in all subjects, but overbite measurements were not reported. Based on these results, the investigators concluded that the reverse-L procedure with rigid fixation is a stable method for open-bite correction. Their results are impressive, but the short follow-up time may have allowed some subjects to be just completing orthodontics. Additionally, cephalometric characteristics of the sample were not described at the pretreatment time.

Haymond et al[14] investigated the stability of open-bite correction using rigid fixation for maxillary procedures alone (n = 15), maxillary procedures in combination with mandibular advancement (n = 16) or set-back (n = 4), and isolated mandibular set-back (n = 3). In this case series, records were available at the preoperative, postoperative, and 1 to 5 year postoperative periods; 6 of the 38 subjects (16%) had negative incisal overlap at the latest follow-up. The investigators reported that dentoalveolar changes were primarily responsible for relapse, especially in 3 cases that were expanded orthodontically. They did not note relapse in sub-

jects with surgically assisted or surgical expansion. From this data, they concluded that surgical correction of openbite using rigid fixation is relatively stable, and that orthodontic expansion may contribute to relapse in the vertical dimension. As in many of the surgical studies, pretreatment cephalometric characteristics were not described, and the earliest follow-up period may have occurred before removal of orthodontic appliances.

McCance et al[15] reported on 21 high-angle subjects who underwent fixed appliances and bimaxillary surgery for open-bite correction. Rigid fixation was used in the maxilla, with wire fixation in the mandible, and intermaxillary fixation. Records were available at the preoperative, postoperative, and 1-year postoperative times. He reported variable postoperative movements of the maxilla and mandible. In the Class III subjects (n = 11), overbite decreased form −6 mm to 3.1 mm postoperatively but relapsed to 2.4 at the follow-up time. The overbite values for the Class II subjects (n = 10) were −4.6, −1.6, and −1.6, respectively. The results of this study are difficult to interpret because the method for measuring overbite was not described nor was the actual number of subjects who achieved or maintained positive overlap reported. Additionally, the follow-up time was short.

Oliveira and Bloomquist[16] investigated the stability of bilateral sagittal split osteotomy (BSSO) with rigid fixation in 10 subjects who had records from the preoperative, postoperative, and ≥1-year postoperative time points (all subjects completed orthodontic treatment before the last follow-up). The mandibular plane angle was evaluated as an indicator of surgical stability, with a mean operative change of 3.9° of closure followed by a mean increase of 1.3° during the postoperative period. Two subjects had mandibular plane angles at the latest follow-up that were greater than the preoperative value. However, all 10 subjects had positive incisal overlap at the latest follow-up. Although these results are encouraging for correcting open bites with isolated mandibular surgery, pretreatment characteristics were not reported, and the minimum follow-up period was quite short.

Ermel et al[17] reported on the Schuchardt technique for open-bite correction, which is a segmented maxillary osteotomy involving impac-

tion of the buccal segments. Of 44 subjects who underwent this procedure at the University of Tubingen (Germany) from 1980 to 1994, 26 subjects agreed to participate, but only 20 had complete records at the preoperative, postoperative, and long-term follow-up period (1-15 years postretention). Fifteen of the 26 subjects also had BSSO, and in all subjects, rigid fixation was used. At the last follow-up visit, 3 of the 26 subjects (12 %) exhibited a negative overbite, and the investigators concluded that the Schuchardt technique is a relatively stable method to address anterior open bite when the maxillary anterior teeth are in good relationship with the upper lip. Pretreatment overbite was not reported, although the mean mandibular plane angle was 39°.

In the largest study of surgically treated anterior open bite, Hoppenreijs et al[18] reported on a total of 267 subjects in a multicenter study.[18] Rigid fixation was used in 114 subjects, and wire fixation was used in 153 subjects. In 144 subjects, only a LeFort I was performed, with the remaining 123 subjects receiving a combined LeFort I with mandibular BSSO. Although records were collected at the pretreatment (T1), preoperative (T2), postoperative (T3), 6 to 19 months postoperative (T4), and 20 to 210 months postoperative periods (T5), not all subjects had complete records from all time points. All subjects that had T1 cephalometric characteristics had no incisal overlap at that time, as measured relative to the occlusal plane, and at T5, all subjects were at least 1 year out of orthodontic appliances. In comparing the differing surgical procedures and methods of fixation, the investigators concluded that the maxilla exhibited good vertical stability overall, and that the mandible exhibited better stability when rigid fixation was used. Their overall relapse rate was 19% when incisal overlap was used as the criterion for success at T5. Again, pretreatment cephalometric characteristics were not reported.

Hoppenreijs et al[19] also reported on transverse stability after LeFort I surgery with and without BSSO by using methodology similar to the previous study mentioned. They compared 77 subjects with orthodontic expansion and one piece LeFort I osteotomy with 53 subjects who underwent multisegment LeFort I osteotomy and found no difference in the transverse stability of the two groups at the latest follow-up time,

with only 20% of the subjects in either group exhibiting good transverse stability. For multisegment LeFort I procedures, the stability was better with rigid fixation than with wires. Although the transverse relapse was associated with clockwise rotation of the mandible, it was not well correlated with changes in overbite, suggesting that compensatory eruption occurred in some subjects.

In a study investigating maxillary incisor extrusion and vertical relapse in surgically treated open bites, Lo and Shapiro[20] collected records for 40 subjects who had maxillary LeFort I surgery, with some also undergoing mandibular surgical procedures. All subjects had records from the pretreatment, preoperative, postoperative, and >2-year posttreatment time periods. These subjects were divided into a group that underwent presurgical extrusion of the maxillary incisors (n = 19) and a group that did not (n = 21). The mean pretreatment open bite for these groups was −1.7 and −2.0, respectively. The investigators did not find a significant difference in the amount of relapse because both groups had 5 subjects with no incisal overlap at the final follow-up time. Thus, presurgical extrusion of the incisors did not appear to affect stability of open-bite correction in these subjects, and the overall rate of relapse was 25%.

Arpornmaeklong and Heggie[21] compared 17 subjects undergoing isolated maxillary superior repositioning with 20 subjects who underwent bimaxillary surgery with rigid fixation. Records were available at the preoperative, postoperative, and ≥1-year postoperative times. Good maxillary stability was reported in both groups. In the bimaxillary surgery group, 3 subjects (15%) exhibited considerable anteroposterior relapse of mandibular advancement. The mean overbite for the LeFort I group was 0.9 at the final follow-up and 0.7 for the bimaxillary surgery group. Unfortunately, the number of subjects with vertical relapse was not reported. Additionally, pretreatment cephalometric characteristics were not reported, and the final follow-up period was relatively short.

Proffit[22] reported on the long-term stability of all open-bite subjects in the University of North Carolina database who had maxillary osteotomies (n = 28) or bimaxillary osteotomies (n = 26), along with complete records. All subjects had at least 2-mm open bite at the pretreatment

time, and records were available at the preoperative, postoperative, 1 year postoperative, and at least 3 years postoperative time periods. He found that 12% of the subjects had decreases of 2 to 4 mm in overbite during the follow-up period. Although facial height increased in more than 35% of the subjects, this was usually accompanied with incisor eruption, which maintained the overbite relationship. The actual overbite measurements at various time points are not reported, and therefore it is difficult to compare this study with results from other studies. Also, although relapse <2 mm was considered stable, it is difficult to know if those subjects maintained positive incisal overlap.

Moldez et al[23] compared a random selection of 23 Class III open-bite subjects who underwent maxillary impaction and BSSO to 11 Class III subjects without open bite but similar surgical correction. The open bites were further divided into two groups: one with maxillary impaction but no rotation (n = 13) and one with clockwise rotation of the maxilla (n = 10). In this well-documented study, cephalometric characteristics were reported at the pretreatment (T1), preoperative (T2), postoperative (T3), postorthodontic (T4), 1-year postorthodontic (T5), and 5-year postorthodontic (T6) time periods. The pretreatment overbites for the impaction, rotation, and non–open-bite groups were −2.2, −3.8, and 2.0, respectively. Moldez et al reported that 2 of 13 subjects (15%) in the maxillary impaction group exhibited relapse of the open bite, whereas no subjects from the rotation group or non–open-bite group displayed vertical relapse. Thus, they concluded that the LeFort I osteotomy with rotation, in which the vertical dimension was maintained, was more stable than LeFort I osteotomy with impaction, in which the mandible rotated in a counterclockwise manner. The proposed rationale is the temporary alteration of freeway space in the impaction subjects.

Perhaps the most interesting finding from the latter study is the change in overbite during the postoperative periods. From T3 to T4 (postoperative to debanding), both the rotation and impaction group displayed increases in the overbite. This could be due to dental movements in the finishing stages of orthodontics. Many surgical studies report stability at the 1-year postoperative time, which may be very close to the time

of orthodontic appliance removal. Therefore, the overbite measurements at that time may reflect orthodontic finishing rather than true stability. From T4 to T5 (debanding to 1 year postorthodontics), both the rotation group and impaction group showed vertical relapse. From the T5 to T6 period (1 to 5 years after orthodontics), the overbite continued to decrease slightly. Thus, it would seem that the minimal period required to monitor overbite stability is at least 1 year after the removal of orthodontic appliances.

Fischer et al[24] reported on 58 consecutive subjects who were diagnosed with retrognathia and open bite and underwent bimaxillary surgery. Records were available at the pretreatment, preoperative, postoperative, and ≥2-year postoperative periods. They found that 17 of the 58 subjects (29%) had no incisal overlap at the final follow-up. Of these, 8 had multisegment LeFort I osteotomies. They concluded that maxillary stability was good but that the mandible tended to rotate downward. It is interesting that the relapse rate was so high, especially because the range of overbite at the pretreatment period was −7.9 to 5.8, with a mean of −0.8.

In the most recent surgical study, Swinnen et al[25] evaluated 49 consecutively treated open-bite subjects.[25] Of these, 38 had maxillary intrusion, whereas 11 had maxillary extrusion. Records were available at the pretreatment, preoperative, postoperative, 20-weeks postoperative, and 1-year postoperative time points, and all subjects had rigid fixation. Both the intrusion and extrusion groups exhibited good maxillary skeletal stability at the 1-year postoperative period, but 11% of the subjects had no incisal overlap at that time.

The surgical studies display considerable variation in methodology. The comparison of pretreatment characteristics is difficult because preoperative, rather than the pretreatment, characteristics are more commonly reported (Table 1). Although the mean mandibular plane angles from these studies tended to be steeper than the nonsurgical studies, the mean open-bite measurements were not more severe (Table 1). Thus, the surgical subjects were typically adults with very steep mandibular planes and 1 to 2 mm of open bite. Again, these are subjects in which spontaneous improvement is unlikely.

Another issue that arises when assessing the

surgical studies is the follow-up period. In the orthodontic studies, all subjects were out of treatment at least 1 year. In the surgical studies, more than half use the 1-year postoperative time as the minimum follow-up. As previously mentioned, this time point is likely to coincide with the removal of orthodontic appliances, and therefore the overbite would be expected to be positive. The study by Moldez et al[23] shows increased overbite from the postoperative period to the end of orthodontic treatment and then a decrease during the first year after debanding. Therefore, although it may be possible to evaluate surgical stability 1 year postoperatively, overbite stability, which reflects both skeletal and dental movements, cannot truly be assessed until a sufficient period of time has passed after the removal of appliances. From the work by Moldez et al, 12 months would seem to be an appropriate period.

An attempt was made to measure overall success for the surgical studies by using the conventions from the nonsurgical studies. Surgical therapy should allow positioning of the maxilla or mandible to achieve a positive overlap of the incisors so the treatment success was assumed to be 100%. With this assumption, the overall success, which varied from 71% to 100%, only depended on the subsequent stability (Table 2). The four surgical studies that documented a negative overlap at the pretreatment or preoperative time and had a minimum follow-up of 1 year postorthodontics (Table 2 in bold) reported a range of overall success from 75% to 88%. This is very similar to the range of 75% to 93% reported for the nonsurgical studies. However, the nonsurgical studies tended to report less treatment success and better stability. It is difficult to predict what the overall success of the surgical studies would have been if incisor overlap were not achieved in all surgical subjects because the treatment success would have decreased, but the stability of subjects who were successfully treated may have improved. Unfortunately, this assumption was necessary because most surgical studies did not report the percentage of subjects with incisal overlap postoperatively or posttreatment.

It is important to critically assess the level of evidence provided by these studies. The generally recognized hierarchy of clinical evidence, from strongest to weakest, is (1) randomized

controlled trials, (2) cohort studies, (3) case/control studies, (4) case series, and (5) expert opinion. The small number of nonsurgical studies is all case series, with relatively small samples and the potential for selection bias. Thus, we cannot be sure that the nonsurgical therapies are truly as successful or as stable as the current literature suggests. The surgical studies consist of case series and cohort studies that compare different therapies or dental characteristics. Although most of the surgical studies also have small samples and the potential for selection bias, the large, multicenter study of Hoppenreijs et al[18] suggests that the stability of surgical therapy is approximately 80%. The surgical studies provide a higher level of evidence than the orthodontic studies based on their greater numbers, the case series that report on consecutively treated subjects, and the work of Hoppenreijs et al.[18]

The lack of untreated controls in open-bite studies can be justified by the fact that these subjects usually do not improve without therapy, especially after the eruption of the permanent incisors. Therefore, unless a study is assessing an early intervention, it is probably more important to compare different types or combinations of orthodontic and surgical therapies in cohort or randomized designs. The use of incisal overlap as a criterion for measuring open bite should also be discussed. This measurement has the advantage of being cephalometrically defined. It also is a good indicator of whether the lack of incisor contact is due to a true vertical problem or an anteroposterior discrepancy. Additionally, two studies that have compared subjects with incisal contact, incisal overlap, and no incisal overlap found that the incisal overlap subjects reacted very similarly to the incisal contact group, in which minimal vertical relapse occurred.[4,12] Finally, from a clinical standpoint, a lack of incisal overlap is usually associated with an inability to incise and therefore indicates an abnormal functional relationship of the incisors.

Skeletal stability of the maxilla tended to be good with both wire and rigid fixation because it typically was positioned superiorly. In bimaxillary surgeries, mandibular stability seemed to be more variable than maxillary stability, and Hoppenreijs et al[18] reported that rigid fixation seemed to decrease relapse. Two studies reported that poor transverse stability of the max-

illa contributed to vertical relapse.[14,19] All of these findings are generally consistent with the statements in an article by Proffit[26] reviewing the stability of surgical movements. Relapse of open bites may also occur because of tongue size or posture, unfavorable growth patterns, orofacial musculature, respiratory problems, and dental movements. Additionally, condylar resorption after orthognathic surgery has been reported to be a factor in relapse.[27]

As stated at the beginning of this article, open-bite therapy is still a challenge to the orthodontic profession. The current literature suggests that 80% of anterior open-bite subjects will maintain positive overlap after treatment, whether it is with orthodontics or combined orthodontics and surgery. However, these findings are based on studies that usually have small samples and the potential for selection bias. Reviewing the existing studies allows us to improve future investigations of anterior open bite. For instance, Hoppenreijs et al[18] show the feasibility of large, multicenter studies. If well designed, these types of studies can substantially increase sample size, which results in greater statistical power when comparing different therapies. Several of the surgical studies report on consecutively treated or randomly selected subjects, which minimizes selection bias. Also, the careful documentation by Moldez et al[23] helps to show the importance of an adequate follow-up period after all treatment has been completed. To compare the overall success of orthodontic and surgical therapies, standardized information is necessary. This includes complete records from the pretreatment period to describe the sample (including age and gender); consistent and reproducible methods to measure overbite; and careful documentation of therapies with interim, final, and long-term records. Well-designed studies are necessary to better understand the effectiveness and stability of orthodontic and surgical therapies as well as the mechanisms for relapse. This will provide orthodontists with the evidence necessary to recommend the most appropriate options to their anterior open-bite patients.

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