

The Esthetic Impact of Extraction and Nonextraction Treatments on Caucasian Patients

S. Jay Bowman, DMD, MSD^a; Lysle E. Johnston Jr, DDS, PhD^b

Abstract: This investigation was designed to compare the esthetic effects of extraction and nonextraction treatments. Panels of 58 laypersons and 42 dentists evaluated randomly presented pre- and posttreatment profiles of 70 extraction and 50 nonextraction Class I and II Caucasian patients. The samples were similar at the outset; however, at the end of treatment, the extraction patients' faces were, on average, 1.8 mm "flatter" than the faces of nonextraction subjects. The flatter faces were preferred by both panels, dentists more so than laypersons. In general, nonextraction treatment was seen as having little effect on the profile, whereas the perceived effect of extraction treatment was a statistically significant function of initial soft tissue protrusion—the greater the initial protrusion, the greater the benefit. The point at which a reduction in protrusion produces a perceived improvement was explored by way of regression analysis. Both panels saw extraction as being potentially beneficial when the lips were more protrusive than 2 to 3 mm behind Ricketts' E-plane. It is concluded that extraction treatment can produce improved facial esthetics for many patients who present with some combination of crowding and protrusion. (*Angle Orthod* 2000;70:3–10.)

Key Words: Soft tissue profile, Extraction, Nonextraction

INTRODUCTION

The widespread popularity of nonextraction, 2-stage, and "arch-development" treatments has led to a marked reduction in the percentage of orthodontic treatments featuring premolar extraction.^{1,2} At first blush, arch development, ie, expansion, is an unlikely alternative to extraction, given repeated reports of instability and the apparent advantages of more conservative methods of space management.^{3–10} For many types of patients, extraction treatment seems to offer better long-term stability.^{11–16} Moreover, the dire predictions of condylar displacement (and the TMD that is hypothesized to accompany this displacement), narrowed smiles with dark corners, "dished-in" profiles, and suboptimal mandibular growth (compared with that typically attributed to functional appliances) have been called into question in the refereed literature.^{17–27} Arch development enthusiasts are left with a list of benefits that has shrunk to

the possible production of wider-than-average smiles. Despite the refereed literature, the appeal of nonextraction treatment is nearly irresistible to contemporary orthodontists. Clearly, there is a need for data and a willingness to be guided by it. One area that is especially contentious is the esthetic effect of premolar extraction.

Some treatments, including premolar extraction, commonly produce changes in the facial profile. It would be useful, therefore, for the clinician to know the effects of the various treatment options and their perceived value to the patient. Past studies on the profile effects of orthodontics fall into 2 general categories: evaluations comparing profiles with accepted cephalometric norms and evaluations of profiles by panels of observers. Despite the profession's growing enthusiasm for nonextraction treatment, dentists and lay persons may well differ in their attitudes toward facial esthetics.^{28–31} For example, regardless of the composition of the panels that are asked to render an opinion, extraction treatment seems to produce results that are at least no worse than nonextraction strategies,^{32,33} and they are often superior.^{23,34–36} Obviously, however, the choice of strategies depends on many factors, one of which is the initial form of the face. The question then is not which treatment is better, but rather under what conditions is each preferable.

The purpose of this study, therefore, was to examine the changes in facial esthetics wrought by extraction and nonextraction treatment and to analyze them as a function of pretreatment facial morphology. In the process, the data

^a Private practice, Portage, Mich.

^b Robert W. Browne Professor of Dentistry and Chair, Department of Othodontics and Pediatric Dentistry, the University of Michigan, Ann Arbor, Mich.

Corresponding author: S. Jay Bowman, DMD, MSD, Kalamazoo Orthodontics, 1314 West Milham Ave, Portage, MI 49024 (e-mail: DRJWYRED@AOL.com).

Based on a paper presented by Dr Bowman to the Eastern Component of the Edward H. Angle Society of Orthodontists, Providence, RI, March 1999.

Accepted: July 1999. Submitted: March 1999.

© 2000 by the Edward H. Angle Society of Orthodontists

TABLE 1. Demographic Summary, Patients

Group	n	Males	Females	Angle Classification		Age		Average Treatment Time, mo
				I	II	Average, y/mo	Range, y	
Extraction	70	22	48	37	33	18/7	9 to 44	27.6
Nonextraction	50	22	28	21	28	13/10	9 to 41	24.6

TABLE 2. Demographic Summary, Panelists

Panel	n	Males	Females	Average Age, y	History of Orthodontic Care
Dentists	42	37	5	45	19
Laypersons	58	12	46	34	22

should provide clinically meaningful guidelines to assist in what is admittedly a complex decision-making process.

MATERIALS AND METHODS

A sample of 120 Caucasian orthodontic patients (70 extraction and 50 nonextraction, Table 1) was randomly selected from the senior author's treatment files. Class III patients and those nonextraction patients who had not undergone at least 18 months of fixed appliance treatment were excluded. The extraction sample consisted primarily of premolar extractions in both arches: four first premolars, 39; three first and one second, 5; four second, 2; upper first, lower second, 6. The remaining 18 patients were treated in conjunction with the extraction of maxillary first premolars only.

The sample featured the wide range of starting facial profiles that would be seen in a typical orthodontic practice. All patients were treated with a preadjusted edgewise appliance (without intentional mandibular arch expansion) and had completed treatment no more than 2 years prior to the study. Sample selection was independent of treatment outcome. Indeed, it was hoped that the samples studied here would contain a wide range of treatment results.

Esthetic evaluation

The effect of treatment on the facial profile was determined by asking panels of observers to evaluate tracings of the profiles taken from pre- and posttreatment lateral cephalograms. Line drawings of the pre- and posttreatment profiles of 120 subjects were presented (either by way of slide projection or on printed data sheets) in random order (pre/post; post/pre) for evaluation by 2 groups of Caucasian evaluators: 42 dentists and 58 laypersons (Table 2). The observers were not informed that they were evaluating 2 different treatment methods or that the patients were all Caucasian.

Each observer was asked to evaluate all 120 profile pairs (Figure 1). For each subject, the observer was asked to

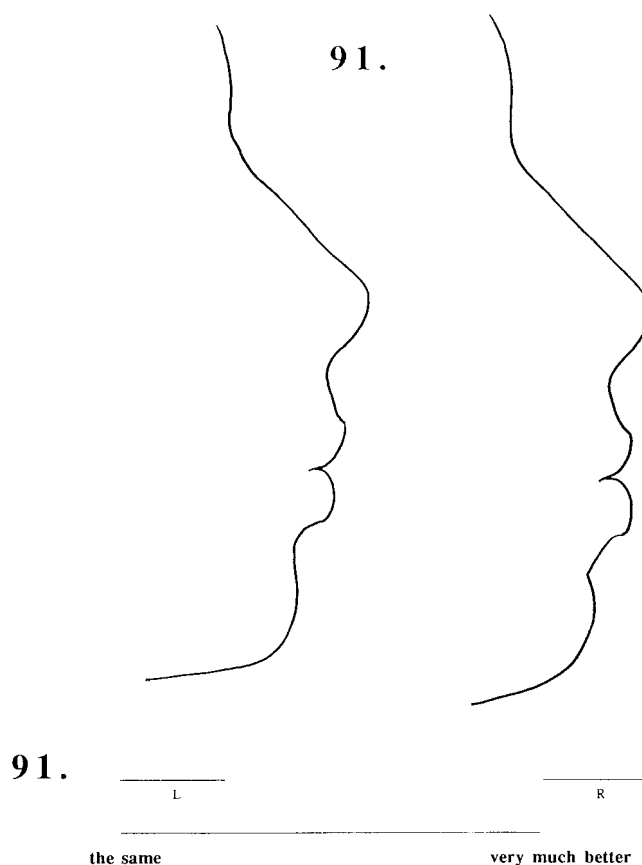


FIGURE 1. An example of the pre- and posttreatment profile tracings, presented in random order (pre-/posttreatment; post-/pretreatment) for evaluation by the 42 dentists and 58 laypersons. Each rater was asked to select the profile from each pair that they thought looked better by checking "L" or "R" and to indicate the intensity of their preference by placing a mark on a visual analogue scale (VAS) below the 2 profiles.

select the profile from each pair that he or she thought looked better. The observers then indicated the intensity of their preference by making a mark along a visual analogue scale (VAS).³⁷ The VAS consisted of a 100-mm line labeled "the same" on the left and "very much better" on the right. The strength of each judge's preference for the profile selected was measured by how far along this line (in millimeters) they made their mark. Thus, each panelist's opinion of the esthetic effect of treatment, along with the effects of facial growth, lip posture, and the like, was estimated by measuring the distance between the mark and the left end of the line using digital calipers. If the observer preferred

the posttreatment profile (ie, the facial profile was better after treatment), the measurement was given a positive score; if the pretreatment profile was preferred (ie, the facial profile was seen as worse after treatment), the measurement was given a negative sign. The esthetic change during treatment, therefore, was measured on a 200-point scale ranging from -100 (very much worse) through zero (the same) to +100 (very much better).

Two panels—42 dentists and 58 laypersons—evaluated the 120 pre- and posttreatment profile tracings. The profiles were presented to the dentists by way of photographic slides. Included among the dentists were 4 specialists (an oral surgeon, a periodontist, a pedodontist, and an orthodontist) and 10 dentists who identified themselves as placing “special emphasis for orthodontics in their practice.” The dentists evaluated the slides as a group during a continuing education seminar.

Booklets of the same 120 sets of profile tracings were presented to 58 laypersons for examination. The laypersons consisted of participants recruited from incidental contacts during the course of this investigation. They included patients’ parents, staff (and their spouses) from various dental offices, hairdressers, salespersons, delivery persons, etc. Given their adventitious selection, it is assumed that they provide a reasonable, if haphazard, representation of today’s orthodontic consumer.

Forty-one of the 100 observers reported that they had undergone some orthodontic treatment themselves. None of the participants was compensated.

Data reduction

To simplify analysis, the scores from each of the 2 panels of judges were averaged to produce a single laymen’s score and a single dentists’ score for each of the 120 patients. These 240 means thus constituted the collapsed raw data that were subjected to standard statistical analysis. Descriptive statistics (means and standard deviations) were calculated for the various main (panels, treatments) and simple (extraction treatments evaluated by dentists, extraction treatments evaluated by laypersons, etc) effects. To test for interaction and for significant mean differences between treatments and between panels, the data were subjected to 2-factor, repeated measures analysis of variance (ANOVA). A repeated measures design³⁸ was employed because each patient’s outcome was evaluated twice—once by the lay panel and again by the dental panel.

The linear correlation between the dentist and lay scores for each of the patients was used to estimate the degree of between-panel agreement. The scores were also plotted as a linear function of initial lower-lip procumbency (lower lip to *E*-plane) to investigate the esthetic interaction between treatment strategy and initial profile protrusion. The purpose of this regression analysis was to determine the lip protrusion at which the retraction that commonly follows

TABLE 3. Mean VAS Scores (and Standard Deviations) by Panel and Treatment (mm)

Category	Dentists	Laypersons	Combined
Extraction	8.2 (24.4)	1.8 (25.0)	5.0 (24.8)
Nonextraction	-4.0 (21.8)	-8.6 (20.0)	-6.3 (21.0)
Combined	3.1 (24.1)	-2.5 (23.5)	0.3 (23.9)

premolar extraction would be seen by the panels as having been beneficial to facial esthetics. The protrusion at which extraction becomes preferable is the point at which the extraction regression line crosses and exceeds its nonextraction counterpart.

This specific “bend point” was determined by solving for *X* (lower lip to *E*-plane in millimeters) after setting the extraction and nonextraction regression equations equal to each other.

RESULTS

Means and standard deviations for the 2 categories of effects (treatments and panels) are summarized in Table 3. As may be seen, the educational background of the examiner had a significant impact: dentist’s VAS scores tended to be higher than those of the laypersons for extraction (8.17 vs 1.85) and nonextraction (-4.03 vs -8.63) treatment.

Based on the repeated-measures ANOVA, both the difference between treatments and the difference between panels produced *F*-ratios—7.8 and 16.2, respectively—that were highly significant ($F_{.99(1,118)} = 6.9$). There was no significant treatment/panel interaction ($F = 0.4$; $P > .05$), and thus no need to examine simple main effects.

The 2 panels’ scores for the 120 patients were highly correlated ($r = 0.8$ for extraction, nonextraction, and combined) with both panels demonstrating a similar response to the effects of treatment (Figure 2). Specifically, for both groups the nonextraction regression lines were essentially horizontal, in contrast to the positive slope of the extraction lines. Both dentists and laypersons apparently felt that nonextraction treatment had little esthetic effect over a wide range of lower lip positions. In contrast, extraction treatment produced VAS scores that were directly proportional to each patient’s initial lip procumbency (lower lip to *E*-plane): extraction hurt retrusive profiles and helped protrusive profiles.

In each set of plots, the intersection of the extraction and nonextraction regression lines provides an estimate of the point at which each panel would favor a reduction in lip procumbency. For the dentists, the extraction line crossed the nonextraction line at an initial lower-lip-to-*E*-plane measurement of about -3.9 mm; for laypersons, the lines crossed at -3.3 mm (Figure 2). Combining both panels’ observations yielded a “bend point” of 3.5 mm *behind* the *E*-plane (Figure 3).

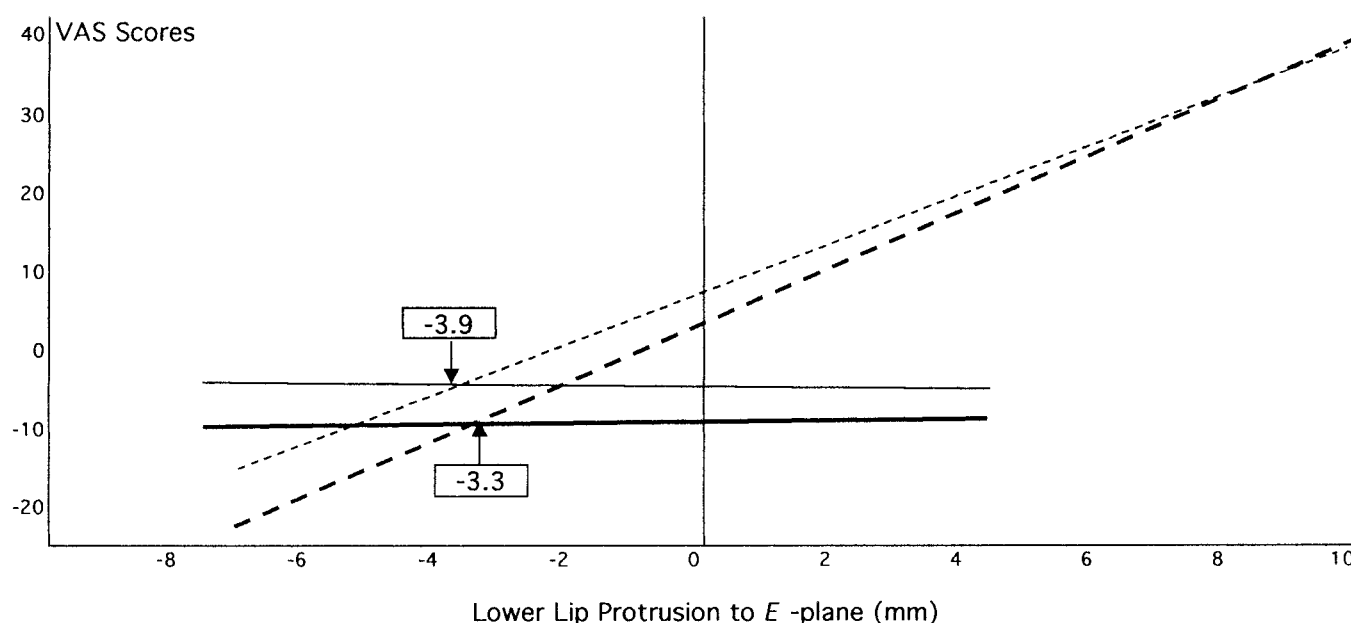


FIGURE 2. VAS scores plotted as linear functions of initial lip protrusion to *E*-plane. Solid lines indicate nonextraction; interrupted lines, extraction. Dentists' evaluations are depicted with thin lines; laypersons' with thick lines. Note that the 2 panels of observers generated similar functions for both extraction and nonextraction; however, the dentists saw extraction as superior treatment when the lower lip was more protrusive than 3.9 mm behind Ricketts' *E*-plane. In contrast, laypersons preferred extraction beyond -3.3 mm.

DISCUSSION

In contemporary orthodontics, there is strong pressure to treat without extraction, even though the alternatives, ie, arch development and air-rotor stripping, are generally unproven. This failure to deliver evidence-based treatment runs contrary to powerful trends in dentistry as a whole. The present study was designed to address this apparent contradiction.

Experimental design

Patients exhibiting crowding and bimaxillary protrusion are susceptible to extraction treatment and might be expected to demonstrate more profile improvement than their "flatter" counterparts, for whom a profile change is not sought. Retrospective comparison of these 2 alternatives might favor extraction treatment merely because of this susceptibility bias.³⁹ In previous investigations, discriminant analysis has been used to identify comparable samples^{23,25,35,40} to provide a valid estimate of the differential effect of various treatment alternatives.

In the present study there was no attempt to select comparable extraction and nonextraction samples. Rather, our goal was to gather a sample with a wide range of initial facial profiles. Although we made no attempt to achieve parity, both the extraction and nonextraction samples demonstrated nearly identical average lip procumbancies prior to treatment (lower lip to *E*-plane of -0.18 mm and -0.13 mm, respectively; Table 4). Thus, the profiles—but perhaps not the rest of the dentofacial complex—demonstrated min-

imal susceptibility bias and thus should support a useful between-treatment comparison.

Panelists' perceptions

Profile tracings eliminate a number of confounding or distracting details (lighting, hair styles, makeup, complexion, etc) that may be present in photographs; however, other details cannot be discounted (lip posture or artistic rendering) in evaluating the tracings. As noted by Drobocky and Smith,³⁶ "subjective evaluations of desirable and undesirable profiles often will not coincide with numerical differences among individuals." Despite these limitations, both panels saw nonextraction treatment as having had little esthetic effect throughout the full range of pretreatment profiles. In contrast, premolar extraction had the capacity to either improve or worsen the profile, depending on the initial protrusion (Figures 2 and 3). Although these findings are, on average, consistent with previous evaluations of profile changes that accompany orthodontic treatment, it is clear that some of the present patients would have benefited from the alternative treatment strategy. In other words, some of the extraction patients were too "flat" at the outset, whereas some of the nonextraction were too "full."

The problem, of course, is to have some idea in advance as to when a full face is too full. The point at which the examiners would categorize a reduction in profile as beneficial was estimated by regression analysis. There was some degree of systematic between-panel variation (dentists preferred more "flattening" than laypersons); however,

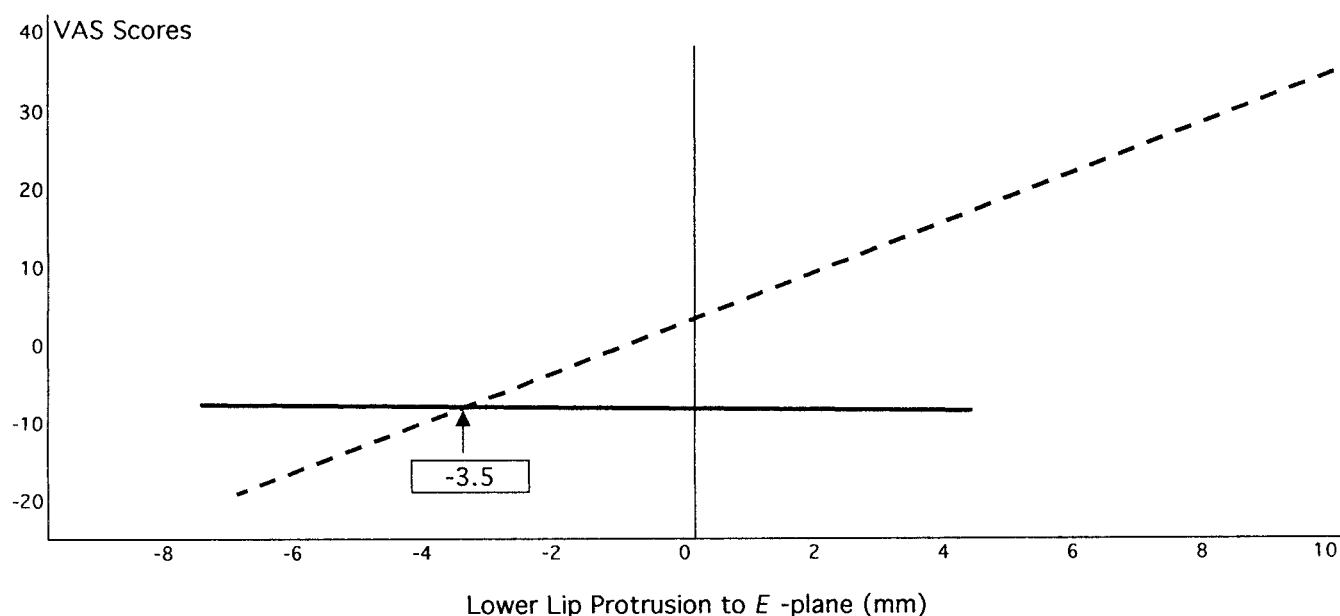


FIGURE 3. Linear regression. All observers' VAS scores plotted against initial lip-protrusion to *E*-plane. Solid line indicates nonextraction; interrupted line, extraction. Nonextraction treatments had little perceived esthetic effect, regardless of initial procumbency. Extraction was seen as the superior treatment when the lower lip was more protrusive than 3.5 mm behind the *E*-plane prior to treatment.

TABLE 4. Descriptive Statistics: Lip Protrusion to *E*-Plane (mm)

Treatment Strategy	n	Initial		LL- <i>E</i> -Plane Final		Change	
		Mean	SD	Mean	SD	Mean	SD
Extraction							
Four premolars	70	-0.18	2.95	-2.27	2.83	-2.16	1.98
Maxillary pre-molars	52	0.09	3.06	-2.33	3.06	-2.51	1.96
	18	-0.98	2.53	-2.10	2.09	-1.14	1.70
Nonextraction	50	-0.13	2.70	-0.51	2.88	-0.36	1.69

both panels tended to prefer the flattening effect of extraction treatment for protrusive patients. The present study thus agrees with past reports that, if an outcome is seen as an improvement by one group of examiners, the chances are that it will be seen as positive by others.^{35,41-48} There are, however, subtle differences that may be of clinical significance.

Dentists' VAS scores tended to be higher than those of the laypersons for both extraction (8.17 vs 1.85) and nonextraction (-4.03 vs -8.63) subjects (Table 4). This tendency reflects previous reports that patients and their parents appear to be less critical of facial esthetics than professionals. It also emphasizes the need to include the patient in the treatment-planning process.^{16,30,31,49-51} Given that the present study's laypersons and dentists agreed on the benefits of extraction in protrusive cases, their evaluations were combined for the purpose of further analysis.

Of 70 extraction patients in the present study, 18 were treated by removal of the maxillary first premolars only. It might be expected that this protocol would yield minimal alteration in mandibular lip position. Although these pa-

tients were initially about 1 mm more retrusive than those who had four premolars extracted, they ended up with about the same final lower-lip position relative to *E*-plane (-2.10 mm compared with -2.33 mm). The maxillary premolar extraction strategy is most often selected for Class II malocclusions, occasionally as a camouflage alternative to orthognathic surgery. Although the "wrong" jaw appears to be receiving treatment, which might, in some circles, be considered a prelude to an appearance in court, the esthetic effect of removing only maxillary premolars received the highest average VAS score (combined evaluators, 8.72) compared with the removal of four premolars (3.05) and nonextraction treatment (-6.69). Indeed, laypersons were especially appreciative of the esthetic effects of this strategy compared with the removal of four premolars (7.81 to -0.21), whereas dentists favored both extraction approaches approximately equally (9.96 to 7.55).

It has been reported that, posttreatment in both Caucasians and African Americans, the lower lips of nonextraction patients are generally 4 mm more protrusive than those of extraction patients.^{23-25,35,40} The average posttreatment lip

TABLE 5. Posttreatment Lower Lip to *E*-Plane: Extraction and Non-extraction

Observer	n	Final LL to <i>E</i> -Plane, mm	
		Extraction	Nonextraction
St Louis University ^{23,25}	126	-2.4	-2.6
Bishara et al ³²	91	-3.1	0.5
James ⁶³	170	-2.6	-4.1
Current sample	120	-2.3	-0.5

TABLE 6. Change in lower lip to *E*-Plane following premolar extraction

Observer	n	Change in LL to <i>E</i> -Plane, mm
St Louis University total	66	-3.5
Paquette et al ²³	33	-3.1
Luppananpornlarp et al. ²⁵	33	-3.9
Hagler ⁴²	30	-3.7
James ⁶³	108	-3.3
Bravo ³⁴	18	-3.8
Bishara et al ³²	44	-3.4
Drobocky and Smith ³⁶	160	-3.6
Current sample	52	-2.5

position in the present study was -2.3 mm to the *E*-plane for the extraction patients and -0.5 mm for nonextraction patients (Table 5). The present extraction sample, as a consequence, underwent less lip retraction than has been reported in a number of previous studies (Table 6). The trend in the 1980s toward nonextraction treatment, based partly on the influential but anecdotal reports of dished-in profiles and the use of a preadjusted rather than standard edgewise appliance, may be responsible for the reduced anterior retraction seen in patients treated in the 1990s.

When the results from this and other studies are combined, it appears that extraction treatment has about a 50% to 60% probability of producing an improvement in facial esthetics (despite producing an average of 1.8 mm less lip protrusion than nonextraction), whereas nonextraction has only a 30% to 50% likelihood.^{23,52} These findings stand in marked contrast to the contention of some that only nonextraction treatments (those featuring 2 phases of treatment, removable appliances, air-rotor stripping, arch development, bite jumping, etc) are capable of producing improvements in facial esthetics.⁵³⁻⁵⁶ Indeed, the potentially negative esthetic consequences of techniques that can produce excessive proclination of the incisors, eg, bimaxillary expansion, fixed and removable functionals, and straightwire mechanics, warrant at least a portion of the concern commonly engendered by extractions.

In an assessment of the profiles of 40 preadolescent patients, based on the Steiner, Merrifield, and Ricketts cephalometric analyses, it has been estimated that 50% might benefit esthetically from profile reduction.⁵⁷ Interestingly enough, prior to the current groundswell of enthusiasm for

nonextraction treatments, Drobocky and Smith³⁶ reported that the frequency of excessively flattened extraction profiles was only about 4%. Seventeen of the extraction patients in our sample (24%) ended up with a lower lip more than 4 mm behind the *E*-plane posttreatment. These patients might be considered in some circles to be excessively flat; however, their average VAS score was a more or less neutral -1.1, a score that compared favorably to the average nonextraction score of -6.7.

McNamara and coworkers⁵⁸ examined 136 Caucasian adults with "ideal occlusions and well-balanced faces" and found a combined average lower lip to *E*-plane for males and females was -3.58 mm. Nanda and Ghosh⁵⁹ examined 50 Caucasian adults with "Class I occlusions and esthetically pleasing and balanced faces" and reported an average protrusion of -3.13 mm. Most recently, Bishara and associates⁶⁰ described changes in facial esthetics for 35 Caucasians from 5 to 45 years of age. Their reported average measurement for males and females was -3.37 mm at age 45. These 3 reports stand in contrast to Ricketts' norm of -2.0 mm for lower lip to *E*-plane.⁶¹

If the average effects of posttreatment facial growth, as roughly estimated from the results reported by Paquette and coworkers,²³ are added to the current sample, the expected long-term lower lip to *E*-plane measurement would be -4.6 mm for extraction patients and -3.5 mm for nonextraction patients. If the average incremental facial changes as reported by Bishara's group⁶⁰ is added to the current sample, the resulting measurement would be -3.9 mm for extraction and -2.2 mm for nonextraction patients at age 45. As a result, the current nonextraction sample might, in the long run, be expected to demonstrate profiles similar to "ideal and untreated adult norms." In contrast, extraction patients would be, on average, 1 to 1.5 mm more retrusive. This difference, although probably clinically noticeable, might not be esthetically objectionable, given the benefits of resolved crowding and protrusion.

Only 7 of the 70 extraction patients in our sample presented with an initial lower lip more retrusive or than our bend point of -3.5 mm. The panels judged the esthetic effects of extraction as being detrimental for 4 of these 7 patients; however, the average VAS score was only -2.9 (compared with the average nonextraction score of -6.7). This surprisingly minor effect on the profile underscores the need to consider other factors that may be equally important to the extraction decision, including crowding, midline deviation, and molar relationship.⁶² Occasionally, the need for extractions may outweigh the chance of a slightly negative effect on the profile.

In any event, a somewhat more conservative bend point to compensate for the effects of continued facial growth on the profile (the additional 1 to 1.5 mm of flattening by adulthood) may be appropriate. If so, a bend point 2 to 3 mm behind the *E*-plane for Caucasians and 2 to 3 mm in front of the *E*-plane for African Americans³⁵ might constitute a

more valid treatment-planning guide than a blanket reliance on Ricketts' current standard of -2 mm.

During the time the present patients were treated, fashions have come and gone with respect to orthodontic treatment. Indeed, at the outset, the 2 groups featured similar amounts of protrusion, a fact that implies at the very least that the extraction decision was based on many factors, only one of which was profile protrusion. When the results of all 120 treatments provided in this study are combined, the average VAS score is 0.3. From the standpoint of the profile, the net esthetic result for the typical patient in this study, therefore, was negligible—some faces got better and others worse. It is hoped that, by using the diagnostic criteria presented here, the next 120 patients will receive a more individualized, evidence-based treatment and perhaps a generalized improvement in esthetics for both extraction and nonextraction patients.

SUMMARY AND CONCLUSIONS

The purpose of this study was to compare the esthetic impact of 2 treatment strategies, extraction and nonextraction, on the profiles of Caucasian patients as judged by panels of Caucasian dentists and laypersons. A sample of 120 Class I and II patients—50 nonextraction and 70 extraction—were selected without respect to final result from the practice of the senior author. Two panels of observers (42 dentists and 58 laypersons) were asked to select between randomly ordered pre- and posttreatment profiles, and then to quantify the strength of their preference on a VAS scale.

The esthetic effect of treatment on the facial profile proved to be a function of the type of treatment, the initial protrusion of the profile, and the background of the observer. Extraction treatment had an esthetic effect that was proportional to the patient's pretreatment lip procumbency (lower lip to *E*-plane). In contrast, nonextraction treatment had little effect on facial esthetics, regardless of initial profile protrusion. Linear regression was used to develop guidelines for choosing between these 2 treatment approaches. Although the profiles of most of the extraction patients were thought by panels of observers to have been improved by treatment, the profiles of those whose lips were more than 2 to 3 mm behind the *E*-plane prior to treatment tended to be seen as having worsened as a result of premolar extraction.

This study supports previous findings that extraction treatment commonly produces positive results for patients where the objective is to reduce lip procumbency. The current sample of extraction patients demonstrated, on average, only 1.8 mm less lip protrusion posttreatment than the nonextraction sample; however, even this small difference proved beneficial to facial esthetics. Considering the potentially negative aspects of many types of nonextraction treatment (such as instability, procumbency, inefficiency), a

blanket indictment of extraction may be harmful to many patients. Instead, careful diagnosis followed by evidence-based treatment decisions should be the norm.

ACKNOWLEDGMENTS

Supported in part by NIDCR grant DE08716. The authors express their appreciation to the members of the Kalamazoo Valley District Dental Society for their assistance in this project.

REFERENCES

1. Weintraub JA, Vig PS, Brown C, Kowalski CJ. The prevalence of orthodontic extractions. *Am J Orthod Dentofac Orthop*. 1989;96:462–466.
2. O'Connor BMP. Contemporary trends in orthodontic practice: a national survey. *Am J Orthod Dentofac Orthop*. 1993;103:163–170.
3. Little M, Riedel RA, Stein A. Mandibular arch length increase during the mixed dentition: postretention evaluation of stability and relapse. *Am J Orthod Dentofac Orthop*. 1990;97:393–404.
4. Burke SP, Silveira AM, Goldsmith LJ, Yancey JM, Stewart AV, Scarfe WC. A meta-analysis of mandibular intercanine width in treatment and postretention. *Angle Orthod*. 1998;68:53–60.
5. Geran, RE. *Long-term Stability of Rapid Maxillary Expansion in the Mixed Dentition* [thesis]. Ann Arbor, Mich: University of Michigan; 1998.
6. Bowman SJ. One-stage versus two-stage treatment: are two really necessary? *Am J Orthod Dentofac Orthop*. 1998;113:111–116.
7. Gianelly AA. One-phase versus two-phase treatment. *Am J Orthod Dentofac Orthop*. 1995;108:556–559.
8. Gianelly AA. Crowding: timing of treatment. *Angle Orthod*. 1994;64:415–417.
9. Gianelly AA. Leeway space and the resolution of crowding in the mixed dentition. *Semin Orthod*. 1995;1:118–194.
10. Dugoni SA, Lee JS, Varela J, Dugoni AA. Early mixed dentition treatment: postretention evaluation of stability and relapse. *Angle Orthod*. 1995;65:311–320.
11. Boley JC. Extraction versus nonextraction: has the pendulum swung too far? [Summary of presentation to the Southern Region, PCSO meeting June 1991, Los Angeles, Calif] *PCSO Bulletin*. 1991;63:58–59.
12. Boley JC. Face quiz study. Presented to the Southern Component of the Pacific Coast Society of Orthodontists (June 14) and the national meeting of the Edward H. Angle Society of Orthodontists (August 14), 1991.
13. Boley JC. Face quiz study. Presented to the 92nd Annual Session of the American Association of Orthodontists, St. Louis, Mo, (May 11), 1992.
14. Rossouw PE. *A Longitudinal Study of the Stability of the Dentition Following Orthodontic Treatment* [PhD dissertation]. Stellenbosch: University of Stellenbosch, Republic of South Africa, 1992.
15. Sandusky WC III. *A Long-term Postretention Study of Tweed Extraction Treatment* [thesis]. Memphis: University of Tennessee, 1983.
16. Franklin GS, Rossouw PE, Woodside DG. A longitudinal study of dental and skeletal parameters associated with stability of orthodontic treatment. *Am J Orthod Dentofac Orthop*. 1995;108:452–453.
17. Sadowsky C. The risk of orthodontic treatment for producing temporomandibular mandibular disorders: a literature overview. *Am J Orthod Dentofac Orthop*. 1992;101:79–83.
18. Luecke PE III, Johnston LE Jr. The effect of maxillary first premolar extraction and incisor retraction on mandibular position: testing the central dogma of "functional orthodontics." *Am J Orthod Dentofac Orthop*. 1992;101:4–12.
19. McNamara JA Jr., Seligman DA, Okeson JP. Occlusion, ortho-

- dontic treatment, and temporomandibular disorders: A review. *J Orofac Pain*. 1995;9:73-90.
20. Management of temporomandibular disorders. NIH Technol Assess Statement. 1996; Apr 29-May 1;1-31.
 21. Greene CS. Etiology of temporomandibular disorders. *Semin Orthod*. 1995;1:222-228.
 22. Johnson DK, Smith RJ. Smile esthetics after orthodontic treatment with and without extraction of four first premolars. *Am J Orthod Dentofac Orthop*. 1995;108:162-167.
 23. Paquette DE, Beattie JR, Johnston LE Jr. A long-term comparison of nonextraction and premolar extraction edgewise therapy in "borderline" Class II patients. *Am J Orthod Dentofac Orthop*. 1991;102:1-14.
 24. Beattie JR, Paquette DE, Johnston LE Jr. The functional impact of extraction and nonextraction treatments: a long-term comparison in patients with "borderline," equally susceptible Class II malocclusions. *Am J Orthod Dentofac Orthop*. 1994;105:444-449.
 25. Luppanapornlarp S, Johnston LE Jr. The effects of premolar-extraction treatment: A long-term comparison of outcomes in "clear-cut" extraction and nonextraction patients. *Angle Orthod*. 1993;63:257-272.
 26. Livieratos FA, Johnston LE Jr. A comparison of one-stage and two-stage nonextraction alternatives in matched Class II samples. *Am J Orthod Dentofac Orthop*. 1995;108:118-131.
 27. Johnston LE Jr. Growing jaws for fun and profit: A modest proposal. In: McNamara JA Jr, ed. *What Works, What Doesn't, and Why*. Craniofacial Growth Series 35. Ann Arbor: Center for Human Growth and Development, The University of Michigan, 1998: 63-86.
 28. Kerns LL, Silveira AM, Kerns DG, Regennitter FJ. Esthetic preference of the frontal and profile views of the same smile. *J Esthetic Dent*. 1997;9:76-85.
 29. Lines P, Lines R, Lines C. Profilemetrics and facial esthetics. *Am J Orthod*. 1978;73:648-657.
 30. Prah-Anderson B, Boersma H, van der Linden FPGM, Moore AW. Perceptions of dentofacial morphology by laypersons, general dentists, and orthodontists. *J Am Dent Assoc*. 1979;98:209-212.
 31. Kerr WJS, O'Donnell JM. Panel perception of facial attractiveness. *Br J Orthod*. 1990;17:299-304.
 32. Bishara SE, Cummins DM, Jacobsen JR, Zaher AR. Dentofacial and soft tissue changes to Class II Division 1 cases treated with and without extractions. *Am J Orthod Dentofac Orthop*. 1995;107:28-37.
 33. Young T, Smith R. Effects of orthodontics on the facial profile: A comparison of change during nonextraction and four premolar extraction treatment. *Am J Orthod Dentofac Orthop*. 1993;103:452-458.
 34. Bravo LA. Soft tissue facial profile changes after orthodontic treatment with four premolars extracted. *Angle Orthod*. 1994;64:31-42.
 35. Scott SH, Johnston LE Jr. The perceived impact of extraction and nonextraction treatments on matched samples of African American patients. *Am J Orthod Dentofac Orthop*. 1999;116:352-8.
 36. Drobocky OB, Smith RJ. Changes in facial profile during orthodontic treatment with extraction of four first premolars. *Am J Orthod Dentofac Orthop*. 1989;95:220-230.
 37. Price DD, McGrath PA, Rafii A, Buckingham B. The validation of visual analogue scales as ratio scale measures of chronic and experimental pain. *Pain*. 1983;17:45-56.
 38. Winer BJ. *Statistical Principles in Experimental Design*. New York: McGraw-Hill 1971: 513-39.
 39. Johnston LE Jr, Paquette DE, Beattie JR, Cassidy DW, McCray JF, Killiany DM. The reduction of susceptibility bias in retrospective comparisons of alternative treatment strategies. In: Vig KD, Vig PS, eds. *Clinical Research as the Basis of Clinical Practice*. Craniofacial Growth Series 25. Ann Arbor: Center for Human Growth and Development, The University of Michigan, 1991:155-177.
 40. Hagler BL, Lupini J, Johnston LE Jr. Long-term comparison of extraction and nonextraction alternatives in matched samples of African American patients. *Am J Orthod Dentofac Orthop*. 1998;114:393-403.
 41. Martin JC. Racial ethnocentrism and judgment of beauty. *J Soc Psychol*. 1964;63:59-63.
 42. Peck H, Peck S. A concept of facial esthetics. *Angle Orthod*. 1970;40:284-318.
 43. Farrow AL, Zarrinnia K, Azizi K. Bimaxillary protrusion in black Americans: an esthetic evaluation and the treatment considerations. *Am J Orthod Dentofac Orthop*. 1993;104:240-250.
 44. Polk MS Jr, Farman AG, Yancy JA, Gholston LR, Johnson BE. Soft tissue profile: a survey of African-American preference. *Am J Orthod Dentofac Orthop*. 1995;108:90-101.
 45. Cox NH, van der Linden FPGM. Facial harmony. *Am J Orthod*. 1971;60:175-183.
 46. De Smit A, Dermaut L. Soft-tissue profile preferences. *Am J Orthod*. 1984;86:67-73.
 47. Dunlevy HA, White RP, Proffit WR, Turvey TA. Professional and lay judgment of facial esthetic changes following orthognathic surgery. *Int J Adult Orthod Orthog Surg*. 1974;2:151-158.
 48. Spadafore CA. *Long-term Esthetic Impact of Class II, Division 1 Treatments in "Borderline" Samples* [thesis]. St. Louis, Mo: Saint Louis University, 1995.
 49. Peck S, Peck L. Selected aspects of the art and science of facial esthetics. *Semin Orthod*. 1995;1:105-126.
 50. Bishara SE, Jakobsen JR. Profile changes in patients treated with and without extractions: assessments by lay people. *Am J Orthod Dentofac Orthop*. 1997;112:639-644.
 51. Cochrane SM, Cunningham SJ, Hunt NP. Perceptions of facial appearance by orthodontists and the general public. *J Clin Orthod*. 1997;31:164-168.
 52. Oynick, CA. *The Impact of Orthodontic Treatment on Perceived Facial Esthetics* [thesis]. St. Louis, Mo: St. Louis University, 1988.
 53. Witzig JW, Spahl TJ. *The Clinical Management of Basic Maxillofacial Orthopedic Appliances. Vol. 1, Mechanics*. Littleton, Mass: PSG Publishing, 1987:10-13.
 54. Stoner CC. An interview: AFAO's man of the year 1984, Dr. John W. Witzig. *Funct Orthod*. 1984;1:9-15.
 55. Broadbent JM. Facing malocclusion: achieving harmony and balance. *Dent Today*. 1990;9:41-45.
 56. Bowbeer GRN. Saving the face and the TMJ, part 2. *Funct Orthod*. 1986;3:9-24.
 57. Gianelly AA. Extraction Versus Nonextraction. In: Bolender CJ, Bounoure GM, Barat Y, eds. *Extraction versus nonextraction*. Paris: SID Publisher, 1995:174-184.
 58. McNamara JA Jr, Brust EW, Riolo M. Soft tissue evaluation of individuals with an ideal occlusion and a well-balanced face. In: McNamara JA Jr, ed. *Esthetics and the Treatment of Facial Form*. Craniofacial Growth Series 28. Ann Arbor: Center for Human Growth and Development, The University of Michigan, 1993: 115-146.
 59. Nanda RS, Ghosh J. Facial soft tissue harmony and growth in orthodontic treatment. *Semin Orthod*. 1995;1:67-81.
 60. Bishara SE, Jakobsen JR, Hession TJ, Treder JE. Soft tissue profile changes from 5 to 45 years of age. *Am J Orthod Dentofac Orthop*. 1998;114:698-706.
 61. Ricketts RM. Esthetics, environment, and the laws of lip relation. *Am J Orthod*. 1968;54:272-289.
 62. Bowman SJ. More than lip service: facial esthetics in orthodontics. *J Am Dent Assoc*. 1999;130:1173-1181.
 63. James RD. A comparative study of facial profiles in extraction and nonextraction treatment. *Am J Orthod Dentofac Orthop*. 1998;114:265-276.