Predicting soft tissue changes in mandibular advancement surgery: A comparison of two video imaging systems

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In recent years, there has been an enormous demand for combined surgical-orthodontic treatment to facilitate correction of severe skeletal dysplasias. Whereas in the past, orthodontists were confined to "camouflaging" severe skeletal problems with dental movements, patients are now increasingly opting for surgical treatment, citing esthetics as a major factor in the decision to undergo orthognathic surgery.[1-3] Consequently, the need to accurately predict facial profile outcomes has never been as important as it is now. As a result, contemporary orthognathic diagnosis and treatment planning frequently includes a detailed evaluation of the projected facial esthetic outcomes as well as the usual skeletal and dental predictions.

Prediction tracings are an essential component in planning for orthognathic surgery.[4] They involve not only hard tissue structures, but more importantly, the soft tissue counterparts. While surgical hard tissue movement certainly affects the resulting profile, it is the final soft tissue response that determines the extent of the change in appearance that is produced.[5] Several factors affect the final surgical outcome and the resulting soft tissue response. These include the type of surgical technique employed; the soft tissue morphology; the thickness, posture, and tonicity of the soft tissue attached to the underlying bone; and complications (such as scarring) that may arise from the surgical procedure.[5,6] Thus, an accurate prediction requires careful consideration of the diverse factors that could influence the final outcome.

Surgical outcomes can be predicted manually using acetate overlays, tracing templates, and

Abstract

The purpose of this study was to evaluate the accuracy of two video imaging systems, Prescription Portrait and Orthognathic Treatment Planner, in predicting the soft tissue profiles of 39 patients who underwent mandibular advancement surgery. Presurgical cephalograms and profile photographs were entered into a computer. Computerized cephalometric line and video image predictions were generated and compared with the actual postsurgical results. The results indicate that both programs were equally accurate clinically in their line drawing and video image predictions. In the line drawings, clinically acceptable accuracy was shown in approximately 80% of the upper lip and chin predictions and in less than 50% of the lower lip predictions. The video images produced by both programs received fair to good ratings from a panel of professional and lay judges. Orthodontists and surgeons rated all aspects of the images similarly, while lay people were most critical of the chin and submental areas and least critical in their overall evaluation.

Key Words

Video imaging • Prediction • Orthognathic surgery

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paper or photographic cutouts coupled with model surgery.[7,8] While these may aid the clinician in visualizing the estimated final result, they have a variety of disadvantages. Significant time and effort are required to produce the necessary surgical changes, and the above mentioned methods are not very consistent, being very much open to human error. In addition, the resultant soft tissue changes do not truly represent the final facial esthetic outcome, and may lead to an unrealistic posttreatment estimate.[8-10]

Computerized video imaging can simplify the prediction process. Software systems can be programmed using mathematical algorithms to generate digitized cephalometric tracings, capture pretreatment profile photographs, and blend the tracing and photograph to produce a simulated postsurgical appearance. Operator time and effort are significantly decreased, as the computer can perform the necessary hard tissue movements rapidly and consistently. Changes in specific segments (e.g., dental intrusion, mandibular rotations) can be accurately measured to tenths of a millimeter and to the exact degree. Moreover, since most systems allow the user to adjust the computer's algorithms to the desired soft and hard tissue ratios, the most recent and valid data can be used to visualize the expected profile changes.[11-15]

Currently, the most significant benefit to be gained from using these systems is the ability to generate lifelike video representations of the patient's facial appearance.[14] This greatly facilitates treatment planning and communication between professionals and provides a means by which to demonstrate to patients a projection of the possible surgical treatment result.[16]

In Sarver's 1988 study, 89% of surgical patients who had undergone preoperative video imaging sessions expressed satisfaction with the esthetic outcome 6 months following the procedure, as contrasted to a satisfaction rate of only 45% among a nonimaged group.[12] This implies that video imaging consultations greatly influenced patient understanding of the procedures being planned and allowed them to appreciate the proposed effects of treatment on their appearance. Unrealistic expectations and, consequently, disappointment over the outcome, were greatly diminished.

Previous studies have shown that while patients' expectations were clarified and their confidence heightened by imaging sessions, their decisions to undergo or decline surgery were not directly affected.[12,17] In addition, fears that the video image would be construed as an assurance of posttreatment outcome appear to be unwarranted; current research has revealed that the actual surgical results are generally esthetically superior to the video predictions.[18]

However, despite the many advantages offered by video imaging, this method has some drawbacks. The expense involved in setting up the computer system can be substantial. Added to this is the cost of continually updating programs with improved functions,[19] since innovations are introduced as often as every 6 months. Considerable time and effort are required in learning to operate each system. Moreover, the image produced is only as good as the records entered and the soft tissue ratios employed to produce the images.[18] However, with a little effort, patience, and accurate record-taking, the clinician can use video imaging to enhance the surgical-orthodontic treatment planning and patient communication processes.[20]

A large number of patients seeking orthognathic treatment require mandibular advancement surgery,[21] and information on the accuracy of video imaging as a tool for predicting specific soft and hard tissue changes produced by this procedure is limited. In addition, no comparison has been made of the accuracy of the currently available software systems.

This study was undertaken to answer the following research questions: Using the same hardware and records, would two of the commonly used video imaging programs, Orthognathic Treatment Planner (OTP) (Pacific Coast Software, Inc, Pacific Palisades, Calif) and Prescription Portrait (Portrait) (Rx Data, Inc, Ooltewah, Tenn) prove accurate enough in predicting postsurgical profiles after mandibular advancement to be used in diagnosis, treatment planning, and patient education? Is each accurate in all areas of prediction? And do orthodontists, oral and maxillofacial surgeons, and lay people assess the accuracy of video image predictions similarly?

Materials and methods

The database for this study, the records of 39 adult Caucasian patients, was obtained retrospectively from the office of one of the authors (RK). All subjects underwent mandibular advancement (ranging from 5 to 10 mm) with no other associated surgeries. Patient selection was based solely on the availability of presurgical and posttreatment lateral cephalograms and profile photographs. All records had been taken with similar head position, teeth in centric occlusion, and lips in repose.

The headfilms were manually traced by one investigator (SS) on acetate paper. Data from these tracings and the matching profile photographs were entered into the computer using a Numonics digitizer (Numonics Corp, Montgomeryville, Penn), a JVC (JVC Corp, Elmwood Park, NJ) RGB (TK-1070U) camera positioned at a standardized distance with uniform lighting on a Kaiser (Kaiser, Inc, Buchen, Germany) copy/viewstand, and a Testrite (Testrite Instrument Co, Inc, Newark, NJ) viewbox attached to a 486sx, 66 MHz, 250 MB, 8 RAM computer, and a 20" sVGA .28 monitor. Two software programs, OTP and Portrait, were used to store the records and generate the image predictions for comparison.

Presurgical and posttreatment cephalometric tracings were digitized using OTP and Portrait, and a cranial base superimposition was performed. The actual amounts of anteroposterior and vertical surgical changes that had occurred in each patient during surgery were measured at lower incisor tip, B-point, and pogonion. Using these known surgical changes, each program generated an estimated line drawing cephalometric hard and soft tissue prediction of the final result. The computer-generated hard tissue prediction was then superimposed on the actual final cephalometric tracing. Thus, it was possible to compare and analyze the accuracy of the cephalometric soft tissue outlines (i.e., the actual final soft tissue outline versus the computer-predicted soft tissue outline). This technique eliminated orthodontic and surgical errors and resulted in an evaluation of the prediction methodology of the computer itself.

From the superimposition, any vertical and horizontal differences between the actual result and computer generated prediction were measured at the following 10 points: subnasale, superior labial sulcus, upper lip, stomion superior, stomion inferior, lower lip, inferior labial sulcus, soft tissue pogonion, soft tissue gnathion, and soft tissue menton.

The two programs differed in how the actual measurements were performed. Portrait's superimpositions were printed out and differences were measured using a Mitutoyo (Mitutoyo Corp, Tokyo, Japan) electronic caliper. OTP's superimpositions were measured on-screen using an internal analysis program called Measure (Pacific Coast Software, Inc, Pacific Palisades, Calif). For both programs, measurements were calibrated to match the actual dimensions of the digitized cephalograms using the known presurgical sella-nasion distance.

A repeated measures analysis of variance (ANOVA) was performed to determine the overall and specific differences between OTP and Portrait. Where differences were found, the Student-Newman-Kuels procedure was used to perform multiple comparisons between the two programs at different points. After the presurgical photographs and the digitized line drawings had been combined, the actual hard tissue surgical movements (as measured from the pre- and postsurgical cephalograms) for each case were simulated on both OTP and Portrait, and predicted postsurgical video images were produced using the latest soft tissue to hard tissue ratios.[22] The predicted and actual final video images were then put side by side on the screen to facilitate subjective comparisons by a panel of raters composed of two orthodontists, two oral and maxillofacial surgeons, and two lay people. Each examiner's perception of the concordance between the actual posttreatment photograph and the predicted video images was evaluated using a visual analog scale ranging from poor to excellent on a 10 cm line. Each examiner was asked to mark a point on the line denoting his or her perception of the prediction's likeness to the actual result.

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Although the clinicians discussed the use of the scale before scoring, no formal calibration session was held. Assessments were made of the upper lip, lower lip, labiomental fold, chin, and submental areas. Overall comparisons between the two images were also performed.

The following numerical values on the visual analog scale were assigned to the different ratings:

0 - Poor: Little agreement between predicted and actual images;

33.3 - Fair: General form of prediction acceptable but with noticeable differences from actual image;

66.6 - Good: Predicted image clinically accurate with only minor differences from actual image;

100 - Excellent: Predicted image indistinguishable from actual image.

The distance in millimeters between 0 and the point marked by the examiner was measured using an electronic caliper and recorded as the scored value.

A multiple ANOVA test (three-factor factorial in completely randomized design) was employed to examine whether there were noted subjective differences between OTP and Portrait, or among orthodontists, surgeons, and lay people. Where differences were noted, paired *t*-

Table 1
Horizontal axis differences between actual and predicted line drawing soft tissue values

	Orthognathic Treatment Planner (mm) $\bar{x} \pm$ S.D.	Prescription Portrait (mm) $\bar{x} \pm$ S.D.
Upper lip		
Subnasale	0.33 ± 0.44	0.48 ± 0.40
Superior labial sulcus	0.59 ± 0.58	0.66 ± 0.64
Upper lip	0.66 ± 0.75	0.70 ± 0.67
Stomion superior	0.42 ± 0.63	0.53 ± 0.79
Lower lip		
Stomion inferior	1.04 ± 1.05	1.18 ± 0.94
Lower lip	1.61 ± 1.24	1.60 ± 1.01
Inferior labial sulcus	1.40 ± 1.04	1.09 ± 0.97
Chin		
Soft tissue pogonion	0.91 ± 0.78	0.88 ± 0.78
Soft tissue gnathion	0.76 ± 0.85	0.77 ± 0.85
Soft tissue menton	0.43 ± 0.50	0.32 ± 0.67

Table 2
Frequency (%) of differences between actual and predicted line drawings (x-axis)

	Clinically insignificant error < 1.0 mm		Clinically questionable error 1.0 - 2.0 mm		Clinically significant error > 2.0 mm	
	OTP	Portrait	OTP	Portrait	OTP	Portrait
Upper lip						
Subnasale	90	86	10	12	0	2
Superior labial sulcus	75	80	23	15	2	5
Upper lip	80	79	18	13	2	8
Stomion superior	85	77	13	18	2	5
Lower lip						
Stomion inferior	57	46	21	31	22	23
Lower lip	42	31	23	47	35	22
Inferior labial sulcus	39	62	33	28	28	10
Chin						
Soft tissue pogonion	57	69	36	13	7	18
Soft tissue gnathion	80	67	13	23	7	10
Soft tissue menton	85	88	15	10	0	2

tests were performed to determine the areas at which OTP and Portrait, the orthodontists, surgeons, and lay people differed significantly. A power analysis was performed and the level of significance was set at .05.

A reproducibility study to examine intraexaminer error was carried out. Ten patients in each program (OTP and Portrait) were reexamined and rescored by each rater. The scores were then tabulated and compared using correlation tests. The examiners' scores all had correlations ranging from 0.64 to 0.82, with the exception of one lay person, whose scores were found to correlate at 0.34.

Results

Cephalometric line drawing comparisons (horizontal axis)

No significant differences were found between the accuracy of the two programs' predictions in the horizontal (x) axis (Table 1). OTP and Portrait were also found to be similar in the nature of their predictions in that both produced predictions that tended to be more anterior than the actual result. Both programs were most accurate when estimating upper lip and chin position (mean error +0.6 mm) and least accurate with the lower lip (mean error +1.3 mm).

When comparing the frequency with which each program's predictions fell within specific ranges of clinical acceptability (Table 2), it was clear that both programs were quite similar in their prediction patterns. In the upper lip area, as might be expected since the surgery included the mandible only, both OTP and Portrait produced clinically insignificant errors (i.e., < 1.0 mm) an average of 80% of the time, while clinically significant errors (i.e. > 2.0 mm) occurred on average in 3% of the predictions. Similarly, for the chin, 74% of both programs' predictions differed by less than 1 mm from the actual final result, while 7% differed by more than 2 mm. However, less accuracy was seen in the lower lip, where only 46% of the predictions could be considered to have clinically insignificant errors (< 1 mm error), while 23% of the predictions fell in the clinically significant error category of greater than 2 mm. In this study, following previously established protocols,[18] clinically insignificant errors (< 1 mm) were specified as those not likely to affect either treatment planning or patient communication; clinically questionable errors (1 to 2 mm) might affect treatment planning accuracy only; clinically significant errors (> 2 mm) were likely to affect both treatment planning and patient communication.

Cephalometric line drawing comparisons (vertical axis)

In the vertical (y) axis, the two programs' predictions were found to be significantly different ($p < .001$), with Portrait consistently producing slightly (+0.2 mm) more accurate predictions than OTP (Table 3). However, the prediction patterns were similar in that upper lip predictions were the most accurate and lower lip predictions were the least accurate, with both programs overestimating in an inferior direction. For example, in the upper lip and chin regions, the mean difference between the predictions and the actual final results for both programs was only 0.5 mm. In contrast, the average error of the predictions in the lower lip area for both programs was 1.4 mm.

The frequency with which the programs were able to make accurate predictions varied in different areas of the face. In the upper lip region, 88% of prediction errors were less than 1 mm for both programs, while only 3% of the predictions produced errors of over 2 mm (Table 4). Chin predictions were slightly less accurate, with 72% being within 1 mm and 7% being over 2 mm. Lower lip predictions by both programs were the least accurate, with only 48% differing less than 1 mm from the actual result and 29% of the predictions showing errors of over 2 mm.

Video image comparisons (Tables 5, 6, 7)

Overall, the raters found the quality of the predicted video images fell between the fair and good categories, with an average score of 55% (Table 5). When specific areas were studied, the raters evaluated both programs' predictions similarly, except that the upper lip was perceived to be better predicted by Portrait and lower lip predictions were better in OTP. The highest evaluations were given to the upper lip, chin, and submental areas with an average of 64 out of a possible 100. The lower lip received the lowest ratings, with an average of 51 out of 100.

When comparisons were made among the ratings of the three groups (Table 6), the orthodontists and surgeons were found to be consistently similar in their evaluations of all aspects of the video images. Lay people, however, while giving a higher overall score for the video images ($p < .001$) than the orthodontists and surgeons, gave the lowest scores for the chin and submental areas as compared with the other raters ($p < 0.01$).

Table 3
Vertical axis differences between actual and predicted line drawing soft tissue values

	Orthognathic Treatment Planner (mm) $\bar{x} \pm$ S.D.	Prescription Portrait (mm) $\bar{x} \pm$ S.D.
Upper lip		
Subnasale	0.42 ± 0.49	0.31 ± 0.41
Superior labial sulcus	0.27 ± 0.53	0.10 ± 0.34
Upper lip	0.52 ± 0.79	0.29 ± 0.71
Stomion superior	0.69 ± 0.74	0.68 ± 0.88
Lower lip		
Stomion inferior	1.34 ± 1.12	1.00 ± 0.96
Lower lip	1.71 ± 1.33	1.77 ± 1.26
Inferior labial sulcus	1.54 ± 1.22	1.06 ± 1.18
Chin		
Soft tissue pogonion	0.76 ± 0.81	0.37 ± 0.68
Soft tissue gnathion	0.81 ± 0.74	0.60 ± 0.75
Soft tissue menton	1.02 ± 0.71	0.62 ± 0.72

Table 4
Frequency table for differences between actual and predicted line drawings (y-axis)

	Clinically Insignificant Error < 1.0 mm		Clinically Questionable Error 1.0 - 2.0 mm		Clinically Significant Error > 2.0 mm	
	OTP*	Portrait**	OTP	Portrait	OTP	Portrait
Upper lip						
Subnasale	87	95	13	5	0	0
Superior labial sulcus	93	98	5	2	2	0
Upper lip	83	93	12	2	5	5
Stomion superior	77	74	16	21	7	5
Lower lip						
Stomion inferior	52	62	28	20	20	18
Lower lip	38	34	23	28	39	38
Inferior labial sulcus	41	62	18	18	41	20
Chin						
Soft tissue pogonion	65	83	28	15	7	2
Soft tissue gnathion	70	77	20	18	10	5
Soft tissue menton	56	80	34	15	10	5

* Orthognathic Treatment Planner; ** Prescription Portrait

Discussion

In general, the line drawing and video image predictions evaluated in this study were found

Table 5
Quality of video image predictions

	Orthognathic Treatment Planner (x̄ ± S.D.)	Prescription Portrait (x̄ ± S.D.)	p value
Upper lip	62.7 ± 23.1	71.6 ± 21.0	< 0.001
Lower lip	54.2 ± 24.0	48.3 ± 25.2	< 0.01
Labiomental fold	51.6 ± 22.9	48.7 ± 24.0	ns
Chin	59.7 ± 21.7	61.2 ± 23.9	ns
Submental area	64.8 ± 21.9	66.2 ± 24.5	ns
Overall comparison	55.2 ± 22.5	55.8 ± 22.2	ns

Clinical acceptability scale:
0 to 33.3 poor - fair
33.4 to 66.6 fair - good
66.7 to 100 good - excellent

Table 6
Comparisons of video image quality ratings between lay and professional evaluations

	Orthodontists	Surgeons	Lay people
Upper lip	70.1 ± 25.1	66.6 ± 17.1	62.7 ± 24.2
Lower lip	49.9 ± 25.5	50.0 ± 24.2	53.8 ± 48.3
Labiomental fold	50.5 ± 25.5	48.0 ± 22.2	51.9 ± 22.5
Chin	63.7 ± 24.7	61.8 ± 18.8	55.7 ± 23.9
Submental area	70.4 ± 22.8	67.6 ± 21.9	58.5 ± 23.5
Overall comparison	52.1 ± 22.5	54.8 ± 22.2	59.5 ± 22.3

Clinical acceptability scale:
0 to 33.3 poor - fair
33.4 to 66.6 fair - good
66.7 to 100 good - excellent

Table 7
Comparisons among orthodontists, oral and maxillofacial surgeons, and lay people of video image prediction quality

	Orthodontists vs. surgeons	Orthodontists vs. lay people	Surgeons vs. lay people
Upper lip	ns	**	ns
Lower lip	ns	ns	ns
Labiomental fold	ns	ns	ns
Chin	ns	**	**
Submental area	ns	***	***
Overall comparison	ns	***	*

* Marginally significant; $p < 0.05$
** Significant; $p < 0.01$
*** Highly significant; $p < 0.001$

to be fairly accurate in simulating the soft tissue changes seen after mandibular advancement, with only a small percentage of the predictions showing clinically significant errors that would affect both treatment planning and patient communication. The two programs tested, OTP and Portrait, were found to be almost equally accurate in their prediction of the postsurgical results (Figures 1 and 2).

As expected, the upper lip area, followed by the chin region, were the areas that were most accurately predicted by both programs, with close to 75% or more of all cases studied (in both the x- and y-axes) producing clinically insignificant errors (< 1.0 mm), and less than 10% showing clinically obvious errors (> 2.0 mm). These results were not surprising, as the upper lip did not undergo any kind of surgical manipulation, while the mandible and the chin followed the previously well-documented and predictable 1:1 hard tissue to soft tissue ratio.[22,23]

In contrast, only half of the cases exhibited clinically negligible errors in their lower lip predictions, while 20% or more manifested errors greater than 2 mm. The mean error of lower lip predictions was +1.3 mm for the horizontal axis and +1.4 mm for the vertical counterpart. These results are similar to past findings, which have indicated that the postsurgical position of the lower lip is the most difficult area of the soft tissue profile to predict.[18,22-26]

This study, in agreement with both Quast[22] and Lines,[24] showed that the actual postsurgical position of the lower lip was often more posterior and more superior than the prediction. When using a Macintosh-based program (i.e., QuickCeph [Orthodontic Processing, Chula Vista, Calif]), Hing noted that the actual postsurgical lower lip was more posterior (mean +1.9 mm.) than the predicted result.[4] A recent study of QuickCeph's accuracy also found that the lower facial area was inaccurately predicted, although the direction in which it occurred was not indicated.[25]

However, Sinclair et al., when using Portrait, found that the actual postsurgical lower lip was significantly more anterior (mean -0.9 mm) than the prediction.[18] The results of this study, along with conflicting evidence found in the current literature, lead us to believe that an acceptable soft-to-hard-tissue ratio has yet to be developed to accurately predict the postsurgical position of the lower lip. Since the lower lip is pliable and subject to a variety of influences (e.g. upper incisor position, lower incisor angulation, soft tissue thickness and tonicity, muscle pull, etc.), it

Figure 1

Figure 2

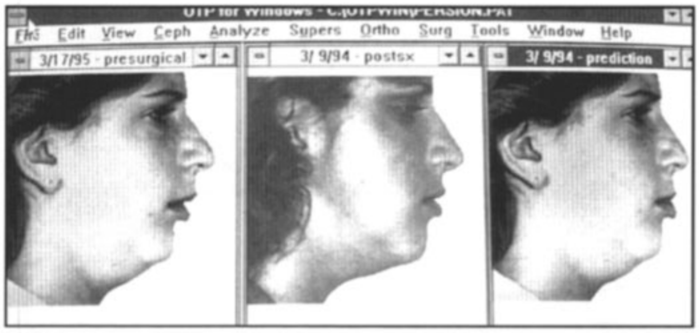

Figure 3

Figure 4

is often difficult to pinpoint exactly where it will end up after hard tissue movement.[22-24,26] Mandibular advancement cases usually exhibit lower lips that are trapped beneath the maxillary incisors, such that forward repositioning of the mandible releases the lip and allows it to assume a more natural position that is very difficult to estimate[22,24] (Figures 3 and 4).

In estimating the soft tissue line drawing profiles after surgery, both OTP and Portrait had almost equal accuracy. While Portrait was consistently better than OTP in predicting the vertical postsurgical positions ($p < 0.001$), it was more accurate by only 0.2 mm, a value that may hold little clinical significance. When video image predictions were tested subjectively by the rating panel, the programs were judged to be similar, except for the upper lip, where Portrait was deemed to be better ($p < 0.001$), and conversely, in the lower lip, where OTP was perceived to be more accurate ($p < 0.01$).

Both programs produced similar predictions because the same soft-to-hard-tissue ratios were employed. However, certain differences in how both the line drawings and the video images were inputted may have contributed to the subtle differences found between the two programs.

In our experience, OTP and Portrait were equally easy to learn, with OTP being slightly less sensitive to minor record imperfections (such as poor background for profile photographs) than Portrait. However, OTP did have some difficulty in combining three photographs to provide pretreatment-to-posttreatment comparisons without occasionally cutting off part of the nose (Figure 1). In addition, it was more technique-sensitive when inputting the facial profile line drawing, as it used individually digitized dots as the basis from which to indirectly generate the different curves and continuous lines comprising the profile. This creates a problem for OTP, as the resulting image may not appear as good as the original, depending on how much expertise the operator has in placing the dots upon which the subsequent lines and curves are based. On the other hand, Portrait used the stream mode to digitize the entire line drawing profile directly. Portrait, therefore, relies less on the operator's experience and ability and more on the quality of the photographs to produce an accurate outline of the facial profile. With properly trained operators and excellent records, however, both programs should be able to produce equally accurate and esthetically pleasing video image predictions.

While the majority of cephalometric line drawing predictions showed clinically insignificant errors (most less than 1.0 mm), the panel's subjective ratings for both programs' predicted video images did not receive very high scores (on average, between fair and good). This was primarily due to a decision not to use any of the smoothing, blending, or other artistic functions (e.g., paintbrush) available in the computer programs tested in this study. While these added functions could have significantly improved the

Figure 1
Mandibuar advancement prediction using Orthognathic Treatment Planner showing, from left to right: pretreatment, actual postreatment result, and computer prediction.

Figure 2
Mandibuar advancement prediction using Prescription Portrait (for the patient shown in Figure 1) showing, from left to right: pretreatment, actual postreatment result, and computer-predicted final result.

Figure 3
The OTP prediction for a patient in whom lower lip morphology was less than satisfactory. Left to right: presurgical, postsurgical and computerized prediction images.

Figure 4
Portrait prediction for the patient in Figure 3, also demonstrating an unrealistic lower lip prediction.

appearance of the video images, it was felt that by allowing the operator to make adjustments, undue influences would be introduced. However, in actual clinical situations, it is imperative that the operator create cosmetic changes in the video images to make them seem more life-like.[18] Without any alterations, edges and boundaries may appear rough and fuzzy, thereby significantly decreasing their attractiveness to an observer.

When comparisons of specific sensitivities to image differences were made among orthodontists, oral and maxillofacial surgeons, and lay people, both the professional groups were found to be consistently similar when judging the video images. These findings contradict those of both Dunlevy[27] and Romani,[28] who indicated that general agreement in assessing facial appearance existed among all three groups. In this study, lay people were found to be more critical of the chin and submental regions, but were, surprisingly, less discriminating than the professionals when overall comparisons of images were performed. This data appears to contradict Burcal's paper; he found that lay people were less cognizant of differences between images along the horizontal plane than either orthodontists or oral and maxillofacial surgeons.[29] However, many of these studies used only profile drawings or cutouts. This may account for the differences between their findings and video imaging studies, such as the recent paper by Giangreco et al.,[30] whose results using the Dentofacial Planner Program were in agreement with the results of this study.

These results suggest that lay people are as sensitive to certain aspects of the video images as are the professionals who work with them, if not more so. Specific areas, in particular the submental region, which may not hold as much importance to professionals, are actually very crucial to lay persons and thus must be given increased attention in the treatment planning process. A positive sign, however, was that lay people did indeed perceive the improvements in appearance that orthodontic and surgical treatment could offer. This reinforces the belief that treatment planning and counseling should involve visual aids such as video imaging to increase the patient's total understanding of the procedures to be performed and their potential effects on the patient's facial appearance.

Concerns that the video image may be misconstrued as a guarantee of the success of the surgical outcome are usually resolved by adding phrases such as "Treatment Simulation Only."[14,18] In addition to this, the patient is asked to sign a waiver acknowledging that the video image prediction is only an approximation of how he or she could look after treatment. Furthermore, it has been shown that decisions to undergo surgery have not been directly attributed to video imaging sessions,[12,17] thus allaying fears that this type of patient education may unfairly influence patients' treatment decisions.

Although the overall perception of video images was acceptable, the lower lip prediction was clearly inaccurate. Despite numerous previous studies done, there are still no acceptable soft-to-hard-tissue ratios for lower lip changes. It is recommended that future research concentrate on understanding the lower lip movements as they relate to hard tissue changes. Presurgical lower lip position (whether it is trapped under or over the maxillary incisor), lip thickness, and race may be studied as factors that may influence the resultant lower lip position after surgery. Various soft-to-hard-tissue algorithms may be created for certain situations (e.g., thick as opposed to thin lower lips), thus leading to more predictable postsurgical outcomes.

The importance of clear, reproducible records in any video imaging session cannot be overemphasized. Good quality photographs and cephalometric radiographs taken within the same time period using the same camera/cephalometer-to-subject distance are imperative in generating accurate images. Patient position must be repeatable with lips in repose and jaws in centric relation. It must be remembered that the predicted images can only be as good as the original photographs and the radiographs (or tracings) that they are based upon.

Mastery of any program is crucial to any practitioner who plans to use video images as part of his or her practice. Digitizing and duplicating curves is an art in itself. It requires a patient and determined professional who is willing to constantly improve his or her computer skills. A thorough understanding of both the orthodontic and surgical procedures is also necessary, as this is vital in instructing the computer program to make the required changes to the dentition, bony structures, and soft tissues.

New programs are continually being created and old ones upgraded as technology keeps up with the professionals', as well as the patients', demands. However, as shown in this study, the computer can only do so much. Total reliance upon the computer's ability to consistently produce accurate treatment results and appraisals must never be allowed. The computer is, after all, only a machine, and if there is any fundamental key to success in video imaging, it must be found in the professional who controls the keys and manipulates the machine to do his or her will.

Conclusions

1. Both Orthognathic Treatment Planner and Prescription Portrait were equally accurate in producing cephalometric line drawing and video image predictions of facial profiles following mandibular advancement surgery. However, in the vertical axis, Portrait's line drawings were consistently more accurate by 0.2 mm than Orthognathic Treatment Planner's predictions ($p < 0.05$) for all areas of the soft tissue profile.

2. The upper lip and chin regions were the areas most accurately predicted by the cephalometric line drawings, with less than 10% of cases in both programs showing errors over 2.0 mm. However, the lower lip area appeared to be the least predictable, with more than 20% of all cases in both programs showing errors over 2.0 mm.

3. Overall, the video images received subjective ratings that were between fair and good. The predicted upper lip and submental areas were perceived to be most similar to the actual postsurgical result, while the predicted lower lip and labiomental fold regions were deemed to be the least accurate.

4. Orthodontists and oral and maxillofacial surgeons assessed all aspects of the video images similarly. Lay people were more critical of the chin and submental regions than the professionals but were the least discriminating when making overall comparisons.

5. It is recommended that a greater understanding of the nature of the lower lip and its response to changes of the underlying hard tissue be attained. The need for accurate soft-to-hard-tissue ratios is imperative to improve the accuracy of video imaging in predicting soft tissue profiles following orthognathic surgery.

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