Sensory Retraining After Orthognathic Surgery: Effect on Patients' Perception of Altered Sensation

Ceib Phillips, MPH, PhD, Greg Essick, DDS, PhD,†*
John S. Preisser, PhD,‡ Timothy A. Turvey, DDS,§
Myron Tucker, DDS,¶ and Dongming Lin, DDS‖

Purpose: The primary research hypothesis was that the magnitude and duration of the perceived burden from altered sensation reported by patients after bilateral sagittal split osteotomy and trauma to the third division of the trigeminal nerve are decreased when facial sensory retraining exercises are performed in conjunction with standard opening exercises as compared with standard opening exercises alone.

Subjects and Methods: A total of 186 subjects were enrolled in a multicenter, double-blind, 2 parallel group–stratified block randomized clinical trial. Oral and facial pain, unusual sensations, numbness, and loss of sensitivity were scored from "no problem" to "serious problem" before surgery and 1 month, 3 months, and 6 months after surgery. A proportional odds model for the ordered multinomial response was used to compare the responses of the 2 exercise groups.

Results: The 2 exercise groups did not differ significantly at any postsurgical time in terms of perceived problem level from intraoral of facial pain. The difference between the 2 groups at each visit was not statistically significant for unusual sensations, although the trend was for the sensory retraining group to have a higher likelihood of reporting fewer problems. By 6 months, the likelihood of a subject reporting lower problem or interference level related to numbness or decreased lip sensitivity was significantly higher in the sensory-retraining group, approximately twice that of the opening exercise-only group.

Conclusions: Our results support the premise that a simple noninvasive exercise program initiated shortly after orthognathic surgery can lessen the objectionable impression of negative altered sensations.

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Although exact numbers are not available, likely more than 1 million people in the United States suffer from altered facial sensation in a given year. More than 50% of mandibular fractures between the mental foramen and sigmoid notch,[1,2] 38% of posterior mandibular implant placements,[3] 1 in 750,000 mandibular nerve blocks,[4] and 0.5% to 4% of third molar extractions[5] result in long-term facial sensory impairment. Virtually all patients experience at least temporary neurosensory impairment after orthognathic surgery for correction of developmental dentoskeletal disharmonies,[6] and more than 50% may never recover normal orofacial sensory function.[7]

Pharmacological, psychological, and surgical treatments have been evaluated as approaches to promote recovery from altered facial sensation[8,9]; however, little systematic evidence exists on the success of simpler and less intrusive therapies, such as sensory retraining. Sensory retraining or sensory reeducation has been used, with documented clinical success, in patients with injured hand nerves since the 1960s.[10-15] Anecdotally, the use of sensory retraining

*Professor, Department of Orthodontics, University of North Carolina, Chapel Hill, NC.

†Professor, Department of Prosthodontics, University of North Carolina, Chapel Hill, NC.

‡Research Associate Professor, Department of Biostatistics, School of Public Health, University of North Carolina, Chapel Hill, NC.

§Professor, Department of Oral and Maxillofacial Surgery, University of North Carolina, Chapel Hill, NC.

¶Private Practice, Charlotte, NC.

‖MPH Candidate, Department of Biostatistics, University of North Carolina, Chapel Hill, NC.

Address correspondence and reprint requests to Dr Phillips: Department of Orthodontics, CB 7450, University of North Carolina, Chapel Hill, NC 27599; e-mail: ceib_phillips@dentistry.unc.edu

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has been reported in patients with trigeminal nerve injuries.[16,17] The aim of this physical/behavioral therapy is to improve the patient's ability to interpret the altered sensory response from injured sensory nerves and to improve his or her perception of function.

Laboratory and animal research has shown that sensory training enhances central nervous system reorganization, particularly that of the somatosensory cortex.[18-20] The reorganization and changes in the response properties of individual cortical neurons strongly suggest that altered sensory signals are better interpreted and translated into functionally meaningful motor functions. If the clinical findings from the hand surgery literature applied to the trigeminal region as well, then sensory retraining would be expected to help patients with altered oral-facial sensation after nerve injury by *1*) improving the ability to interpret lip/chin sensations and movements, *2*) improving perioral motor function subjectively and objectively, and *3*) decreasing the objectionable impression of numb/paresthetic sensations in the lip and chin.

Candidates for orthognathic surgery constitute an ideal subject group for the investigation of novel putative therapies such as sensory retraining for at least 2 reasons. First, baseline data can be obtained before altered sensation develops (ie, presurgically), and subsequently these baseline responses can be compared with those obtained during the severe loss in sensation that often occurs immediately after surgery and with responses obtained over longer periods during the recovery process. Second, the surgery is elective, and the patients are typically healthy young adults without complicated medical and psychological histories, complications that would make detection of a therapeutic effect more difficult. To evaluate these possibilities, we conducted a multicenter, double-blind, parallel 2-arm–stratified block randomized clinical trial.

The intent was to assess whether the magnitude and duration of patient-reported burden from altered sensation are decreased when facial sensory retraining exercises are performed in conjunction with standard opening exercises compared with opening exercises performed alone.

The analyses presented in this article focus strictly on "burden" as defined by patients' reports of objectionable impressions of numb or unusual sensations, including pain, in the facial, perioral, and oral regions. Subsequent work will address patient-reported burden due to altered orofacial function (eg, perceived difficulty with speaking or drooling) and burden due to nerve injury–associated alterations in threshold measures of sensory function (eg, altered touch detection and 2-point discrimination thresholds).

Patients and Methods

PATIENTS

Subjects were screened at a university-based clinic and a community-based practice. Written consent/assent (and parental permission if the subject was younger than 18) was obtained in accordance with the policies of the Biomedical Institutional Review Board. A Health Insurance Portability and Accountability Act (HIPAA) authorization was obtained for the use of protected health information.

Subjects age 13 to 50 scheduled to undergo a bilateral sagittal split osteotomy either alone or in combination with a maxillary procedure for treating a developmental dentofacial disharmony were enrolled. Genioplasty was permitted, but implant surgery to the chin was not. Subjects were excluded if they had a congenital anomaly or acute trauma, had undergone previous facial surgery, were pregnant, reported moderate to severe numbness or unusual feeling on the face before surgery (added in September 2002), had a medical condition associated with systemic neuropathy (eg, diabetes, hypertension, kidney problems), or were unable to follow written English instructions or unwilling to sign an informed consent form. The eligibility of subjects who at baseline self-reported on the SCL-90-R indications of homicidality or suicidality (a score of 2 on either item) was determined after consultation with a licensed mental health professional.

ENROLLMENT

Enrollment began in December 2001 and closed on April 1, 2005. A total of 191 subjects gave consent. Five subjects were not included in the intent-to-treat analysis: 3 who had not undergone surgery by the closing date, 1 who withdrew after baseline data collection, and 1 with an unreported medical condition (meeting exclusion criteria) who withdrew after the first level of the exercise program. The number of subjects enrolled at each of the 2 centers was approximately equal (Table 1).

RANDOMIZATION

Subjects were randomized to 1 of the 2 exercise programs using a stratified block randomization. The stratification factors for randomization were the center, the surgical procedure (mandibular only vs 2-jaw osteotomy), and the addition of genioplasty (yes vs no). These stratification factors were selected based on previous studies indicating that the rate of sensory recovery is affected by the type of surgery performed and the number of procedures performed in the same area.[21-23] Stratification was performed for the purpose of balancing the assignment of the 2 exercise groups within these characteristics at each enrollment cen-

Table 1. DEMOGRAPHIC AND SURGICAL CHARACTERISTICS FOR THE ENTIRE SAMPLE AND FOR SUBJECTS RANDOMIZED TO EACH EXERCISE GROUP

	All Subjects	Sensory Retraining Plus Opening Exercises	Opening Exercises Only	*P* Value
Age, years				
Mean	25.1	24.6	25.5	.61
Standard deviation	11.8	12.1	11.5	
% Female	71	72	70	.82
% Caucasian	94	95	93	.58
% Mandible only	61	62	61	.91
% Genioplasty	29	29	29	.93
% Center 1	49.5	48.9	50	.88

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ter. Separate randomization schedules were constructed for each center using randomly alternating, permuted blocks of 4 and 8, ensuring approximately equal numbers of sensory-retraining and opening-only exercise assignments at each center. The block size was randomly selected to prohibit determination of the next likely assignment. The randomization schedule was prepared using Proc Plan[24] for each of the 8 strata (2 centers × 2 surgical procedures × 2 genioplasty additions).

The randomization schedule was maintained by the coordinator at each center, who also acted as the exercise trainer. The assignment labels were kept in envelopes in numerical sequence separately by stratum. A subject was assigned to an exercise group based on the next sequential treatment assignment number from the appropriate stratum envelope, and the assignment was recorded in a patient assignment log. The assignment number, but not the exercise group, was recorded in the subject's casebook.

MISCLASSIFICATIONS

Twelve subjects were incorrectly randomized. In the original protocol, the classification of the surgery procedure was determined from the surgical treatment plan. When it was noted that the actual surgery performed did not always agree with the surgical treatment plan, the protocol was amended so the classification was determined from operative notes detailing the actual surgery performed. For all analyses, however, subjects were categorized according to the surgical procedure used for randomization purposes (intent to treat).

EXERCISE PROGRAMS AND TRAINING

Three time-dependent levels of instruction for the sensory-retraining and opening-only exercise programs were given during training sessions at 1 week, 1 month (actually, 4 to 6 weeks), and 3 months after surgery. The time points were selected based on their use in clinical studies of the impact of sensory reeducation in patients with median or ulnar nerve injury[11] and in clinical studies of sensory impairment in patients after orthognathic surgery.[25-28] The exercises were started early after surgery—1 week, when the affected area was often insensate—to obtain the maximum affect of sensory retraining.[29] The 3 levels of sensory retraining were designed to increasingly challenge patients in a manner similar to that of the early and late phases of sensory education commonly used after injuries to nerves of the hand.[12,14,15,30] Patients learned to discriminate among nonmoving touch, orientation of moving touch, and direction of moving touch in turn. The opening-only exercise program was based on current clinical practice at our institution. A synopsis of the instructions given at each session is provided in Table 2. Each subject viewed a video tape explaining and demonstrating the exercises appropriate for that session. The exercise trainer answered any questions and verified that the subject could perform the exercises.

Before each exercise session, the trainer consulted with the attending surgeon regarding any instructions for removal of elastics and contraindications to the exercises. As a result, the exercise program was not implemented according to protocol for 11 subjects (6%); 10 were not permitted to start the exercise program at 1 week postsurgery for clinical reasons, and 1 had the exercise program delayed or interrupted. Six of these subjects had been assigned to the sensory-retraining exercise group, and the other 5 had been assigned to the opening-only exercise group. No serious adverse events were noted.

OUTCOME MEASURES

Before surgery and at 1 month (4 to 6 weeks), 3 months, and 6 months after surgery, the subjects were appointed for data collection visits. Two subject perception questionnaires were completed at each visit: Postsurgical Perceptions (PSP) and Problems with Facial Sensation (PFS).[31] A subject's responses to the items on the PSP reflected the level of interfer-

Table 2. SYNOPSIS OF THE INSTRUCTIONS GIVEN TO THE OPENING-ONLY EXERCISE GROUP AND THE SENSORY-RETRAINING GROUP AT EACH OF THE 3 TRAINING SESSIONS

Visit	Opening Exercises (3 times/day)	Sensory Retraining Exercises (2 times/day)
1 week	Simple open/close and side/side using jaw muscles only. Movement until discomfort only occurs, not until pain occurs. "Hold and relax."	Alternate simple touch and stroke with cosmetic brush (motion training). Feedback from mirror. Visualization with eyes closed.
1 month	"Hold and relax." "Finger stretch" for simple open/close. Movement until discomfort only occurs, not until pain occurs.	Alternate up/down and side/side strokes (orientation training). Feedback from mirror. Visualization with eyes closed.
3 months	If opening is ≥35 mm, repeat exercises occasionally. If opening is <35 mm, increase the frequency of exercises.	Alternate up→down and down→up strokes (directionality training). Feedback from mirror. Visualization with eyes closed.

Subjects in the sensory-retraining group were also instructed to perform the opening exercises.

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ence of postsurgery sensory alteration on daily routine, health, and quality of life. Responses to the items on the PFS reflected the level of interference with different aspects of orofacial sensation and function. On both questionnaires, the subject rated the individual items on a scale of 1 ("no problem") to 7 ("serious problem"). The subject was instructed to report the magnitude of the problem during the preceding 2 weeks.

Based on the literature, 5 items (Table 3) were theorized to be linked to the hypothesized effect of sensory retraining. These items assessed the subject's perception of difficulty with pain inside the mouth (mouth pain), pain in facial areas (face pain), unusual feelings in the face or mouth (unusual feelings), numbness in facial areas or around the mouth (numbness), and loss of sensitivity in the lips to touch, such as when using a straw or kissing (less lip sensitivity). A *visit burden score* for altered sensation was calculated as the average of the responses to the 5 items.

Three subjects did not complete data collection at 3 months, and 3 subjects did not complete data collection at 6 months. Missing values were assigned the score of the nearest preceding data collection visit with a recorded value (last observation carried forward).

MASKING

The attending surgeon and the research associate responsible for data collection were masked to the exercise group assignment throughout the entire clinical trial. The statistician was masked to the subjects' assignments until all subjects had completed the 6-month data collection visit.

SAMPLE SIZE DETERMINATION

Initial sample size calculations were performed based on variability estimates from a previous study using the PSP and PFS. The 2-group repeated-measures analysis of variance with the Greenhouse-Geisser correction, computed using methods of Muller and Barton[32] in Nquery, version 4,[33] was used.

Because the primary interest was in comparing the effect of exercise group on the burden scores summed across visits, a sample size of 85 was chosen to provide 90% power with 0.05 2-sided significance to detect a marginal mean difference between the

Table 3. FIVE ITEMS SELECTED FROM THE PATIENT PERCEPTION QUESTIONNAIRES FOR EVALUATION OF PERCEIVED PROBLEMS WITH ALTERED SENSATION

Instructions: Doctors need to know when patients have problems after orthognathic surgery. Listed below are problems that some patients have mentioned as being a concern after orthognathic surgery. Choose the response which best describes how much of a problem in each area you have experienced in the past 2 weeks.

1. Pain inside the mouth (mouth pain)
2. Pain in facial areas (face pain)
3. Unusual feelings in the face or mouth (unusual feelings)
4. Numbness in the facial area or around the mouth (numbness)
5. Lips feeling less sensitive to touch when, for example, using a straw or kissing (less lip sensitivity)

Rate each item on a scale of 1 (no problem) to 7 (serious problem).

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exercise groups with a moderate effect size of 0.4.[34] Assuming a 2-year retention rate of 70%, the target sample size per group was set at 122, for a total of 244.

An interim descriptive analysis of unmasked data from the clinical trial confirmed that the initial estimates of standard deviations and correlational pattern were reasonably accurate and the proposed effective sample size of 85 per group was appropriate. Because by January 2005, only 1 subject had withdrawn from the study and the intermittent missing visit rate did not exceed 5% for any visit, the Data Safety and Monitoring Board approved a change in the proposed retention rate to 90% and a decrease in the target recruitment goal to 180 participants.

STATISTICAL ANALYSIS

A *cumulative burden score* was calculated as the sum of the visit-specific burden scores at 1 month, 3 months, and 6 months to serve as the subject-based overall outcome measure. By placing equal emphasis on the 3 time points, the measure represented the total burden of altered sensation reported by each subject during the first 6 months after orthognathic surgery.

The cumulative burden scores from the 2 exercise groups were compared using nonparametric analysis of covariance for sets of 2-way tables.[35] The presurgery (baseline) data served as the covariate, giving results that statistically adjust for different baseline values of burden among subjects. Stratification factors (number of jaws operated on and presence of genioplasty) also were included. Details of the procedure are provided in the Appendix. The level of significance was set at .05.

Although succinct, the cumulative burden score may not be sufficiently sensitive to detect differences between the 2 exercise groups regarding the impact of altered sensation on patients' quality of life. Consideration of only the cumulative or the visit-specific burden scores may mask differences between the 2 exercise groups in recovery that occur for some but not all of the 5 items. It is also possible that group differences on 2 or more items could be reversed in sign, yielding the same cumulative or visit-specific burden scores.

For this reason, a secondary repeated-measures analysis was performed for each of the 5 items using a proportional odds model for the ordered multinomial response fit, with generalized estimating equations implemented with an across-time working independence correlation structure.[35-37] Each model included the stratification factors (number of jaws operated on and presence of genioplasty), visit (1 month, 3 months, and 6 months), the visit-by-exercise group interaction, as well as the primary explanatory variable, exercise group. Details of the procedure are provided in the Appendix. The stratification factors were maintained in all analyses as design features even though neither the number of jaws operated on nor the presence of genioplasty was significantly related to the perception of problems (see the appendix). The level of significance was set at .05.

Results

A total of 186 subjects gave consent for the Sensory Retraining Clinical Trial, were randomized to exercise programs (sensory retraining exercises in conjunction with standard opening exercises or standard opening exercises only), and completed the first exercise training session. The demographic characteristics of the subjects for the entire sample as well as a comparison of the demographic characteristics of the 2 exercise groups as randomized are presented in Table 1. As expected, based on randomization, the percentages for each of the stratification factors were very similar for the 2 exercise groups. The 2 groups were also similar in terms of average age and percentages of females and Caucasians.

CUMULATIVE BURDEN SCORE

The cumulative burden score was not significantly different ($P = .43$) between the 2 exercise groups (Table 4). However, the recovery trend over the 6-month period differed substantially for the 5 items (Figs 1-5).

INTRAORAL AND FACIAL PAIN

The subjects' perception of problems in everyday life related to intraoral and facial pain decreased rapidly. By 3 months, 75% of all subjects reported no problem or interference related to pain inside the mouth (Table 5; Fig 1), and by 6 months, more than 75% reported no problem or interference related to pain in facial areas (Table 5; Fig 2). The proportional odds model incorporating the time-by-exercise group interaction indicated no statistically significant difference in the problem level from mouth pain or face pain between the 2 exercise groups at any time (see the appendix for P values for the repeated-measures proportional odds models).

UNUSUAL FEELINGS

In contrast to pain, approximately half of the subjects continued to report at least mild interference in everyday life related to unusual feelings on the face or in the mouth at 6 months postsurgery (Table 5; Fig 3). The distributions of responses were slightly higher at 1 month and slightly lower at 3 and 6 months in the sensory-retraining group. At 6 months, 52% of the opening-only group and 58% of the sensory-retraining

Table 4. THE 25TH, 50TH, AND 75TH PERCENTILES FOR THE PRESURGERY (BASELINE) AND CUMULATIVE POSTSURGERY BURDEN FROM ALTERED SENSATION BY EXERCISE GROUP

	Presurgery			Cumulative Postsurgery		
Exercise Group	25th	Median	75th	25th	Median	75th
Opening only	1.0	1.0	1.6	5.0	7.5	9.4
Sensory retraining	1.0	1.0	1.4	5.2	6.4	8.7

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group reported no problem related to unusual feelings. Although the time-by-exercise group interaction was statistically significant (see the Appendix), the difference between the 2 groups at each visit time was not statistically significant (Table 6; Fig 3).

NUMBNESS AND LESS LIP SENSITIVITY

More than two thirds of all subjects reported problems or interference in everyday life related to numbness in facial areas or around the mouth at 6 months postsurgery (Table 5; Fig 4), and approximately half of the subjects continued to report problems related to loss of sensitivity in the lips (Table 5; Fig 5). For the 2 items that specifically target negative symptoms of altered sensation, the reported median problem level was slightly higher in the sensory-retraining group at 1 month, but lower at 6 months. At 6 months, only 22% of the subjects in the opening-only exercise group reported no problem or interference in everyday life related to numbness, whereas 37% of the subjects in the sensory-retraining group reported no problem (Table 5). A similar difference between groups was observed for loss of sensitivity in the lips (38% vs 57%). The proportional odds model indicated a statistically significant time-by-exercise group interaction for these negative symptom items (see the Appendix). The 2 exercise groups did not differ statistically at the 1-month and 3-month visits; however, by 6 months, the likelihood of a subject reporting lower problem or interference levels related to numbness or less lip sensitivity was significantly higher in the sensory-retraining group (Table 6). The odds of reporting lower problem levels or less interference in the sensory retraining group were approximately twice that in the opening-only exercise group.

Discussion

The sensory branches of the trigeminal nerve carry information about facial movements, pressures, and expressions to those areas of the cerebral cortex that underlie recognition and discrimination of skin stimuli and determine "how the face feels" (ie, facial sensibility). Damage to the nerve by any means negatively affects the quality of facial sensibility as well as the patient's ability to translate altered and impoverished patterns of nerve activity into functionally meaningful motor behaviors.[38-42] After healing of damaged tissues, residual altered sensation is predominately associated with nerve injury and resulting changes within the central nervous system.

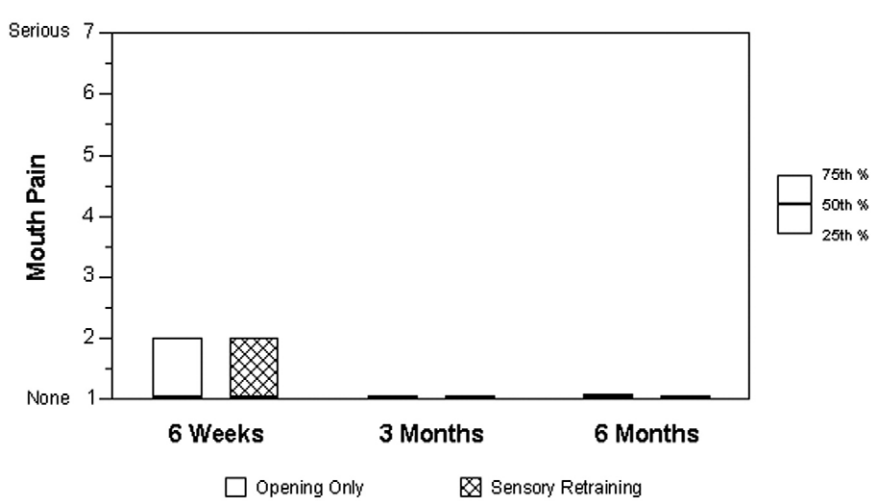

FIGURE 1. Descriptive statistics comparing the sensory-retraining and opening-only exercise groups for the problem or interference level associated with pain inside the mouth over the 6-month postsurgical period.

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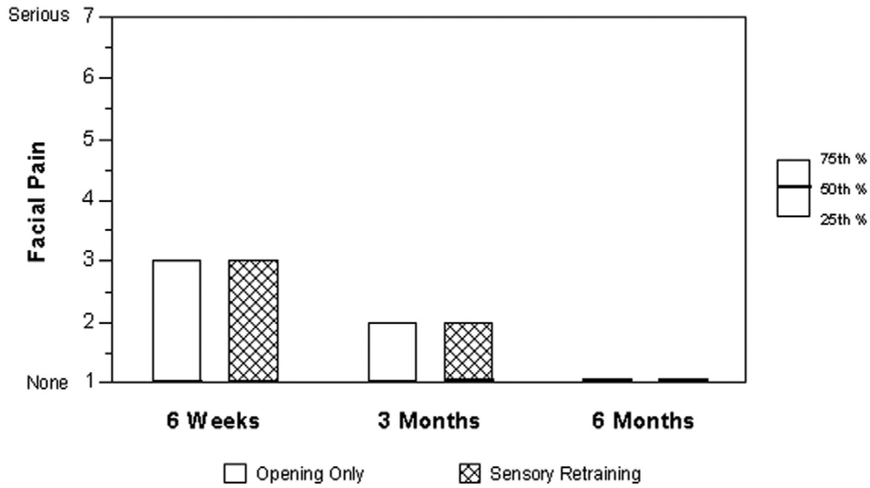

FIGURE 2. Descriptive statistics comparing the sensory-retraining and opening-only exercise groups for the problem or interference level associated with pain on the face over the 6-month postsurgical period.

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The emphasis of the present study differs notably from that of previous studies on sensory retraining of the hand after injuries to the median and/or ulnar nerve. With few exceptions, hand studies have concentrated on the return of functional sensation defined by subjects' ability to manipulate and identify small objects and to use the hands in skilled purposeful manners.[10-15,43] Subjects' ability to discriminate 2 points of contact from 1 point of contact, particularly for moving stimuli (ie, the moving 2-point discrimination threshold), is often measured, because it correlates most highly with the ability to use the hand in a dexterous manner.[44,45] Overall, sensory recovery is scored by objective testing using a modified Medical Research Council Scale ranging from no recovery (S0) to complete recovery (S4).[17,30] Although this scale incorporates the presence of hyperesthesia or overresponsiveness to tactile stimuli, it does not include subjects' subjective reports or assessment of the burden imposed by the altered sensation.

Only rarely have subjects' subjective reports been considered of primary interest when evaluating the effectiveness of sensory-retraining protocols implemented for injuries of the hand nerves.[43] The present emphasis on subject-reported burden of altered sensation on daily life was motivated in large part by recognition of the different functions of the facial and digital sensory innervation. The terminal distribution of the inferior alveolar nerve (ie, the mental nerve) innervates skin functionally more akin to that inner-

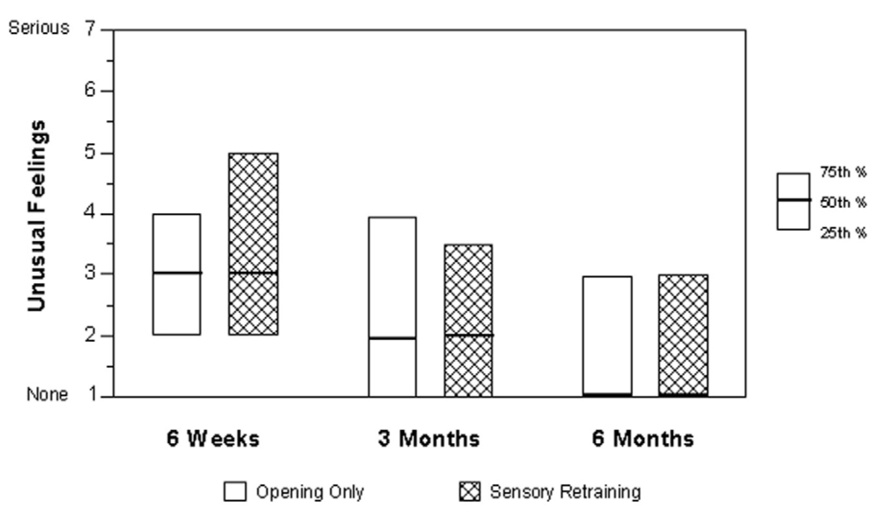

FIGURE 3. Descriptive statistics comparing the sensory-retraining and opening-only exercise groups for the problem or interference level associated with "unusual feelings" over the 6-month postsurgical period.

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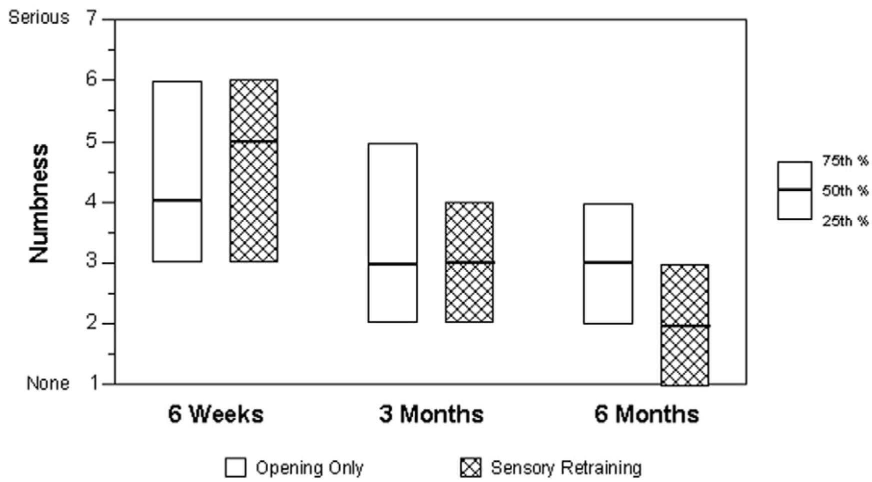

FIGURE 4. Descriptive statistics comparing the sensory-retraining and opening-only exercise groups for the problem or interference level associated with numbness over the 6-month postsurgical period.

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vated by the radial nerve than by the median and ulnar nerves of the hand.[46] Both the skin of the back of the hand and of the hairy lower lip/chin deform in response to movements during function, and as such, the evoked neural discharge serves a proprioceptive role as well as providing conscious awareness of these affectively important areas of the body.[47,48] In humans, neither the back of the hand nor the face assumes explorative and manipulative roles, in contrast to the fingertips and palmar surfaces of the hands. Since initiation of the present clinical trial, others have suggested that the goals of orofacial sensory reeducation should include decreased hyperesthesia and decreased subjective differences in, say, numbness, between affected and unaffected skin areas.[17] These goals have been perhaps best stated by Callahan: "If sensory re-education results in a person's increased ability. . .or to better enjoy the tactile sensations of everyday living, then re-education has been meaningful and successful."[15]

CUMULATIVE BURDEN SCORE

In previous work, we found that difficulty in everyday life imposed by altered sensation was related to the quality of the alteration. For example, unusual feelings were more problematic for subjects reporting dysesthetic sensations than for those reporting paresthetic sensations. Paresthetic sensations, in turn, were more problematic than simpler losses in sensation or numbness.[49] It was thought that patients who experience positive (dysesthetic or paresthetic) sensations after healing of the tissues might have a heightened

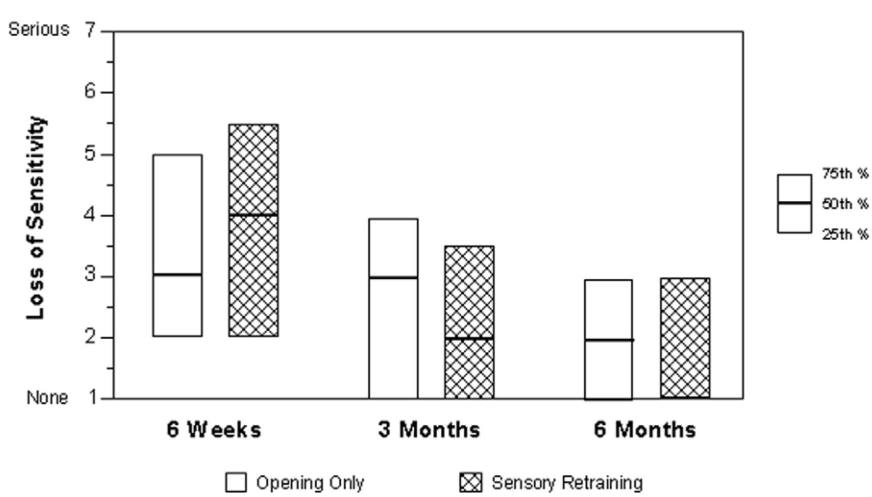

FIGURE 5. Descriptive statistics comparing the sensory-retraining and opening-only exercise groups for the problem or interference level associated with less lip sensitivity over the 6-month postsurgical period.

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Table 5. PERCENTAGE OF SUBJECTS REPORTING NO (SCORE 1), LITTLE TO SOMEWHAT (SCORE 2 TO 4), OR MODERATE TO SEVERE (SCORE 5 TO 7) DIFFICULTY OR PROBLEM LEVEL WITH ALTERED SENSATIONS OR PAIN EXPERIENCED IN THE PRECEDING 2 WEEKS

	1 Month						3 Months						6 Months					
	No		L/S		M/S		No		L/S		M/S		No		L/S		M/S	
PAS Item	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
Mouth pain	60	57	35	36	5	8	79	80	17	16	4	4	88	78	9	21	3	1
Facial pain	51	53	42	38	7	9	68	74	27	22	5	3	79	82	18	15	2	2
Unusual feelings	22	16	55	53	22	30	30	43	58	47	12	10	51	57	47	37	2	6
Numbness	6	4	46	42	48	53	12	19	63	62	25	19	23	36	68	51	9	13
Less lip sensitivity	21	21	48	46	31	34	33	39	49	46	18	16	38	56	55	34	7	10

Abbreviations: L/S, little to somewhat; M/S, moderate to severe; O, opening-only exercise group; S, sensory-retraining exercise group.

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awareness of abnormal and intrusive sensation on the lower lip and chin, eroding their quality of life more severely than simple loss of sensation from the lower face. The cumulative burden score of the present study was constructed to include the subject's perceived difficulty with dysesthetic (painful), paresthetic, and hypoesthetic sensations. However, the recovery trend over the 6-month period differed substantially for the 5 questionnaire items, and the reported difficulty with positive (painful) versus negative (numb) altered sensations was affected very differently by sensory retraining, indicating that the cumulative burden score was not sufficiently discriminating (Figs 1-5).

MOUTH AND FACE PAIN

The present study found no evidence that sensory retraining decreased the unfavorable impact of painful altered sensations on the face or in the mouth (Figs 1, 2). This is likely related to the low proportion of subjects (~30%) who reported any problem related to pain as early as 3 months postoperatively and the relatively low incidence of neuropathic complications after orthognathic surgery.[50] In addition, studies of sensory retraining after injuries to the hand nerves do not report alterations in pain per se, because subjects who are in pain are generally not candidates for sensory retraining.[51] The skin stimulation required for sensory retraining may be prohibitive in subjects with unpleasant hypersensitivities to touch (eg, allodynia, hyperalgesia, hyperpathia).[16,17,51] Behavioral desensitization, pharmacologic therapies, physical therapies, or transcutaneous nerve stimulation may be required before these subjects will accept or comply with sensory retraining protocols. On the other hand, some forms of vibrotactile stimulation used in sensory retraining also may be used to "desensitize" the skin[15]; such desensitization is often viewed as part of sensory retraining.[15,17,30,43] Sensory retraining teaches the subject to ignore or blot out the new, postinjury unpleasant sensations to optimally tune into and decipher the weakened and damaged signals from the tissues.

UNUSUAL FEELINGS

Sensory retraining tended to decrease the unfavorable impact of unusual feeling. However, the difference between the 2 groups was not statistically significant at any given postsurgery visit (Table 6). It may be that "unusual feelings" was too broad in context to allow clear differentiation between the 2 groups, because dysesthetic, paresthetic and hypoesthetic sensations all can be construed as unusual. The burden that these sensations impose on subjects' daily life varies with the qualitative nature of the sensations,[49] and the qualitatively different sensations are differen-

Table 6. CUMULATIVE ODDS RATIO ESTIMATES AND 95% CONFIDENCE INTERVALS FOR COMPARISON OF THE 2 EXERCISE GROUPS AT EACH OF THE 3 POSTOPERATIVE VISITS

	Unusual Feelings		Numbness		Less Lip Sensitivity	
	OR (SE)	95% CI	OR (SE)	95% CI	OR (SE)	95% CI
1 Month	0.67 (0.17)	0.40, 1.11	0.95 (0.25)	0.57, 1.58	0.87 (0.23)	0.52, 1.45
3 Months	1.58 (0.42)	0.93, 2.66	1.50 (0.39)	0.90, 2.50	1.54 (0.41)	0.91, 2.59
6 Months	1.20 (0.33)	0.69, 2.07	1.92 (0.51)	1.14, 3.25	1.83 (0.50)	1.07, 3.13

Abbreviations: CI, confidence interval; OR, odds ratio; SE, standard error.

The ORs indicate the odds of subjects in the sensory-retraining group reporting lower problem levels related to the altered sensation and pain items than those in the opening-only exercise group.

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tially responsive to sensory retraining. Although the current study did not question subjects specifically about paresthesias, a positive benefit of sensory retraining in reducing paresthesias on the hand has been demonstrated previously. Imai et al[43] studied subjects with median nerve injuries (clean cut and repaired), about half of whom received sensory reeducation. Although subjects in both groups reported paresthesias, the sensory-retrained group reported less interference with daily life.

NUMBNESS AND LESS LIP SENSITIVITY

Sensory retraining significantly decreased the unfavorable impact of hypoesthetic altered sensations and negative symptoms on the face and lips that can be attributed to loss of innervation (Figs 4, 5). As noted previously, more than two thirds of all subjects reported difficulty or problems related to numbness at 6 months postsurgery, and approximately half of the subjects continued to report problems related to loss of lip sensitivity. The recovery trend for these 2 items suggests that sensory-retraining exercises are most effective in decreasing the perceived burden associated with hypoesthetic altered sensations. The problem levels reported by the sensory-retraining group were slightly higher at 1 month, but lower by 6 months. At 1 month, when surgically traumatized tissues were healing, sensory loss was most noticeable. Because the retraining exercises demanded greater attention to the sensory loss and its severity, a transient increase in the burden might be expected during the first months after surgery, followed by the longer-term hypothesized effect of lower burden. Overall, the results from this clinical trial support the premise that a simple, noninvasive exercise program initiated shortly after orthognathic surgery can decrease the objectionable impression of negative altered sensations.

FUTURE DIRECTIONS

The findings of this clinical trial are encouraging and support further investigations and efforts to refine sensory reeducation protocols. The subjects were recruited from a university-based practice and a community-based practice, both of which serve Standard Metropolitan Areas. The subjects were predominantly female and Caucasians. Although greater ethnic diversity would have been desirable, the enrollment reflects the demographics of the participating practices. The findings of a positive benefit from sensory retraining are limited to healthy individuals whose trauma and nerve injuries are of acute onset and known duration. Whether retraining exercises would be beneficial for subjects who have sustained trigeminal nerve injury or could be successfully used as desensitization for neuropathic pain patients is not known.

Many questions remain unanswered. Is a reduction in subject-reported burden due to a reduction in the altered sensation, a change in subjects' impression of the alteration, or both? Is there specificity to the sensory-retraining exercises; for example, are other retraining exercises, using different types of tactile stimuli, equally or more effective than those used in the clinical trial? How does the retraining effect vary with patient compliance? Can visual cues, auditory cues, and/or mental exercises be incorporated in sensory retraining to improve or speed up the effect? This simple noninvasive exercise program is a largely unexplored avenue of treatment that may help those suffering from altered facial sensations.

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Appendix

CUMULATIVE BURDEN ANALYSIS PROCEDURE

The procedure was as follows:

1. Within each stratification level, the cumulative burden scores and the presurgery scores were ranked.
2. Within each stratification level, the ranked cumulative score was regressed through a simple linear regression on the ranked covariate to produce residuals.
3. A Mantel-Haenszel stratified linear rank statistic was calculated using the SAS Proc Freq procedure, with the number of jaws operated on and addition of genioplasty as the stratification variables, the exercise group as the row variable, and the residuals as the column variables.

ITEM-SPECIFIC ANALYSIS PROCEDURE

The model for each item was fit, and empirical sandwich standard errors robust to misspecification of the correlation structure were produced using Proc Genmod (SAS/STAT). Reference cell parameterization was used with the sensory-retraining group and the 6-month visit as the reference levels. In this parameterization, the P value for the main effect of exercise group was the comparison of the 2 groups at the 6-month visit. For those items for which the time-by-exercise group interaction was statistically significant, odds ratios and their 95% confidence intervals were computed at each visit for the comparison of exercise groups. The reported cumulative odds ratios indicate the odds of subjects in the sensory-retraining group reporting lower problem levels related to the individual altered sensation and pain items than those in the opening-only exercise group.

SCORE STATISTIC *P* VALUES FOR VARIABLE-ADDED-LAST TESTS FROM INDIVIDUAL ITEM-SPECIFIC REPEATED-MEASURES ANALYSIS BASED ON PROPORTIONAL ODDS MODELS FIT WITH GENERALIZED ESTIMATING EQUATIONS

Source	Unusual feelings	Numbness	Less lip sensitivity	In mouth	On face
Exercise group	.52	.02	.03	.07	.88
No. of jaws operated	.27	.30	.06	.21	.84
Genioplasty	.07	.38	.39	.11	.055
Baseline value	.04	.29	.08	.03	.01
Visit	<.001	<.001	<.001	<.001	<.001
Exercise visit	.004	.04	.04	.24	.82