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Outcomes following temporalis tendon transfer in irradiated patients

Garrett R. Griffin, MD¹, Waleed Abuzeid, MD¹, Jeffrey Vainshtein, MD², and Jennifer C. Kim, MD¹

¹ Division of Facial Plastic and Reconstructive Surgery, Department of Otolaryngology – Head and Neck Surgery, University of Michigan Health System, Ann Arbor, Michigan

² Department of Radiation Oncology, University of Michigan Health System, Ann Arbor, Michigan

Abstract

Objective—To compare objective outcomes and complications following temporalis tendon transfer in patients with and without a history of radiation to the parotid bed.

Methods—Retrospective chart review comparing dynamic movement of the oral commissure and resting symmetry achieved in 7 irradiated (group R) and 7 non-irradiated (group N) patients after temporalis tendon transfer for unilateral facial paralysis.

Results—There were no significant differences between the two groups of patients in terms of age, additional facial reanimative procedures, or baseline lip position. Post-operatively, good resting symmetry was achieved in both groups. Mean commissure excursion was significantly inferior in the irradiated group of patients (–1.5 mm in group R vs. 2.1 mm in group N; $p < 0.05$). Two patients in the irradiated group experienced surgical site infections requiring hospital admission and eventual debridement of their tendon transfers.

Conclusion—Temporalis tendon transfer appears to produce less dynamic movement in patients that have received radiation to the parotid bed, and these patients may also be at higher risk of

Corresponding Author/Request for Reprints: Jennifer Kim, MD, Department of Otolaryngology – Head and Neck surgery, University of Michigan Health System, 1904 Taubman Center, 1500 East Medical Center Drive, SPC 5312, Ann Arbor, MI 48109, jennkim@med.umich.edu, Ph: 734-936-9178, Fax: 734-232-0810.

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AUTHOR CONTRIBUTIONS

1. Dr. Garrett Griffin wrote the majority of the primary manuscript, and takes full responsibility for data collection and analysis. He created all tables and generated Figure 1. He performed the photographic analysis, and obtained photographs and consent from half of the participants. He incorporated edits and feedback from the other authors into the final manuscript.
2. Dr. Waleed Abuzeid wrote portions of the Methods section. He generated Figures 2 and 3. He assisted in obtaining photographs and consent for photograph publication from half of the study participants.
3. Dr. Jeffrey Vainshtein obtained the radiation treatment plans depicted in Figure 2, and wrote the portions of the manuscript that dealt with radiation oncology treatment planning.
4. Dr. Jennifer Kim performed the surgeries on all of the subjects. She participated in study design, and provided final manuscript editing and approval. She also obtained photographs on many of the subjects.

postoperative infection. Temporalis tendon transfer can achieve good resting symmetry in both irradiated and non-irradiated patients.

INTRODUCTION

Facial paralysis has enormous implications impacting daily routines and quality of life. From a functional standpoint, facial paralysis results in paralytic lagophthalmos, ectropion, epiphora, ipsilateral nasal obstruction, and oral incompetence. Even more debilitating is the loss of facial symmetry and emotive expression that are so integral to daily human communication and interaction. Over the past four decades, significant progress has been made in the surgical interventions for facial paralysis, and we are now able to reliably protect the eye and reanimate the face.

Although attaining static symmetry is an improvement, the ultimate goal is to restore a mimetic smile. Dynamic facial motion requires stimulatory input to functioning musculature. Options for input include the native nerve when available, the contralateral intact facial nerve via cross-facial nerve grafts, or various ipsilateral motor nerves including the hypoglossal and masseteric nerves. However, chronic denervation leads to facial muscle atrophy. After a critical period, estimated at 18-24 months, reinnervation of these atrophic muscles will usually not result in facial movement. In the absence of functional native facial musculature, regional or free muscle transfer is required.¹

Free-muscle transfer most commonly is a two-stage procedure with initial cross-facial nerve grafting followed by microneurovascular muscle transfer once axons have reached the paralyzed side of the face. This process may take up to two years. While the results can be impressive, disadvantages to this technique include technical complexity, prolonged surgery and recovery time, potential facial nerve injury on the unaffected side, and somewhat unpredictable results even in the most experienced hands.²

Regional muscle transfer offers a viable alternative in patients that are poor candidates for free tissue transfer or who are unwilling to undergo the more protracted treatment course. The masseter and temporalis muscles have both been used in this capacity. Over the past decade, Labbe and others have published extensively on orthodromic temporalis tendon transfer (TTT) for dynamic reanimation of the oral commissure. Through careful attention to the anatomy of the tendinous insertion on the mandible and to that of the normal smile, one can achieve impressive dynamic excursion rivaling that obtained with free muscle transfer and cross-facial nerve grafting.³

Practice patterns vary, but at our institution facial paralysis is frequently due to primary or metastatic malignancy in the parotid gland. Typically, these patients receive adjuvant radiation for perineural invasion and other high-risk factors. Radiation-induced soft tissue fibrosis is a phenomenon well known to otolaryngologists caring for head and neck cancer patients. It has been our experience that patients that have received adjuvant radiation to the parotid bed prior to TTT obtain less dynamic excursion and have an increased incidence of postoperative complications.

The purpose of this study was to compare the objective outcomes achieved following temporalis tendon transfer in patients that have and have not received radiation to the parotid bed prior to facial reanimation surgery.

METHODS

This study was approved by the University of Michigan Health System Institutional Review Board. We performed a retrospective chart review of all patients that underwent TTT in the Department of Otolaryngology at the University of Michigan. The inclusion criteria were adult patients (>18 years of age) presenting with unilateral facial paralysis, who received temporalis tendon transfer, and who had at least three months of follow-up. Exclusion criteria included inadequate photographic documentation, ongoing treatment for residual or recurrent malignancy, or non-compliance with basic post-operative instructions such as wound care and administration of antibiotics. The independent variable was radiation therapy to the parotid bed prior to temporalis tendon transfer. We also collected data on age, radiation technique and dose received, additional facial reanimation surgeries, and hematoma or infection requiring return to the OR or hospital admission (Table 1). Informed written consent was obtained from each patient prior to their inclusion in this study. A separate consent for publication of photos was obtained from patients whose images appear in this publication.

The primary outcome was oral commissure movement pre- and at least three months postoperatively in irradiated and non-irradiated patients who underwent temporalis tendon transfer surgery. Commissure excursion was calculated from pre- and post-operative standardized photographs taken during neutral facial expression and closed-mouth smile. Proprietary facial metrics software (*MEEI FaceGram*, Massachusetts Eye and Ear Infirmary, Boston, MA) was used to calculate the long-diagonal or hypotenuse of movement (termed c , measured in millimeters), as well as the angle formed with the vertical (termed A , measured in degrees). This program is described elsewhere⁴, and uses the patient's irises to set a vertical midline and to calculate distances, as demonstrated in Figure 1. The value c was calculated for each side of the face and time point using the formula $c = c_{\text{smile}} - c_{\text{rest}}$. A was similarly tabulated as $A = A_{\text{smile}} - A_{\text{rest}}$. Resting symmetry was calculated as a secondary outcome by comparing the values of c and A between the intact and paralyzed sides. This was done for both pre- and post-TTT time points, and for both patient groups.

The primary and secondary between-group comparisons were performed using two-tailed t -tests in Microsoft Excel 2010 (Redmond, WA).

A brief description of our technique for temporalis tendon transfer is as follows. Under general anesthesia, an incision is made in the melolabial crease. Blunt finger dissection is performed starting at the modiolus establishing a plane between the buccinator and buccal fat until the anterior border of the masseter muscle is encountered. The masseter muscle is retracted laterally, exposing the coronoid. The temporalis tendon is left attached to the coronoid process which is then transected at the base of the mandibular notch using a reciprocating saw. A tensor fascia lata (TFL) graft is harvested from the thigh. Holes are drilled in the coronoid process and the TFL is sutured to the coronoid process with the

attached temporalis tendon with 3-0 polydioxanone (PDS) suture. Medially, the TFL graft is cut such that it is longer inferiorly and shorter superiorly. Through the melolabial incision, dissection between the subcutaneous tissues and superficial facial musculature is performed into the midline lower lip. A separate 15 mm incision is made in the midline submental crease. The TFL graft is tunneled into the lower lip and sutured to the midline orbicularis musculature through the submental incision using 3-0 PDS. The superior part of the TFL is then sutured to the facial muscles just medial to the melolabial crease using the same suture. This is done in such a manner that the temporalis muscle is on no tension at rest. The melolabial and submental incisions are closed in two layers.

Patients receive post-TTT physiotherapy from an affiliated occupational therapist.

RESULTS

The senior author (JCK) began performing TTT in October 2008 and has performed 16 cases since. At the time of writing, all patients had at least three months of post-surgical follow up. Seven patients had not received radiation to the parotid bed (group N). Nine patients had received radiation prior to TTT. Two of the patients in the radiated group are deceased from cancer with inadequate follow-up for inclusion, leaving seven patients in the radiated (R) group. All 14 patients included in this study are still alive.

Patient characteristics are summarized in Table 1. The mean age in the two groups is not different ($p = 0.84$). The type and number of additional facial reanimative procedures is similar between the two groups. There was one hematoma requiring surgical drainage in both groups. Patients R3 and R7 developed infections requiring inpatient admission, parenteral antibiotics, and eventual tensor fascia lata debridement. There were no serious infections in the non-irradiated group.

We were unable to obtain complete radiation therapy (XRT) details in all cases as many patients received this treatment at outside institutions, some greater than 10 years prior to their TTT. Patient R1 received concomitant cisplatin and three dimensional conformal radiotherapy (3D-CRT) with 70 gray (Gy) to the left tonsillar fossa and neck. Given her high-dose treatment and the proximity of the tonsil to the masticator space, she was included in the radiated group. Patient R2 received concurrent chemoradiation with 3D-CRT to the parotid bed. Patient R3 received 40 conformal, 30 Gy proton beam and 10 Gy neutron beam radiotherapy to the parotid bed for parotid malignancy. Patient R4 received 60 Gy of 3D-CRT to the left parotid bed and neck. Patient R5 completed a course of XRT for parotid malignancy, unknown technique or dose. Patient R6 received concurrent chemotherapy with 60 Gy of 3D-CRT to the parotid bed. Patient R7 received 60 Gy of 3D-CRT to the parotid bed. No patients in our study received intensity modulated radiation therapy (IMRT).

Table 2 demonstrates measurements for c and A at rest and with smile for the intact and paralyzed sides prior to TTT. The p -values calculated at the base of a column represent a two-tailed T-test comparing the means of the N and R groups. Importantly, there was no statistical difference between the two groups in c or A preoperatively on either the intact

or paralyzed sides. This suggests that prior to TTT, perioral movement in the two groups was not different.

Table 3 includes these same measurements *after* TTT. Postoperatively, there was no statistical difference in either c or A between the two groups on the normal side. However, post-TTT oral commissure movement as assessed by both c and A was statistically greater in the non-radiated group (mean c = 2.1 mm, range -1.4 to 6.6; mean A = 7.0 degrees, range 0.6 to 20.1 degrees) compared to the radiated group (mean c = -1.5 mm, range -4.3 to 1.8 mm; mean A = 0.3 degrees, range -6.1 to 5.0 degrees). Negative values for c or A essentially mean that the oral commissure moved *inferiorly* (A) or *medially* (c) with smile. This is opposite the desired movement, and can occur if the normal side overpowers the paralyzed side during smile.

The secondary outcome, “resting symmetry”, was assessed by comparing the means for c and A between the paralyzed and normal sides for both groups, both pre- and post-operatively. This yielded eight overall comparisons, summarized in Table 4. All pre-TTT comparisons in both groups revealed a statistical difference in both c and A , suggesting *asymmetry* at rest. However, c and A were not statistically different in either group post-TTT, suggesting that resting symmetry was restored post-TTT.

DISCUSSION

There are several approaches to dynamic facial reanimation, including nerve grafting, nerve substitution, or muscle substitution. Muscle substitution techniques are typically reserved for those patients with facial paralysis in whom the native facial musculature has either undergone denervation atrophy/fibrosis, or has been destroyed by trauma or tumor ablation.⁵ Both regional and free microvascular muscle substitution techniques are well-described in the literature. Despite many articles describing various methods of measuring objective outcomes following muscle transfer for facial paralysis,⁶ relatively few publications have reported objective outcomes data. Erni et al. is, to our knowledge, the only group to have directly compared commissure movement obtained after TTT versus free muscle transfer (gracilis, latissimus, or pectoralis minor). In their study, TTT produced 1.8 mm of excursion with closed-mouth smile compared with 9 mm on the healthy side. Free-muscle transfer yielded 5.5 mm excursion compared with 10 mm on the intact side. The difference in excursion between the TTT and free tissue groups was statistically significant.⁷ Unfortunately, the authors did not include the raw data, or range of excursion, produced by TTT. Byrne et al. reported a range of excursion between 1.6 and 8.5 mm (average 4.2 mm) in seven patients undergoing TTT. Patient details were not included regarding etiology of paralysis or history of radiation to the parotid bed.⁸ Labbe et al. report up to 15 mm of excursion from their lengthening temporalis myoplasty, a modification of the TTT in which the posterior temporalis muscle belly is released thereby placing the muscle at a more optimal location on its length-tension curve.³ Collectively, these studies report commissure excursion after TTT ranging from 1 to 15 mm. Differences in experience and surgical technique may play some role, but other factors contributing to this degree of variability have yet to be identified.

Based on personal observations, we hypothesized that at least some of the variability in our own results could be attributed to radiation status. Other publications describing orthodromic TTT have alluded to possibly worse outcomes in irradiated patients.⁹ We found that there was statistically less commissure movement in patients that had received radiotherapy to the parotid bed. Also, two patients in the irradiated group developed significant infections of their TFL grafts, requiring parenteral antibiotics and eventual TFL debridement. No patients in the non-irradiated group developed a significant infection.

The mechanism of this radiation-related effect is likely multi-factorial. Radiation is well-known to cause masticator fibrosis leading to trismus.¹⁰ Radiation also decreases the vascularity of tissue, making it more susceptible to infection and slower to heal. This in turn may lead to a less-efficient glide plane for the manipulated temporalis muscle and tendon to move within. Also, if the fascial extension graft is slow to revascularize in the irradiated bed, it may provide a nidus for infection. None of the irradiated patients in this study received intensity-modulated radiotherapy (IMRT), which can provide highly conformal radiotherapy dose distributions to spare important normal structures and has been shown to significantly reduce trismus in head and neck cancer patients.¹¹ It is possible that the detrimental effects of XRT seen in our study could be mitigated by the use of IMRT (Figure 2).

Resting symmetry between the two sides of the face was found to be poor pre-TTT as measured by both *c* and *A*, in both groups. However, post-TTT there was good resting symmetry with no statistical difference between the normal and paralyzed sides of the face in either group as measured by *c* and *A*. This suggests that TTT is effective at producing resting symmetry in all patients, even in those that have been irradiated.

The decision to analyze *A* deserves discussion. Change in *c* is a more direct measure of commissure movement, but we postulate that *A* is important to include as well. The strong normal facial muscles can pull the smile toward the intact side in patients with unilateral facial paralysis. When this occurs, the “triangle” of tissue that is measured on the paralyzed side gets smaller overall because there is less lip tissue on that side of the face. As a result, *c* is smaller, potentially leading to a low or negative *c* value. One could argue that the “legs” of the triangle (*a* and *b*) should be measured, but these values would be reduced for the same reason. However, if *A* increases significantly, then the oral commissure will still appear to be moving superiorly, thus fulfilling the goal of communicating a smile to an observer. The post-TTT values for patient N4 reflect this concept well (Figure 3).

This study is important because it identifies a patient factor that impacts the results of TTT. One weakness of this investigation is that no subjective patient-derived outcome questionnaire data is included. This would be interesting given that irradiated patients did achieve good resting symmetry, and may still perceive this as a significant improvement. We are currently performing a larger multi-institutional study that will include both objective measurements and subjective patient evaluation of benefit. Another potential weakness is the method by which the measurements were performed. We used frontal photographs, which permit evaluation of movement in two dimensions (*x* and *y*). However, smiling is a three-dimensional movement, particularly when generated by the temporalis muscle which has a significant vector in the anterior-posterior (*z*) plane. Other studies have attempted to solve

this problem using 3-quarter view photographs. However, such views do not allow automated, computerized measurements to be performed because the irises cannot be used as a standard measure or to set the midline. Rulers can be included in photographs in an attempt to allow post-photo measurement, but these techniques are cumbersome.¹² Furthermore, several recent publications regarding dynamic smile restoration have all used two-dimensional analysis similar to that reported in this publication.^{4,8,9} Three-dimensional cameras have recently been added to several academic facial plastic surgery departments and might allow accurate, automated three-dimensional measurements of smile in the future.

The results of this study should be taken into consideration when evaluating irradiated patients for facial reanimation. We are particularly concerned about the two significant infections that occurred in the radiated group, which may have been related to the placement of a free TFL graft in poorly vascularized environment. One straightforward alternative would be to perform TTT without an extension graft, akin to the technique originally described by Labbe. In appropriate candidates, single-stage microneurovascular free muscle transfer driven by the masseteric nerve would also be an option. Further evaluation of TTT after IMRT – which may prove to be less detrimental to functional outcomes than conventional XRT – is warranted.

CONCLUSION

Temporalis tendon transfer produces less objective commissure excursion in patients that have received radiation to the parotid bed. Both non-irradiated and irradiated patients can achieve good resting symmetry with TTT. Further studies are needed to confirm these findings and to evaluate alternatives to temporalis tendon transfer in this patient population.

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Figure 1. method of photographic analysis

Patient R7 3 months after temporalis tendon transfer. Her pupils have been manually outlined, and the computer program uses this information to drop a vertical midline. The intersection of this line with the vermiliocutaneous border of the lower lip, and the commissure, are then manually identified. This allows the program to draw and calculate values for a, b, c and angle A. Note that A measures between c and the midline below the lip; thus, “good” values are usually over 105 degrees.

Figure 2. comparison of conformal and intensity-modulated radiotherapy to the parotid bed
 Comparison of treatment planning for post-parotidectomy adjuvant radiotherapy using (a) conformal or (b) intensity-modulated techniques (IMRT). In 2a, numbers along isodose lines signify a percentage of the maximum. In 2b, IMRT isodose lines refer to the actual dose delivered to that area. Note how the masticator space receives 54 Gy (90% of 60 Gy) with traditional radiotherapy, but only 35-45 Gy using IMRT.

Figure 3. the importance of angle A

Patient N4 post-temporalis tendon transfer (TTT) at rest (a) and smiling (b). The patient is able to produce an acceptable and obvious smile post-operatively, despite a small $c = 1.6$ mm. This is due to the large $A = 20.1$ degrees.

Table 1

Patient Characteristics

Patient	Age at TTT	Duration paralysis	Reason for paralysis	Other facial reanimative surgeries	Hematoma	Major Infection
N1	81	53 yrs	unknown CPA tumor	FA, DT, LLT, SL	N	N
N2	74	10 mos	Ramsay-Hunt	BL, FA, DT, LW	N	N
N3	67	12 yrs	vest. schwannoma	FA, LLT, AC, PW, BL, DT, SL	N	N
N4	59	12 mos	vest. schwannoma	PW, LLT, LW, AC, SL, DT	N	N
N5	55	12 yrs	idiopathic	FA, SL, LLT, DT, NVS	Y	N
N6	51	5 yrs	facial schwannoma	PW, SL, LLT, AC, LW	N	N
N7	41	2 yrs	vest. schwannoma	PW, LLT, FA, AC, SL, GT	N	N
<i>Mean</i>	<i>61.1</i>					
R1	54	4 yrs	met. tonsillar scca	FNG, PW, LLT, SL, DT	N	N
R2	56	2 yrs	parotid malignancy	SL, BL	N	N
R3	50	5 yrs	parotid malignancy	SL, AC, DT, FA, LLT	N	Y
R4	72	14 mos	met. cutaneous scca	PW, DT, AC, SL, MNT	N	N
R5	66	8 mos	met. cutaneous scca	FA, SL, LLT, AC, BL, LW, DT	Y	N
R6	75	3 mos	parotid malignancy	FNG, AC, SL, DT, BL, PW	N	N
R7	64	5 yrs	parotid malignancy	SL, MNT, NVS, PW, BL, MC	N	Y
<i>Mean</i>	<i>62.4</i>					

Key: FA=facial advancement; DT=depressor transection; SL=sub-orbicularis oculi (SOOF) midface lift; LLT=lower lid tightening procedure; PW=upper lid platinum weight; LW=lower lip wedge resection; GT= free gracilis transfer (performed at another institution prior to TTT with poor result); FNG=facial nerve grafting; MNT=marginal nerve transection; NVS= nasal valve suspension; BL=direct brow lift; AC= auricular cartilage to support lower eyelid; MC=medial canthoplasty.

Table 2

Pre-TTT measurements

Patient	Normal Side				Paralyzed Side			
	At rest		With smile		At rest		With smile	
	c	A	c	A	c	A	c	A
N1	27.9	122.8	36	127.1	8.1	4.3	31.1	109.8
N2	31.7	104.0	33.6	105.5	1.9	1.5	18.0	68.9
N3	30.9	108.2	35.7	113.6	4.8	5.4	21.8	94.7
N4	32.9	103.6	35.3	105.7	2.4	2.1	18.3	88.4
N5	30.6	115.2	36.1	121.7	5.5	6.5	28.8	128.2
N6	24.8	101.3	32.6	116.0	7.8	14.7	16.8	90.1
N7	35.2	109.5	39.3	114.5	4.1	5.0	14.0	86.0
Mean	30.6	109.2	35.5	114.9	4.9	5.6	21.3	95.2
R1	24.2	105.9	31.1	117.9	6.9	12	15.8	92.1
R2	35.6	110.2	39.0	112.2	3.4	2.0	22.0	89.0
R3	31.7	95.9	40.7	103.0	9.0	7.1	21.7	80.4
R4	32.4	102.6	40.3	112.0	7.9	9.4	17.5	98.3
R5	*	*	26.2	104.0	*	*	23.1	68.2
R6	35.2	112.8	38.9	104.0	3.7	-8.8	28.7	78.2
R7	22.4	98.6	29.6	113.2	7.2	14.6	27.0	90.8
Mean	30.3	104.0	35.1	109.5	6.4	6.1	22.3	85.3
p-value					0.31	0.91	0.13	0.42

Key:

* signifies data that could not be obtained due to poor quality of preoperative photograph.

Post-TTT measurements

Table 3

		Normal Side						Paralyzed Side					
Patient		At rest		With smile				At rest		With smile			
		c	A	c	A	c	A	c	A	c	A	c	A
N1		24.6	117.6	33.6	123.3	9.0	5.7	38.5	110.5	40.3	111.9	1.8	1.4
N2		27.4	112.3	31.4	117.7	4.0	5.4	19.3	106.1	25.9	117.6	6.6	11.5
N3		26.0	104.7	30.2	109.3	4.2	4.6	31.8	106.3	30.4	106.9	-1.4	0.6
N4		27.0	96.5	35.5	114.1	8.5	17.6	28.1	96.3	29.7	116.4	1.6	20.1
N5		25.7	117.8	29.0	117.0	3.3	-0.8	29.8	115.0	36.3	120.7	6.5	5.7
N6		28.4	110.8	31.2	112.7	2.8	1.9	24.8	102.3	25.9	106.4	1.1	4.1
N7		32.3	101.6	36.7	105.1	4.4	3.5	24.5	101.0	23.1	106.3	-1.4	5.3
Mean		27.3	108.8	32.5	114.2	5.2	5.4	28.1	105.4	30.2	112.3	2.1	7.0
R1		24.8	110.5	28.4	113.1	3.6	2.6	29.4	108.8	31.2	113.6	1.8	4.8
R2		36.2	114.6	35.5	117.8	-0.7	3.2	32.6	110.3	28.3	108.5	-4.3	-1.8
R3		27.1	96.3	37.5	106.0	10.4	9.7	29.0	107.3	26.1	101.2	-2.9	-6.1
R4		31.8	95.8	34.6	103.9	2.8	8.1	19.4	96.8	16.8	98.6	-2.6	1.8
R5		25.9	91.0	26.4	95.8	0.5	4.8	25.0	95.6	25.7	100.6	0.7	5.0
R6		33.9	105.4	42.2	109.7	8.3	4.3	23.7	92.4	21.9	93.0	-1.8	0.6
R7		22.7	101.5	31.0	116.2	8.3	14.7	31.6	108.0	29.8	105.9	-1.8	-2.4
Mean		28.9	102.2	33.7	108.9	4.7	6.8	27.2	102.8	25.7	103.1	-1.5	0.3
p-value						0.82	0.63					0.03	0.04

Table 4

Resting symmetry Analysis

Group	Time-Point	Measure	Intact	Paralyzed	p
N	Pre-TTT	c	30.6	22.9	0.02
		A	109.2	96.9	0.04
	Post-TTT	c	27.3	28.1	0.76
		A	108.8	105.4	0.40
R	Pre-TTT	c	30.3	20.9	<0.01
		A	104.3	93.7	<0.01
	Post-TTT	c	28.9	27.2	0.54
		A	102.2	102.8	0.89