Author, Year Country Study Design Sample Size	Population Intervention Outcome Measure	Results
(Mulcahey et al., 1997) USA Pre-Post N=5	Outcome Measure Population: Age: 16.8±0.8 yr; Gender: males=4, females=1; Time since injury: 25.8±16.1 mo; Level of injury: C5=4, C6=1. Intervention: Implantable Functional Electrical Stimulation (FES) and tendon transfers, lengthenings, and releases of the upper extremity unique to each patient. Outcome Measures: Pinch and grasp, Grasp and Release Test (GRT), six activities of daily living (ADL): eating with a fork, drinking from a cup, placing a telephone call, writing with an ink pen, storing data on a diskette, and brushing teeth.	 Muscle Strength Three of the four adolescents who underwent the deltoid to triceps transfer gained 4/5 muscle strength in elbow extension which, in all cases, was sufficient to stabilize the elbow and expand the horizontal and vertical work areas. One subject achieved 215 elbow extension strength. Three subjects who had brachioradialis transfer gained at least 4+/5 in wrist extension strength to stabilize the wrist during stimulated finger and thumb flexion so this movement had to be limited to preserve each of the subject's ability to control their wrists; FPL split tendon transfer provided good positioning of the thumb during lateral pinch without compromising stimulated force of FPL. In three of the four subjects, intrinsic tenodesis transfer prevented MCP joint hyperextension during stimulated finger extension. The intrinsic transfer of subject 1 had minimal effect on the intrinsic minus posturing of her hand. One subject, who underwent a capsulodesis procedure, had poor stimulated finger extension because of MCP flexion deformities. Crasp and Release Test FES forces were significantly greater than tenodesis forces for lateral and palmer grasps (p=0.043). The primary difference in performance was with the heavier objects; of the four heavier objects (can, weight, tape, fork) no subject could manipulate the weight and fork, 3 subjects could manipulate the can, and 1 could move the tape. Activities of Daily Living Using the FES hand system, independence scores increased in 25 out of 30 cases as compared to baseline testing (six activities, five subjects). All baseline activities performed with PA before surgery could be achieved using the FES hand system eliminated the need to don and use AE. After system training, FES was preferred in 21 out of 30 cases; every subject preferred FES for eating, and except for one, preferred FES for writing. The one subj
		the adolescents to place a phone call and

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		17.	manipulate a diskette with multiple pieces of adaptive equipment or physical assist. For the drinking activity, three subjects had difficulty stabilizing their wrists against stimulated flexion while holding the cup and felt more confident that they would not spill the water when
			using alternative strategies.
(Smith et al., 1996) USA Pre-Post N=5* *Same study sample from (Mulcahey et al., 1994)	Population: Age: 15.8±2.6 yr; Gender: males=3, females=2; Time since injury: 29.8±33.8 mo (<1 yr=3, >4 yr=2); Level of injury: C5=2, C6=3. Intervention: Functional neuromuscular stimulation (FNS) neuroprosthesis for the upper limb; site of stimulation included fingers extensors, thumb abductors, thumb extenders, finger flexors, and thumb flexors. Outcome Measures: Grasp and Release Test (GRT).	17. FNS 1. 2. 3. 4. 5. • • • • • • • • • • • • • • • • • •	For the drinking activity, three subjects had difficulty stabilizing their wrists against stimulated flexion while holding the cup and felt more confident that they would not spill the water when using alternative strategies. Wersens Tenodesis With FNS, subjects were able to manipulate each test object in at least 1 test session with the exception of subject 4 who could never complete the tape task. With a tenodesis, all subjects were able to complete the peg task, 1 subject could not manipulate the block, 2 subjects could never complete the can task and no subject was able to pass the pretest with the weight, fork or tape. For 23 of the 30 (77%) task comparisons, performance was significantly improved with FNS. In 14 of the 15 cases involving the heaviest test objects (weight, fork, tape), tasks could only be completed with FNS. For the lighter test objects (peg, block, can), FNS was more effective in 9 of 15 cases (60%): In 3 cases (2 can, 1 block, 1 peg) there was no difference in completions but significantly more trials where there were fewer failures using FNS. In 4 cases (2 can, 1 block, 1 peg) there was no difference in completions but significantly more trials where there were fewer failures using FNS. In 2 cases (1 block, 1 peg) there were nore completions with FNS in a greater number of trials. Of the 6 remaining cases with the lighter objects, there was 1 case (can) in which there were no differences in completions or failures, occurred with a tenodesis. Lateral pinch forces ranged from 8.9 N to 22.5 N and palmar grasp forces from 2.1 N to 11.1 N; tenodesis grasp force was not measurable. Of 29 testable cases with FNS, completions were consistent across sessions in 8 instances (28 %); 6 of which involved the peg or block. The number of failures was consistent in 10 instances (34%). Tenodesis performance was consistent in 3 of the 12 (25%) instances for failures. With FNS, 5 of the 21 (24%) inconsistent cases were due to increases in completions in early sessions; in 4 of those cases, the median numb
		11.	writh tenodesis, 7 of the 9 (78%) inconsistent cases were related to improved performance, all on peg or block tasks; plateaus in performance occurred between the second and fourth session. With FNS and tenodesis, each case of improved performance in later sessions was significantly better as compared to the initial session (p<0.05).

 (Mulcahey et al., 1996) <l< th=""><th></th><th>Population: Age: 15.8±2.6 yr;</th><th>Acquire Phase</th></l<>		Population: Age: 15.8±2.6 yr;	Acquire Phase
 (Mulcahey et al., 1996) (Mulcahey et al., 1996)<		Gender: males=3, females=2;	1. Without FNS, two hands (<i>self-assist</i>) were required
 (Mulcahey et al., 1996) (Mulcahey et al., 1996)<		Time since injury: 29.8±33.8 mo	in almost all activities to acquire the objects.
 (Mulcahey et al., 1996) (Mulcahey et al., 1996)<		(<1 yr=3, >4 yr=2); Level of	2. Iwo subjects scored <i>physical assist</i> for eating and
 (Mulcahey et al., 1996) <l< td=""><td></td><td>Injury: C5=2, C6=3.</td><td>writing since they required wrist splints specifically</td></l<>		Injury: C5=2, C6=3.	writing since they required wrist splints specifically
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 (Mulcahey et al., 1996) <l< td=""><td>(FNS) neuroprosthesis for the</td><td>3. With FNS, independence increased for at least one</td></l<>		(FNS) neuroprosthesis for the	3. With FNS, independence increased for at least one
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 thumb abductors, thumb extenders, finger flexors, and thumb flexors. Outcome Measures: Common Object Test (COT) involving performance and satisfaction of five activities: eating with a fork, drinking from a cup, writing, applying toothpaste and brushing teeth; device usage survey (activity patterns in home, work, and school setting) with open-ended questions. (Mulcahey et al., 1996) (Mulcahey et		included fingers extensors,	4. Three subjects were able to use stimulation to
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 Mulcahey et al., 1996) (Mulcahey et al., 1996) <li< td=""><td></td><td>extenders, finger flexors, and</td><td>which freed the non-ENS extremity to hold or</td></li<>		extenders, finger flexors, and	which freed the non-ENS extremity to hold or
 (Mulcahey et al., 1996) (Mulcahey et al., 1996)<			stabilize the toothbrush; all three Could independently acquire the toothbrush
 Involving performance and satisfaction of five activities: eating with a fork, drinking from a cup, writing, applying toothpaste and brushing teeth; device usage survey (activity patterns in home, work, and school setting) with open-ended questions. (Mulcahey et al., 1994) (Mulcahey et al., 1996) (Mulcahey et al., 1994) (Mulcahey et al., 1994) (Mulcahey et al., 1994) (Mulcahey et al., 1994) (Mulcahey et al., 1996) (Mulcahey et al., 1996)		Common Object Test (COT)	5. The remaining two subjects acquired a pen and fork
 satisfaction of five activities: eating with a fork, drinking from a cup, writing, applying toothpaste and brushing teetri, device usage survey (activity patterns in home, work, and school setting) with open-ended questions. (Mulcahey et al., 1994) USA Dre-Post NS The activity of performing for extension (<i>physical assist</i>). Performance Phase (repetitive activity or performing for extended period of time) 8. During the hold phase in the majority of the activities without FNS, adaptive equipment or two hands (<i>self-assist</i>) were required to maintain the objects in the hand; for example, to hold a toothbrush and a pen, most subjects used a universal cuff, and two subjects required and fork (thereby not requiring stimulation) and one was able to weave his utensil through his tight fingers independently and, for each activity, lift and lower the arm without assistance (<i>independent</i>). 10. Without FNS four subjects required and independently and, for each activity, lift and lower the arm without assistance (<i>independent</i>). 11. Each subject was able to write and graps a cup independently and, for each activity, lift and lower the arm without assistance (<i>independent</i>). 12. Without FNS, role subjects in each activity, usagistic for subjects were able to use one hand (<i>independent</i>) to subject required two hands (<i>self-assist</i>) to brush both sides of their mouths; one subject used two hands (<i>self-assist</i>) to brush the contra-lateral side. Release Phase 13. Without FNS, release of bipters in each activity usaally required two hands (<i>self-assist</i>) during tenodes flexion, or the mouth (<i>self-assist</i>) during tenodes flexion, or the mouth (<i>self-assist</i>) to doff adaptive equipment. 14. One subject required a physical assistance to remove the wrist splint used specifically in the easting and writing tasks. 15. With FNS, all subjects scient of higher on the independencered. 		involving performance and	with two hands (<i>self-assist</i>), eliminating the need for
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16	16. One subject no longer needed to insert a fork in the cuff and was able to release the toothbrush and fork with one hand (<i>independent</i>).
מו	 For most subjects their quality of performing activities improved and they preferred using the FES system.
18	 Reasons for not using the system included mood (4/5), no time (3/5), no attendant (3/5), skin irritation (1/5), system complications (1/5) and illness (1/5).