Author, Year Country Study Design Sample Size	Population Intervention Outcome Measure	Results
(Mulcahey et al., 1997) USA Pre-Post N=5	**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** 1. 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. 2. One subject achieved 215 elbow extension strength. 3. Three subjects who had brachioradialis transfer gained at least 4+/5 in wrist extension strength; however, they did not have sufficient 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. 4. In three of the four subjects, intrinsic tenodesis transfer prevented MCP joint hyperextension during stimulated finger extension. 5. The intrinsic transfer of subject 1 had minimal effect on the intrinsic minus posturing of her hand. 6. One subject, who underwent a capsulodesis procedure, had poor stimulated finger extension because of MCP flexion deformities. **Grasp and Release Test** 7. FES forces were significantly greater than tenodesis forces for lateral and palmer grasps (p=0.043). 8. The primary difference in performance was with the heavier objects; of the four heavier objects (can, weight, tape, fork) no subject could manipulate them with tenodesis, but with FES all subjects could manipulate the weight and fork, 3 subjects could manipulate the can, and 1 could move the tape. **Activities of Daily Living** 9. Using the FES hand system, independence scores increased in 25 out of 30 cases as compared to baseline testing (six activities, five subjects). 10. All baseline activities performed with PA before surgery could be achieved using the FES hand system without attendant assistance. 11. In 11 out of 12 cases, the FES hand system eliminated the need to don and use AE. 12. 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. 13. The one subject who preferred writing with a splint was unable to maintain his wrist in extension against the stimulated force of the lateral pinch. 14. Satisfaction with the FES hand system came from no longer needing adaptive equipment, citing "I can press harder" (writing, brushing teeth), "it's easier" (writing, phoning, eating) and "it makes me look more normal" (writing, eating, phoning, storing data). 15. For the times FES was not preferred, the most frequently cited reason was "it's too hard" (phoning, storing data). 16. Although they were more independent as defined by the ADL test scoring, it was easier for several of the adolescents to place a phone call and

		manipulate a diskette with multiple pieces of adaptive equipment or physical assist. 17. 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).	FNS versus Tenodesis 1. 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. 2. 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. 3. For 23 of the 30 (77%) task comparisons, performance was significantly improved with FNS. 4. In 14 of the 15 cases involving the heaviest test objects (weight, fork, tape), tasks could only be completed with FNS. 5. 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) FNS was needed to complete the task; 2 of these situations involved subject 1, the only individual who lacked wrist extension. • 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 more 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 and 5 situations (3 peg, 2 block) in which more completions, but also more failures, occurred with a tenodesis. 6. 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. 7. Of 29 testable cases with FNS, completions were consistent across sessions in 8 instances (28 %); 6 of which involved the peg or block. 8. The number of failures was consistent in 10 instances (34%). 9. Tenodesis performance was consistent in 3 of the 12 (25%) testable cases for completions and 7 of 12 (58%) instances for failures. 10. 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 number of completions plateaued by the second or third session whereas for the last subject, they were only able to complete the tape task in the eighth session, after surgery to facilitate stimulated finger extension. 11. With 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. 12. 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., 1994) USA Pre-Post N=5 *Same study sample from (Smith et al., 1996)	**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:** 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.	**Acquire Phase** 1. Without FNS, two hands (*self-assist*) were required in almost all activities to acquire the objects. 2. Two subjects scored *physical assist* for eating and writing since they required wrist splints specifically for those two activities and were unable to don them without help. 3. With FNS, independence increased for at least one subject in each activity. 4. Three subjects were able to use stimulation to acquire toothpaste with one hand (*independent*) which freed the non-FNS extremity to hold or stabilize the toothbrush; all three could *independently* acquire the toothbrush. 5. The remaining two subjects acquired a pen and fork with two hands (*self-assist*), eliminating the need for attendant care (*physical assist*). 6. For the drinking activity, one subject was able to acquire the cup *independently*. 7. One subject was unable to grasp the cup with his fingers because of insufficient finger extension (*physical assist*). **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 (*self-assist*) 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 relied on Wanchik splints to hold their pens. 9. Four subjects used a universal cuff to hold a fork (thereby not requiring stimulation) and one was able to weave his utensil through his tight fingers *independently*. 10. Without FNS four subjects required modifications to the handle of the fork (*adaptive equipment*) to stab food; with FNS, no subject required any modifications to the fork to stab food (*independent*). 11. Each subject was able to write and grasp a cup *independently* and, for each activity, lift and lower the arm without assistance (*independent*). 12. Without FES, all subject typically required two hands (*self-assist)* for squeezing and applying toothpaste, brushing teeth and drinking the first and last sip; with FES two subjects used lateral pinch (*independent*) to squeeze the toothpaste and four subjects were able to use one hand (*independent*) to brush both sides of their mouths; one subject used two hands (*self-assist*) to brush the contra-lateral side. **Release Phase** 13. Without FNS, release of objects in each activity usually required two hands (*self-assist*) during tenodesis flexion, or the mouth (*self-assist*) to doff adaptive equipment. 14. One subject required a *physical assistance* to remove the wrist splint used specifically in the eating and writing tasks. 15. With FNS, all subjects scored higher on the independence; for most, stimulated lateral and palmar extension was sufficient to release the objects (*independent).*

		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 (*independent*). 17. 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).