Two splints were designed to compensate for tight biceps and the lack of active pronation during functional activities of C5 to C6 quadriplegic persons. The basic concept of the splints was originated by a C5 to C6 quadriplegic patient one year after injury. At that time, the patient had spastic biceps, supination contractures, slight limitations in passive elbow extension bilaterally, "good" muscle grades in shoulder motions and elbow flexors, and a "fair plus" muscle grade in wrist extensors. A mobile arm support (MAS) kept his forearm in pronation when he raised his hand to his mouth; he also wore a one-piece wrist support and cuff splint to compensate for weak wrist extensors. The patient was frustrated with the inconvenience and the cumbersomeness of using the MAS for every meal, especially because he had the muscle strength to feed himself without it. He suggested strapping one end of a lever onto the volar surface of his pronated forearm; this would allow the other end of the lever to rest on the medial side of his upper arm. Thus, when he raised his hand toward his mouth, the lever would catch underneath his upper arm and prevent his forearm from supinating.

A one-piece pronation splint was fabricated from a high-temperature thermoplast, which consisted of a trough strapped onto the volar surface of the forearm and a lever that reached back underneath the upper arm at a 45° angle (see Figure 1). Thus, by wearing the pronation splint, wrist support, and cuff splint, the patient was able to feed himself. However, after he used the splint for three weeks, he noted some minor problems. For example, sometimes, when he ate, the end of the lever would hang up in his shirt, catch on the post of his wheelchair, or slip out from underneath his arm when he reached away from his body.

To eliminate these problems, a second, two-piece pronation splint was designed; again it consisted of a trough and lever but now included a track through which the lever passed (see Figures 2 and 3). The trough fits the dorsal surface of the forearm, and the track is strapped to the lateral side of the upper arm. The end of the lever is turned up so that it will not slip out of the track, and it is made longer than the lever of the first splint so as not to limit the amount of reach.

The mechanical problems observed in the first splint were resolved with this second design. However, this splint takes more time to make (thus increasing its cost), more time to put on and ad-

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just, more training to use effectively, and its location on top of the arm (rather than underneath), makes it more noticeable. More important, however, the patient liked this splint better than the first one and has used it for two years now to feed himself and to operate his computer. The patient has also attempted with some success to write, shave, and brush his teeth while wearing this splint.

Splint Fabrication

The levers of both splints are approximately 33 to 35 cm (13–14 in.) long by 5 cm (2 in.) wide and stand at a 45° angle to the trough. The troughs are approximately 22.25 cm (8.5 in.) long by 12.5 cm (5 in.) wide with a 5-cm (2-in.)-wide strap in front of the lever and a 2.5-cm (1-in.) strap behind it. Because the measurements of the trough and lever may vary, depending on the size of the forearm to be splinted, a paper pattern should be made to determine a proper fit as well as the most efficient angle and length of the lever.

The trough of the first splint is shaped to fit the volar surface of the forearm. Distally it should begin 2.5 cm (1 in.) above the wrist flexion crease and 5 to 7.5 cm (2–3 in.) below the medial epicondyle. The trough should not interfere with wrist or elbow flexion. The lever is kept flat, and the edges are sanded to slide more easily underneath the arm. If the lever does not press on the upper arm firmly enough to cause adequate pronation, it is heated at its base and tilted up. Adjustments are made until the lever moves freely under the arm and causes adequate pronation.

The trough of the second splint is shaped to fit the dorsal surface of the forearm, the lever fitting on top of the upper arm. Distally it begins 2.5 cm (1 in.) above the ulnar styloid and 5 to 7.5 cm (2–3 in.) below the lateral epicondyle. The lever is slightly ribbed, to add strength, and is turned up at the end to prevent slipping out of the track. The track is made from two pieces of ¼-in. Kydex that are glued together and shaped. The outside dimensions of the track are approximately 19 cm (7.5 in.) by 5 cm (2 in.). The inside diameter is 1.25 cm (.5 in.) by 15 cm (6 in.). This is cut by drilling 1.2-cm (.5-in.) holes in either end and using a coping saw to connect them. The track and lever are sanded smooth to keep friction to a minimum, so that the lever can move freely in the track. One-inch Velcro straps attach the track to the upper arm.

Application

The first pronation splint was used successfully as a temporary device by two C6 quadriplegic patients, who both were newly injured and manifested general weakness and biceps spasticity. One patient, a 35-year-old female, refused to use the MAS, which was the orthosis of choice for her condition. The forearm supination, which appeared when she raised her hand to her chin, did not permit her to strengthen her wrist extensors through functional activities, although the extensors were at “fair” muscle grade and capable of powering a weak tendodesis grasp. Therefore, she used the pronation splint for feeding but initially required assistance in scooping her food and raising the spoon the last 5 cm (2 in.) to her mouth. Within two weeks, she needed only occasional assistance, depending on the type of food she ate and her endurance at the time. She wore the pronation splint, wrist support, and cuff splint for feeding, typing, and brushing her teeth until four to six weeks following admission. After that, she used only the pronation splint and universal cuff.

The other patient was a 21-year-old male. He initially could raise his arm off his lap (with much effort), had only “trace” to “poor” wrist extensors, could acquire complete passive range of elbow extension and forearm pronation only through painful stretching, and had poor sitting endurance (only 1 hour at a time). He attempted self-feeding only after he made gains in general strength and endurance, which took several weeks. His strength increased slowly, and it was difficult for him to use a MAS in halo traction; thus, he used the pronation splint along with wrist support and cuff splint for self-feeding. For several weeks, he needed assistance in scooping and raising the spoon the last few inches to his mouth. After this time, he needed only occasional assistance. Halo traction interfered with both his vision in scooping the food and in reaching his mouth, thus preventing neck flexion. Six weeks after self-feeding began, the wrist support was eliminated leaving only the pronation splint and universal cuff (see Fig. 1). For several
more weeks, he continued to need the pronation splint in functional activities to counteract the forearm supination during wrist extension when raising his hand to his mouth.

As their forearm supination decreased, both of these patients eliminated the pronation splint and eventually became quite functional with a wrist-driven tenodesis splint. The pronation splint allowed them not only to participate in daily self-care activities at an earlier time in their rehabilitation but also to reap the strengthening benefits of the self-care program and it promoted their early active participation in the treatment programs.

Summary

For two years we have made pronation splints to assist quadriplegic patients who lack adequate forearm pronation but who have enough upper extremity strength to feed themselves and perform other self-care or functional activities. We have found the splints to be an appropriate alternative to the MAS. The first pronation splint fits underneath the arm, is simple in design and fabrication, and is hidden. However, occasionally the lever of the splint hangs up in the shirt, catches on the post of the wheelchair, or slips out from underneath the arm when the patient reaches away from the body. To eliminate these problems, we designed a second splint. But, this splint requires more time to make and adjust, has two parts to put on instead of one, and is more noticeable because it is worn on top of the arm rather than underneath it.

When a patient uses either splint, the degree of pronation may be adjusted according to the activity by slightly rotating the splint either way when strapping it on. For example, full pronation may be required for feeding, but only half the range is necessary to operate the keyboard of a computer or typewriter. Once the Velcro straps are applied, the splints do not slip. The splints are not interchangeable from left to right and assistance is always needed to put them on. For patients with “weak” or “absent” wrist extensors, a wrist support and cuff splint may be used along with the pronation splint or a universal cuff, if wrist extension is adequate. The pronation splints are appropriate for those patients whose forearms supinate when they reach their hand to or near their mouth.