HOW LONG SHOULD AN EXTREMITY BE IMMOBILIZED AFTER NERVE SUTURE?*

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END-TO-END SUTURE of a nerve is hardly ever possible without the use of various procedures for overcoming gaps which result from the loss of substance of nerves or the retraction of their stumps. The methods commonly used for gaining length consist of the often extensive freeing of the nerve, rerouting or suturing it with the neighboring joints flexed. Even when these steps are taken it is sometimes necessary to introduce nerve grafts, but end-to-end suture is preferable to the use of grafts provided that this can be accomplished without great strain on the suture line. In those instances where joints must be flexed in order to bring nerve ends into apposition and remove tension from the suture line, the question arises as to how long the limb must be immobilized in the flexed position. There exists a considerable degree of difference with respect to practice in such cases. Groff and Houtz[1] have suggested a two-week period as adequate while Hambly[2] advocates immobilization of the extremity for a period of 9–12 weeks following nerve repair. The surprisingly high incidence of separation at the suture site of 7.5 per cent (44 out of a total of 604 nerve sutures) reported by Whitcomb[3] was probably to a large extent attributable to inadequate immobilization of the sutured nerve since in some cases "fairly rapid extension of the flexed joint as early as two weeks after operation" was carried out. It is apparent that the period of immobilization must be long enough to avoid rupture of the suture site when the joint is extended. On the other hand, one must avoid too prolonged fixation of the joint since the inevitable muscle atrophy and periarticular changes that ensue delay or even prevent recovery of function. Active and passive motion of the joint over which the sutured nerve passes must not be started before satisfactory healing of the suture line has occurred but it must not be delayed unnecessarily beyond this point. An attempt has been made in this study to resolve this apparent dilemma by the performance of a series of experiments upon rabbits and dogs. Microscopic studies of the process of healing at the suture line together with determinations of the tensile strength of the sutured nerve were made.

A previous attempt was made to settle this problem by Miller.[4] He carried

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FIG. 1.—(A) Nerve sutured with plasma clot and removed four days after operation. Union of stumps has not occurred. (Hematoxylin and eosin, x 22.)

(B) Five-day-old sutured nerve. Streaming of cells across the suture site has occurred. (Hematoxylin and eosin, x 32.)

(C) Nerve sutured with plasma clot seven days before excision of specimen. Slight seepage of plasma into suture line has occurred and there has been cellular proliferation between the stumps. (Hematoxylin and eosin, x 20.)

out experiments in 11 dogs, suturing the sciatic nerve with silk or catgut. Tensile strength determinations were made of the suture site at the following intervals after operation: 1 week, in 3 dogs; 2 weeks, in 2; 3 weeks, in 2; 4 weeks, in 1; and 5 weeks, in 3 animals. Miller concluded that the strength of the suture line was "practically as great at the end of the third week as at the end of the fourth or fifth week." Comparisons of the strength of the suture line with the strength of the intact nerve were not made. Singer[5] showed that the tensile strength of the sciatic nerve of rabbits in which suture was accomplished by the use of fibrin film and thrombin, remained approximately constant during the first three postoperative days, but dropped by the fourth day to an average of 90 Gm. from an initial value of just over 100 Gm. After the fourth day it rose to an average of 338 Gm. on the sixth day and 625 Gm. on the tenth day. The results showed that "sufficient healing occurred by the end of the fifth or sixth day to ensure retention of the stumps without the aid of the suture material." Singer's studies were not carried beyond ten days after suture.

METHOD

In our experiments both sciatic nerves in a series of 14 rabbits were exposed, severed and then sutured by the use of the autologous plasma clot technic.[6] Two of the three untwisted strands of No. 00 corticelli black silk were used as tension sutures to approximate the nerve ends and accurate apposition was achieved with the aid of plasma clot. The tension sutures were employed in order to avoid strain on the suture site during the unrestricted movements of the animal following recovery from the anesthetic. The animals were sacrificed at various intervals after operation, and 4-cm. segments of the nerve were removed (2 cm. to each side of the suture site). Also, 4-cm. segments of intact sciatic nerve were excised. The silk tension sutures were removed and tensile strength measurements were made of the suture site, the intact nerve, and of one of the withdrawn silk tension sutures from each nerve. For the purpose of microscopic study, the same technic of nerve suture was used upon the sciatic nerves of dogs, with the exception that tantalum wire (.003-inch in diameter), which causes less tissue reaction than silk,[6] was used as tension sutures. Observations were made upon several hundred such nerves at intervals ranging up to 18 months after operation. This material was prepared for study by a variety of histologic technics (hematoxylin and eosin, Laidlaw's connective tissue method, Gros-Bielschowski technic for axis cylinders, and osmic acid technic for myelin sheaths). The results of this study of nerve regeneration will be published later. For our present purpose, the observations upon this material concern the process of healing at the suture line with reference to restoration of its structural continuity.

The technic employed for the measurement of tensile strength was essentially that described previously.[7] Increasing increments of weights were applied until rupture of the nerve took place.

OBSERVATIONS

Few monocytes and polymorphonuclear leukocytes appear within the plasma cuff as early as 24 to 48 hours after nerve suture, and an occasional fibroblast may be seen at this time. The fibroblasts increase in number and a

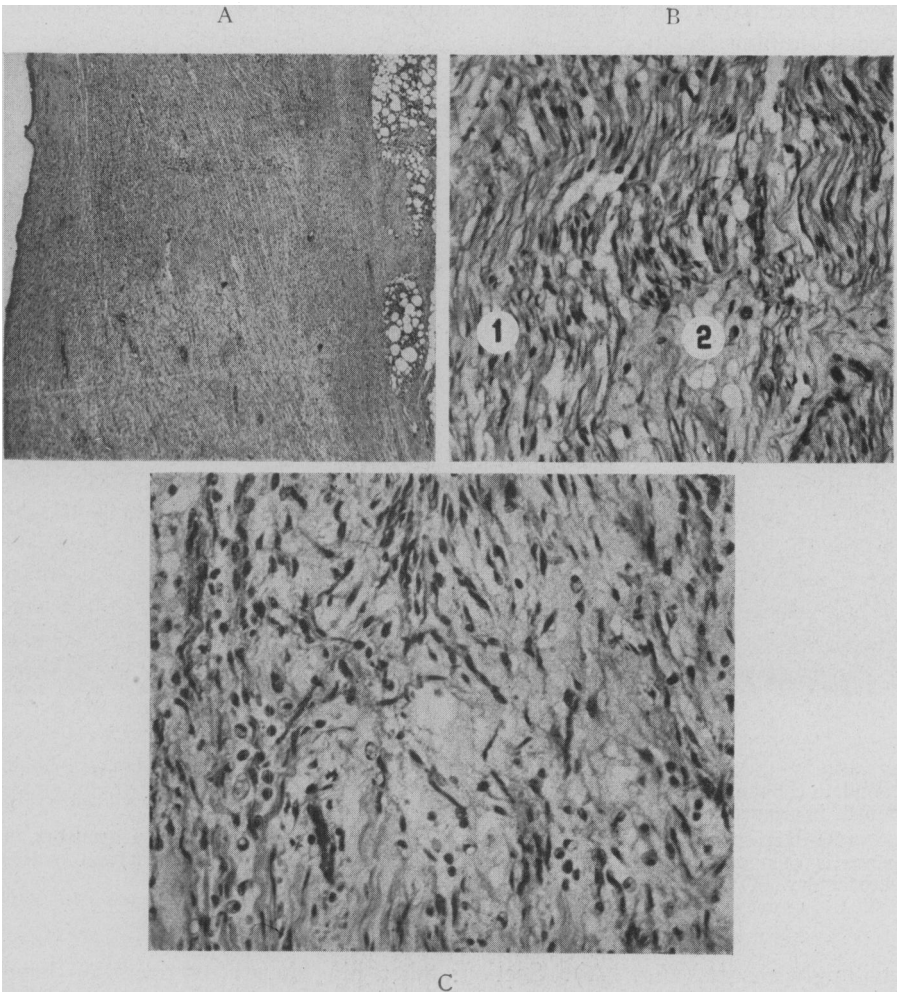

FIG. 2.—(A) Nerve sutured with plasma clot and removed nine days later. Incomplete union of the stumps has occurred. This is more apparent in (B) and (C) where macrophages as well as proliferating cells of the fibroblastic and schwannian types are seen. Cellular and fibrous continuity is seen in (B) at 1, but not at 2. Microphotographs taken from sections stained with hematoxylin and eosin, (A) x 20; (B) x 200; (C) x 200.

normal epineurium is reconstructed from the plasma sheath in seven to ten days. Within a period of two to three days after suture mild, degenerative, exudative and proliferative changes appear at the junction of the nerve stumps

Few polymorphonuclear leukocytes together with some monocytes and lipophages appear at this time. These latter cell types may persist for several weeks. Fibroblasts and Schwann cells proliferate and may frequently be seen streaming out into a slight exudate between the nerve stumps. Although Schwann cells are usually larger and present more oval nuclei than fibroblasts the differentiation between these cells may be impossible without the aid of special staining technics.[8]

As early as 3 to 5 days after suture, cells may be seen streaming across the suture line (Fig. 1B), but occasionally signs of such cellular proliferation are

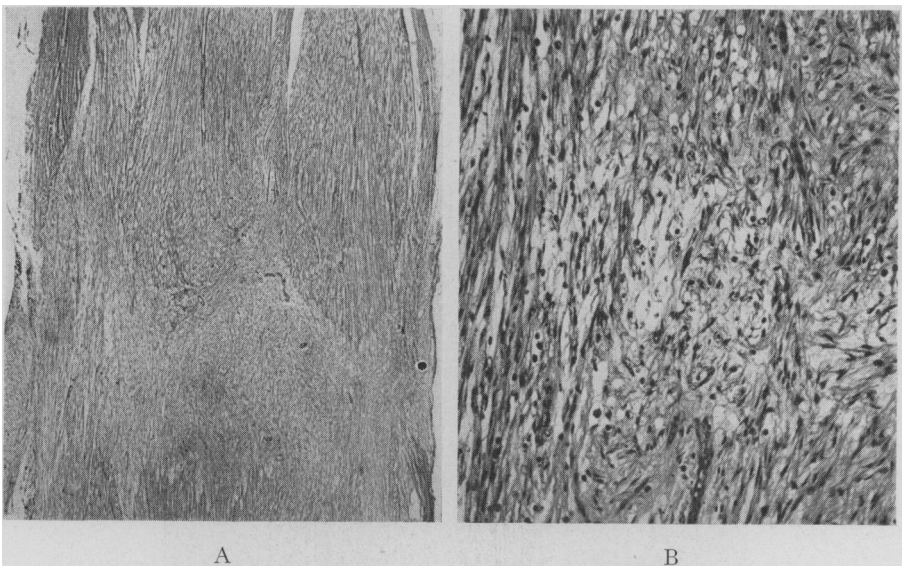

FIG. 3.—(A) Nerve sutured with plasma clot and removed 11 days later. Almost complete cellular and fibroblastic continuity has occurred. (Laidlaw's lithium silver carbonate impregnation for connective tissue, x 20.)

(B) High power view of nerve seen in (A). Structural continuity of framework of nerve is seen on the left but not on the right, where the cellular orientation is less satisfactory. (Hematoxylin and eosin, x 150.)

strikingly absent (Fig. 1A). Sections taken nine days after operation have shown structural continuity of schwannian and endoneurial sheaths, although not uniformly in all cases (Fig. 2). In some nerves at this age, structural continuity was seen at one portion of the suture line, whereas examination of adjacent areas revealed the presence of a coagulum occupied by monocytes and lymphocytes. This same variation in appearance of the suture line was seen in specimens examined 11 days (Fig. 3), and to a less extent 14 days after suture (Figs. 4 and 5). In some instances suture lines nine, 11 and 14 days old proved to be remarkably free from cellular infiltration (Fig. 5B). In practically all cases of sutures 18 days or particularly three or more weeks old, complete restoration of structural continuity has occurred (Figs. 6 and 7).

The growth of nerve fibers through the suture line may be demonstrated at this age.

At times, as a result of seepage of plasma into the nerve junction, or because of faulty apposition of nerve ends, Schwann cells, fibroblasts and connective tissue fibers become oriented transversely to the plane of the nerve. Although this is an undesirable occurrence because of the ensuing disorientation of nerve fibers at the suture line, the intrusion of a few drops of plasma at the suture line has been found to be compatible with satisfactory regeneration.

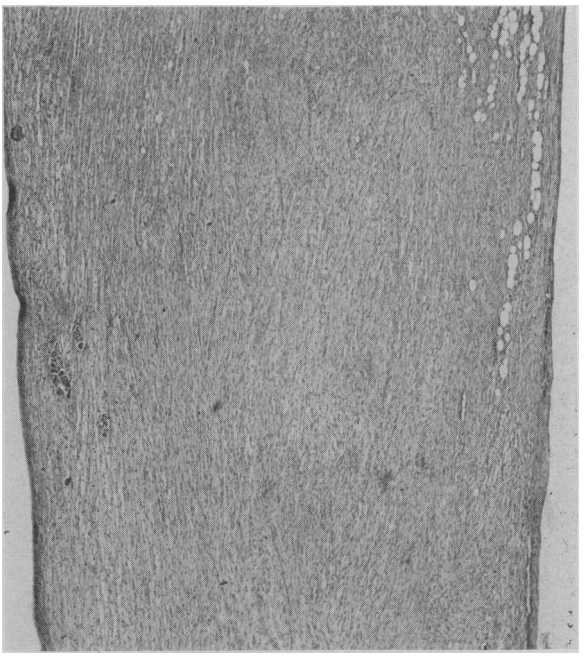

FIG. 4.—Nerve sutured with plasma clot and removed 14 days later. Restoration of continuity has occurred. (Hematoxylin and eosin, x 32.)

Examination of Table I tends to confirm the histologic observations, in that the suture site regained, or even exceeded, the strength of the intact sciatic nerve 19, or more, days after operation. It is of interest that in rabbits Nos. 5 and 12 (17- and 36-day-old nerves), in which the strength of the suture sites was considerably less than that of the intact nerves, the apposition at the suture sites was poor. In two animals (rabbits Nos. 3 and 4) the strength of the sutured nerves (13 days old) closely approximated that of the intact nerves. This is in keeping with the histologic observations which in some instances (Figs. 4 and 5A) showed structural continuity at this time. The degree of variation in tensile strength values of sutured nerves of a certain

age corresponded to the histologic differences observed at the suture site at the same age approximately. The variations seemed to result from differences in the type of apposition obtained at the suture line. The nerves appeared to

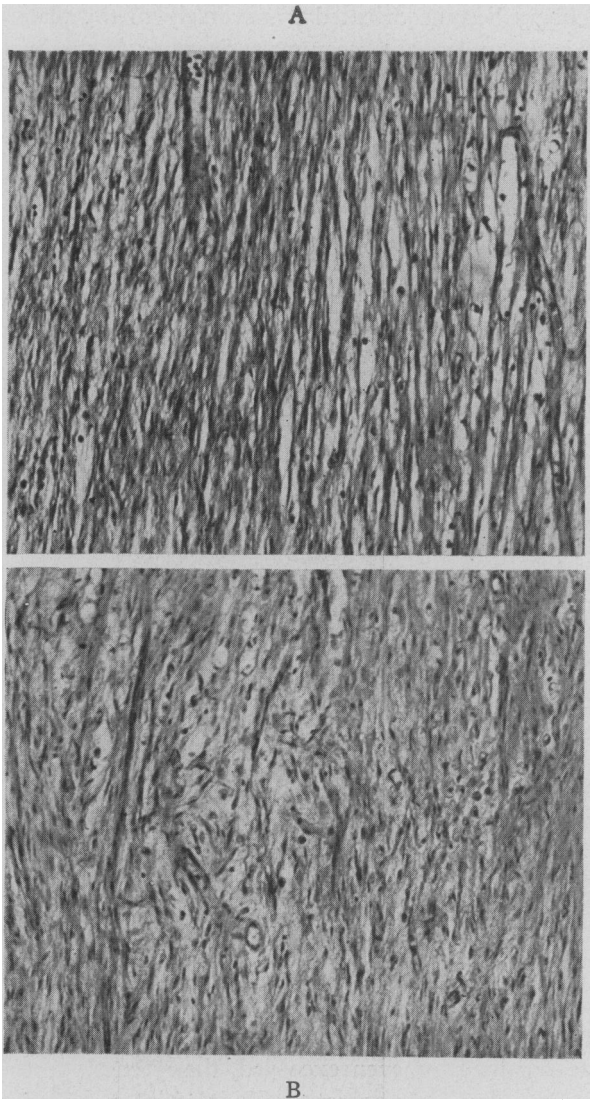

FIG. 5.—High power views of suture sites 14 days old. Microphotographs (A) taken from nerve in Figure 4 shows structural continuity which is not quite complete in (B) where macrophages are seen at the suture line. (Hematoxylin and eosin, x 150.)

achieve a greater tensile strength value at a certain time when their ends were accurately coapted and well-joined. It appeared that the general condition of the animal too played a rôle in governing the rate of healing at the suture site.

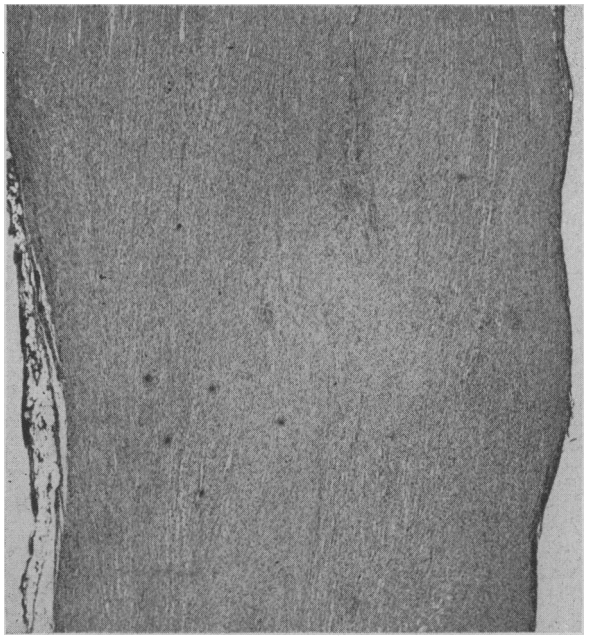

FIG. 6.—Nerve sutured with plasma clot and removed 18 days later. Structural continuity has been restored. (Hematoxylin and eosin, x 27.)

TABLE I

SHOWING THE RESULTS OF TENSILE STRENGTH DETERMINATIONS OF BOTH THE INTACT SCIATIC NERVES AND ALSO NERVES SUTURED WITH AUTOLOGOUS PLASMA CLOT IN RABBITS

Rabbit No.	Tensile Strength (in Gm.) of Sutured Nerve			Tensile Strength (in Gm.) of Intact Nerve			Age of Sutured Nerve (in Days)
	Right	Left	Average	Right	Left	Average	
1.....	30	30	30	820	820	820	6
2.....	317	395	356	600	817	708	10
3.....	875	900	888	900	977	939	13
4.....	1,100	900	1,000	800	1,277	1,038	13
5.....	500	900	700	1,177	1,300	1,238	17
	Poor apposition at suture site						
6.....	600	617	609	651	600	626	19
7.....	1,350	1,250	1,300	1,350	1,250	1,300	21
8.....	800	827	814	827	850	838	24
9.....	1,327	1,627	1,477	1,427	1,527	1,477	24
10.....	1,227	1,667	1,447	1,007	1,227	1,117	28
11.....	1,227	1,200	1,214	1,227	1,300	1,264	28
12.....	800	600	700	1,527	1,327	1,427	36
	Poor apposition at suture site						
13.....	With load of over 1,200 Gm. nerve broke at point of application of clamp rather than at suture site			1,227	1,200	1,214	48
14.....	With load of over 1,550 Gm. nerve broke at point of application of clamp rather than at suture site			1,600	1,550	1,575	65

Rupture of the nerve following the application of a weight-load which was greater than it could hold, occurred at the suture line or, in a few instances, along the point of application of the clamp. At the suture site there was a fusiform enlargement amounting to 1–2 mm. In those cases where the strength of the sutured nerve equaled that of the intact nerve the stretch occurred to a greater extent along the nerve segment than at the suture site. The strength of the silk tension sutures removed at different intervals after operation showed considerable variation. After the age of 13 days they usually broke with the small weight-load of but a few Gm.

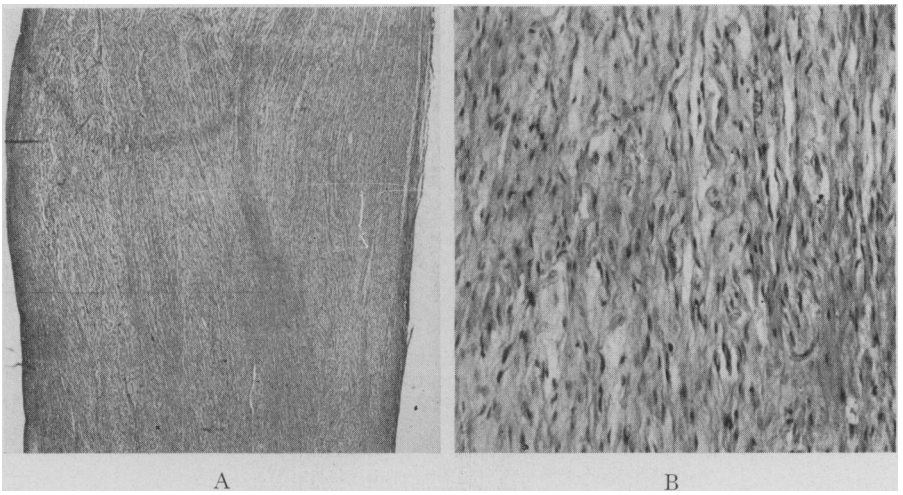

FIG. 7.—Nerve sutured with plasma clot and removed 30 days later. Complete restoration of structural continuity has occurred, including the regrowth of axis cylinders through the suture line. The suture line is free from inflammatory or fibroblastic reaction. (Hematoxylin and eosin, (A) x 21; (B) x 150.) All photographs are from sections taken from dogs' sciatic nerves which were sutured with autologous plasma clot.

DISCUSSION.—The results of tensile strength determinations indicate that the rabbits' sciatic nerve of varying sizes sutured with plasma clot achieves the tensile strength of the intact nerve within a period of three weeks. That this statement holds also for nerves sutured with silk is rather suggested by the investigations of Miller.[4] Our microscopic observations in dogs indicate that this statement applied also to this species since structural continuity at the suture line was found to be complete at approximately this time. There is no reason to suppose that there might be any appreciable difference in the healing time of sutured nerves in man. It seems justifiable then to advocate the removal of plaster of paris encasements or other means of limb fixation three weeks after nerve suture and the institution of gradual extension of the joint at this time. These experiments indicate that there would be no danger of rupture of the suture site in well-made unions when a nerve is subjected to any strain three weeks after suturing. However, there is no doubt that there

is a limit to which a nerve may be stretched and yet remain capable of regenerating, with resultant functional recovery of the innervated part. Highet and Sanders[9] performed extensive resections of the external popliteal nerve of the dog, suturing the nerve with the knee acutely flexed. Subsequent extension of the limb after a period of 14 days resulted in considerable histologic change apart from rupture of the suture site in some instances. The increase in length of the nerve following extension of the joint resulted from elongation of it, whereas the straightening out of the tortuosity of the nerve played only a minor part. Rapid stretching in their animals did not produce any more damage than a more gradual stretching. The animal experiments of Denny-Brown and Doherty[10] demonstrated, likewise, that great damage to nerves accompanies transient stretches applied to them. Highet and Holmes[11] recorded cases in which lateral popliteal nerves were sutured with knees acutely flexed. The limit of stretch had apparently been exceeded in these patients since no recovery followed extension of the limb and microscopic examination of the nerves showed that they had been converted to fibrous tissue. It is a matter of common surgical experience, however, that nerves may be sutured with joints moderately flexed and good functional recovery result. However, the exact limit of nerve stretch that is compatible with satisfactory return of function can not at present be stated. Information is sorely needed on the results of nerve grafting and nerve stretching which are the only present alternatives to nerve suture with joints acutely flexed. Such data, together with information on the functional results following closure of gaps of varying sizes by end-to-end suture of nerves with joints flexed at different angles and then extended, is necessary in order to enable the surgeon to decide which procedure is likely to result in better recovery. The results of nerve grafting have thus far been disappointing, but with the use of the plasma clot technic for forming and suturing cable autografts[12] this method of grafting may yet prove of value.

SUMMARY

In a series of rabbits and dogs the sciatic nerves were cut and sutured with plasma clot and the nerves were removed at various intervals after operation. Combined microscopic observations and tensile strength determinations of the sutured nerves indicated that the tensile strength value of the intact nerve is regained approximately three weeks after operation and structural continuity at the suture line is restored at this time. It is concluded that in those cases in which joints must be flexed in order to perform end-to-end suture of nerves and the extremity encased in plaster, the encasement may be removed three weeks later without danger of rupture of the suture site during the subsequent extension of the limb.

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