MICRO-NEURAL SURGERY
(Third Part)

*Ashok Govila, M.S., M.Ch.,

Repair or replacement of the damaged nerve has been the most frustrating experience for a Plastic surgeon. In the midst of all possible surgical dexterity there persists a shadow of failure when a victim of nerve repair walks into the clinic for follow up. However, the dilemma of optimism in the Plastic microsurgeon has never faded.

Time and time again, different methods of repair, different timings of repair (Primary as against Secondary), different indications of direct suture and a nerve graft has been tried and advocated in the ever present hope of improving the results. Over the period of time, some progress has been made, but this is slow.

Before the introduction of the microscope in the field of surgery, attempts were made by tension relieving techniques (Mikulicz) 13; Use of glue instead of suture (9); Technique of nerve wrapping by various types of tissue or materials such as Collagen (2, 10), Silastic (4, 5, 12), use of preserved allograft such as Lyophilised (10), Irradiated (Marmor), preserved in Cialite, Deep frozen plus millipore wrapping (3).

Significant success has never been achieved, although it might have been reported at times.

In the repair of the damaged tissue, a better anatomical approximation based on better micro-anatomical understanding is expected with better physiology of the part in all branches of surgery. So was the case with the nerves. At a time of this frustration. an operating microscope was timely introduced. Anatomy of the nerve has been worked out in detail and keeping this in mind, a nerve repair is now expected to be more successful than before.

In 1960, Jacobson was the first to pioneer in this field. In 1964, Smith and Korze separately reported the use and stressed the importance of operating microscope in nerve repair. Later on, various surgeons used this technique more and more as the facility and training in microsurgery became more and more available. No body has yet reported the comparative series of conventional technique and micro-neural repair.

Anatomy of a peripheral nerve in brief should here be mentioned before going into the details of repair.

Micro Anatomy of the peripheral nerve

Recently peripheral nerves have been studied by using the electronic microscope and the detailed topography has been defined. Van Beek et al (1). has shown some beautiful pictures of micro-anatomy of the nerve. Peripheral nerves are like electric cables composed of bundles of copper wires wrapped in separate rubber sheaths. A nerve is made up of a number of fibres also called fascicles. A fascicle is a bundle of axons. A normal

*50, Clayton Road, Bridge of Earn, Perthsire, Scotland.

digital nerve commonly has three to four fascicles. A bigger nerve will have fascicles arranged in groups. In digital nerves, each fascicle can have 120 axons. An axon may or may not have its covering layer (Myelin Sheath). Fascicles have a covering layer called a perineurium. The outermost covering of the nerve is called the epineurium. A layer of similar tissue also surrounds perineurium surrounding fascicles and here it is called endoneurium. Surrounding the fascicles towards the periphery of the nerve there are vascular sinusoids which makes an extensive vascular plexus all around the nerve in the entire length to supply it and to drain it. In between fascicles there are also collagen bundles. A schematic drawing of the nerve is shown in Fig. 1 and 2.

Different nerves have different patterns of fascicles. Nerves having one fascicle are known as monofascicular. Most nerves have more than two fascicles. When there are two or more big size fascicles and the rest of them are comparatively small, it is termed as oligofascicular.

A nerve having many small fascicles is called polyfascicular. In a poly-fascicular nerve, fascicles may or may not arrange themselves in groups. Understanding of this fascicular pattern in a nerve has a great bearing on the type of repair performed. A micro-nerve repair has the following advantages ;

1. Better tissue handling leaves more viable nerve endings.
2. Possibility of better alignment of nerve fascicles and thus the axons.
3. Possibility of better assessment of cut ends of the nerve about its viability.

The following techniques of nerve repair have been used :—

1. Epineural Repair—Trunk to trunk coaptation.
2. Perineural Repair—Fascicle to fascicle coaptation.
3. Peri-Epineural Repair.

These names are given according to the location of the coapting stitches.

Factors determining choice of technique

Factors which matter most in a case of nerve injury are the cleanliness of the wound and the gap between the cut ends of the nerve. Even an apparently devitalized wound after thorough wound toilet and scrubbing may have a strong indications for primary nerve repair, while a simple housewife's knife cut, improperly cleaned, may endanger the fine nerve repair. The second point—a gap in between the cut ends of the nerves needs more elaboration. By simple observation, one learns that all tubular longitudinally running soft tissue structures retract when severed. The amount of retraction depends upon the surrounding attachment. For example, a tendon retracts in those places where there is little attachment between its outer surface and the surrounding tissue. This retraction stops when the level of attachment with the surroundings is reached and when these structures are maximally stretched. It seems this retraction is caused by the elastic recoil of tissues, or because of myogenic tone of muscles where they are present.

Peripheral nerves are attached by loose connective tissue to their surroundings when runnings in the subcutaneous tissue, and to the sarcolemma when passing near or through the muscles, and to the fibrous tissue when in the vicinity of bone, periosteum and fascicle layers. The retraction in the nerve is limited as compared to tendon and is stopped by the pull on the surrounding tissues attached at the nerve end. However little retraction it may be in most of the situations it is more than 1 cm. There is no maximum limit as this will depend on the area of the body involved and on the mode of the injury. Any attempt to bring the cut ends together is accompanied by poor results.

A practical point which is worth mentioning here is that if the cut ends of a nerve cannot be held together by a single epineural 8/0 Prolene stitch taking a bite as thick as for micronerve repair, then there is considerable tension and the procedure should be abandoned. A nerve graft is the choice in this situation.

The greatest obstacle seems to be the identification of motor and sensory fascicles in the nerves. Unless sensory to sensory and motor to motor repair is performed, the results would not improve significantly, even after using an operating microscope. There is no simple answer to this problem yet. Electrical stimulation of different fascicles in distal nerve stumps to distinguish motor from sensory fascicles has been tried by **Hakstian** (8), but it is not practicable on the proximal stump under general anaesthesia. Staining techniques based upon acetyl choline esterase concentration in different fascicles which takes about three days to process, was tried by **Gruber** and **Zenker** (7), but again it is not a practicable proposition because of three days elapse of time. This time period has been shortened to one hour using acetyl choline transferase concentration by **Engel** et al. (6), but further trial and late results are awaited.

It definitely sounds very promising.

Technique :

First of all, the devitalized nerve ends are trimmed, in the case of secondary repair, the ends with fibrous tissue are cut until healthy pouting fascicles are seen which has a typical lustre and sheen. These cuts are made with the help of a broken piece of razor blade very carefully by a sawing movement under 6X magnification. It is important to remove as much connective tissue as possible around the epineurium as it has been documented that epineural fibroblasts proliferate faster than Schwann cell and the fibroblasts in the endoneural collagen bundles. These epineural fibroblasts growing from the periphery of the cut nerve end soon forms an envelope on both the stumps and thus forms a great wall for the axon to pass. The connective tissue proliferation is stimulated by tension on the suture line.

This scar tissue proliferation continues weeks after the initial repair to the extent that it can cause axonolysis of these axons which have crossed this wall. Magnification is then raised to 15X and the microscope is zoomed on the cut end of the nerve which is then inspected for the pattern of the fascicles. This is repeated on the other end. If there are 4 to 8 fascicles then these are dissected to separate out for a distance of about 3 milimetres, and then peri-epineural anastomosis is performed. If there are many small fascicles without any attempt to grouping, then only epi-neural repair is performed. If there are some big and some small fascicles, then only big fascicles are repaired. The rest of the nerve is repaired by epineural stitches. If there are any small fascicles but they are in groups, then the groups of fascicles are separated in a similar way as are fascicles themselves. The aim of the repair is to match the fascicles or the group of fascicles of identical size. The fascicles are repaired by peri-epineural stitches.

The first holding stitch is an epineural stitch which is under 6X magnification. Subsequent stitches are passed when the microscope has been zoomed to the site of coaptation (15X). It is important to realise the difference in a vascular repair and a nerve repair, that there are no micro clamps which could be used to bring the posterior vessel wall anteriorly to facilitate the repair. Hence, in nerves, the posterior wall is repaired first. In between these stitches some epineural stitches are applied to aid strength to the repair. The fascicles in the centre of the nerve could be repaired first if there are too many fascicles.

If the cut in the nerve is oblique, caused by a sharp Stanley knife, I then do not perform any dissection, irrespective of a fascicular pattern, because then the best chances of matching the cut ends are lost. The oblique cut surfaces are matched so that the nerve forms a straight line and is not an angulated one, which can happen if the nerve is mobilised and if the ends are twisted.

Sometimes, help is also provided by a significant sized artery, arteriole or venule running on the surface or in the substance of the nerve. It could be used as a matching point of reference.

Although it seems reasonable to aim for perfect possible approximation of the severed ends—but what is the definition and the limit of 'perfect' approximation ? Is it capsule to capsule or organ to organ, or is it tissue to tissue or lumen to lumen, wall to wall, or has it come to be cell to cell ? A 'cellular' surgeon is yet to be born.

Nerve Grafting

In the past, nerve grafting was used as the last resort to save the function of the nerve. Even gapes up to 5 cms. were coapted by extensive mobilization and by joint flexion. Present day study and knowledge has proved that any amount of tension is a stimulus for connective tissue proliferation, which becomes an impermeable wall for axons to pass through. Based on this knowledge, the role of nerve graft has increased dramatically as it is the only way to relieve tension. The problem which appears with the nerve graft is the introduction of another suture line. It is often thought that when axons cannot cross one suture line, how can they cross two ? One forgets to realise that axons may cross two ideal suture lines then a bad one. After a nerve graft distal suture line gets more time for connective tissue proliferation than proximal, and this becomes the site for axonal obstruction in most nerve grafts. The simple solution to this problem is either not to perform distal coaptation initially and do it as a delayed procedure (delay depending upon the length of the graft—1mm. per day) or after a suitable delay period excise the distal suture line and re-do the repair.

The other problem of nerve grafting is the necrosis, when the trunk of the nerve is used. This is overcome by grafting the fascicles as individual units and by bridging the gap between individual fascicles or a group of fascicles, rather than as a trunk. This leaves sufficient spaces between the fascicles for the haemo-perfusion to take place in the initial survival period.

Sural nerve from the leg is the choice as donor but it leads to anaesthesia of lateral border of the foot and may end up with problems of tropic ulcers. This is avoided by taking one or two fascicles only and leaving the rest of the nerve intact. This is performed by 2X or 4X loops. Sural nerve has about 6 fascicles. (See Fig. 3, 4, 5, and 6).

Nerve grafts have been used based on intact arterial net work and by anastomosing the feeding vessels at a new site. Of course, this will give the nerve the best chances of survival, but clinical situations to supply such a nerve are rare.

In conclusion, nerve repair with no tension is ideal. Nerve grafts with no tension are better than end to end repair with tension. Motor to motor and sensory to sensory repair in a mixed nerve has not yet become a practicality but is on its way.

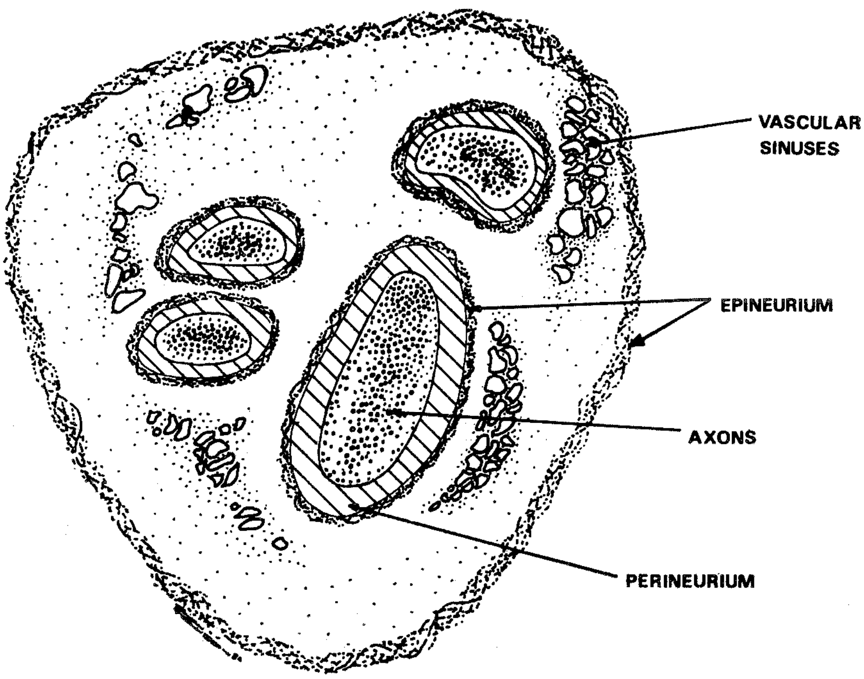

Fig. 1. Schemitic drawing showing microanatomy of perepheral nerve as seen in transverse section, drawn from electron microscope photograph.

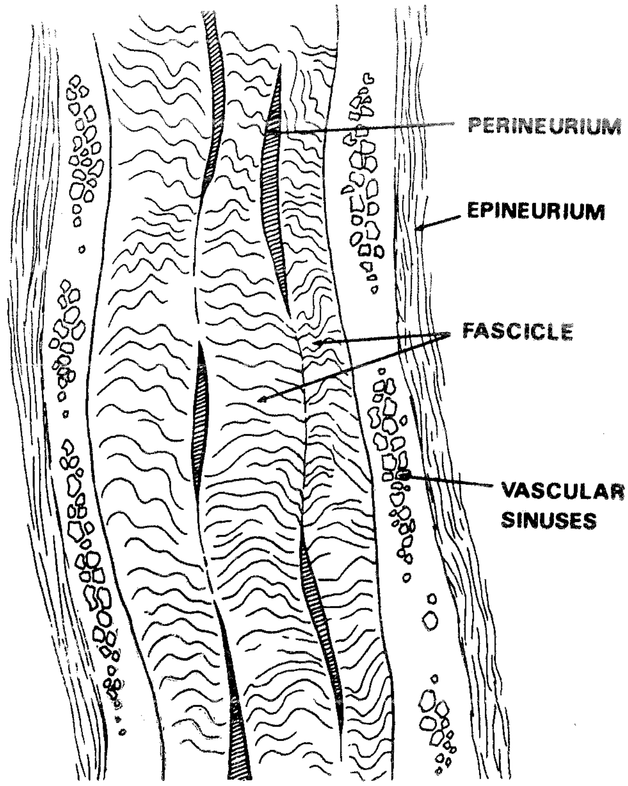

Fig. 2. Schemetic picture showing microanatomy of perepheral nerve as seen in longitudenal section, drawn from electron microscope photograph.

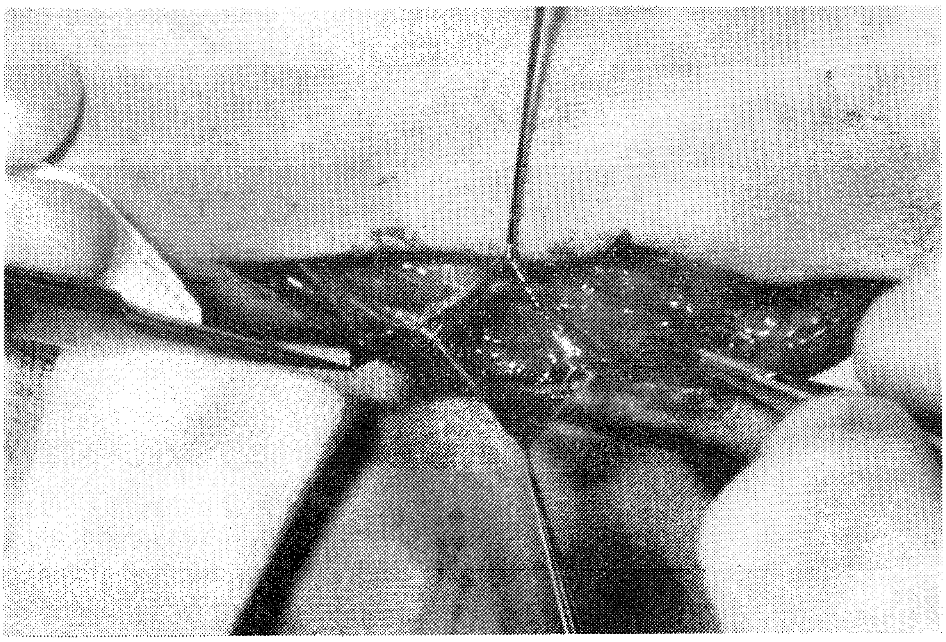

Fig. 3. Microdissection of sural nerve showing about six fascicles twisting arround as they run.

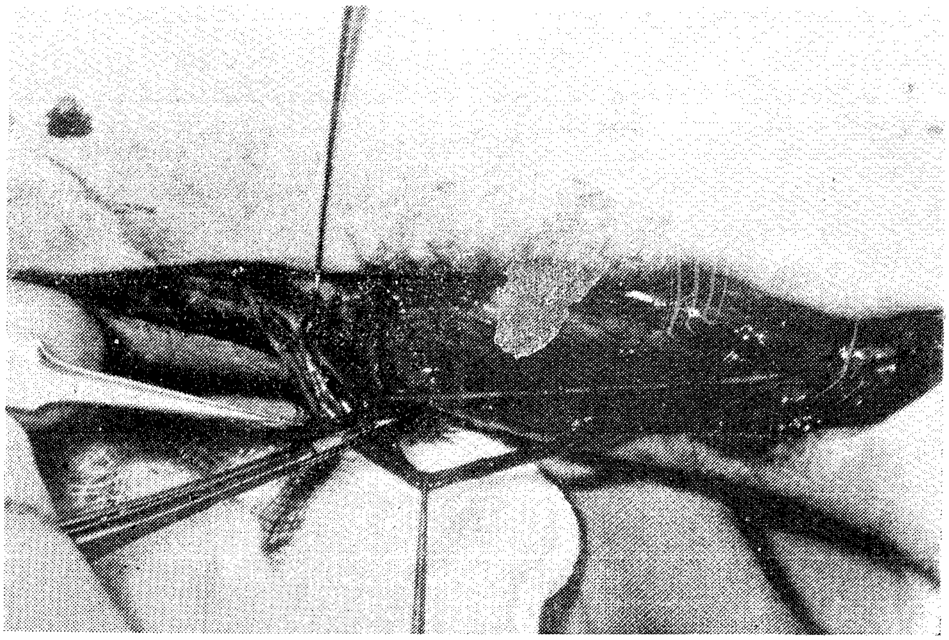

Fig. 4. A single fascicle of sural nerve dissected out (one which is not shown hooked).

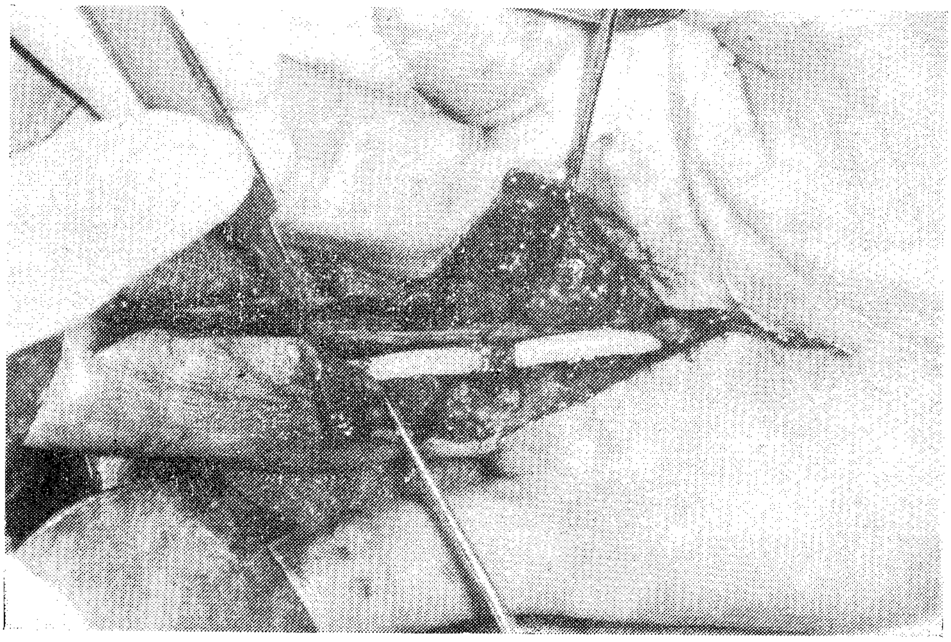

Fig. 5. Sural nerve graft to radial digital nerve to ring finger. Point of jewellers forceps shows distal co-optation of the graft. Incidenaty silastic rod is also seen used in this case for flexer tendon spacer.

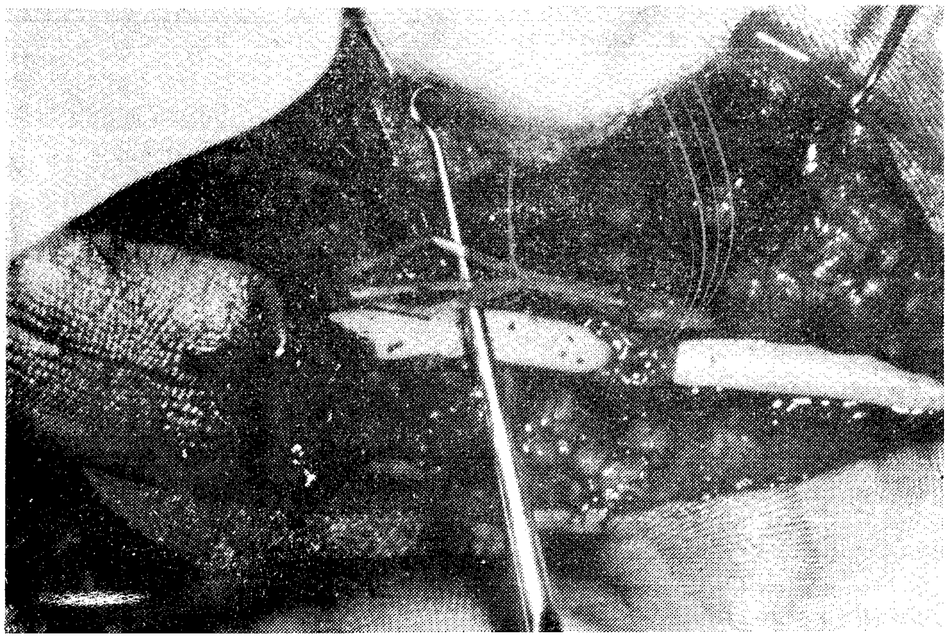

Fig. 6. Three strands of sural nerve graft after anastomosis are seperated to show clearly.

REFERENCES

1. Allen, L., Van Beek et al ; Examination of Peripheral nerve with scanning electron microscope, 63, No. 4, Plast. Reconst. Surg. April, '79.
2. Braun, R. M. ; Experimental Peripheral nerve repair. Surg. Forum 15 ; 452, 1964.
3. Bohler, J. ; Lecture held at 10th Congress of SICOT, Paris, Sept. 6-9-66.
4. Campbell, J. B. ; Lecture at 10th Congress of SICOT, Paris September, '66.
5. Ducker, T. B., Hayes, G. ; Experimental Improvements in the use of silastic cuff on peripheral nerve repair. J. Neurosurg. 28 (6) 582-587, 1968.
6. Engel, J., Ganel, A. et. al. ; Choline acetyl transferase for differentiation between human motor and sensory nerve fibres. Ann. Plast. Surg. 4 376-380, 1980.
7. Gruber, H., Zenker, W. ; Acetylocholinesterase ; Histochemical differentiation between motor and sensory nerve fibres. Brain. Res. 51 207-214, 1973.
8. Hakstian R. W. ; Funicular orientation by direct stimulation. An aid to Peripheral nerve repair. J. Bone, Jt. Surg. 50A 1178-1186, 1968.
9. Heiss, W. H., Faul, P. ; Nervenaht mit Klebstoff. Langenbeck's Arch. Klin. Chir. 313 : 710, 1965.

10. Jacoby, W., Fahlbruch, R., Mackert, B. et al. ; Uberbruckung Peripherer Nervendefekle mit lyophilisidrten and desantigenisierten Trans plantaten Munch. Med. Wschr. 112 ; 586-589, 1970.

11. Kline, D. G., Hayes, G. J. ; The use of resorbable wrapper for Peripheral nerve repair. Experimental studies in chimpanzees. J. Neuro Surg. 11, 243, 1960.

12. Midgley, R., Woodhouse, F. ; Silicone rubber sheathing as an adj. to neural anastomosing. Canad. Med. J. 98, 550, 1968.

13. Mikulicz cited in ; NIGST H. ; Die Chirugie der peripheren nerven Georg Thieme Verlag. Stuttgart 955, 13.

14. Jacobson, H. J., Suarez, E. L. ; Microsurgery in the Anastomosis of small vessels. Surg. Forum 11 ; 243, 1960.

15. Kurze, T. ; Micro Technique in Microneural Surgery, Clinical Neurosurgery, 11, 128-37, 1964.

16. Smith, J. W. ; Microsurgery of Peripheral nerves, Plastic and Reconst. Surgery, 33, 317-29, 1964.