FROM THE ORTHOPAEDIC HOSPITAL, COPENHAGEN

TREATMENT OF NON-UNITED NAVICULAR FRACTURES BY TOTAL EXCISION OF THE BONE AND THE INSERTION OF ACRYLIC PROSTHESES

By

OLAF AGNER

In spite of the appearance of new methods of treatment in the most recent decades and the improvement of the diagnostic aids, especially X-ray diagnosis, defective healing of navicular fractures is no rarity. If not treated the fracture forms a pseudarthrosis which usually by degrees becomes painful and results in reduced strength in the hand, limitation of mobility and possibly deformity of the wrist joint. In these cases deforming arthritis is very often found in the radiocarpal joint on X-ray examination.

In 1920–30 *Böhler* and *Schnek* showed that navicular fractures can be healed by conservative treatment with plaster splint, when the immobilisation is effective and is maintained for a sufficient time. This is confirmed by numerous authors and there is now wide agreement that the treatment of fresh navicular fractures ought to be conservative. The incidence of fracture healing is stated to attain 80–95 % with an average treatment period of 8–10 weeks. (*Böhler* 96 %, *Soto-Hall* 95 %, *Couble* 96 %, *Troyan* 96.4 %, *Watson Jones* 95 %, *Stewart* 98 %, *Luck* 95 %). Other authors, however, found somewhat lower incidence: *Aleman* 74 %, *Rehbein* 78 %, and *Barr* discovered that 26 % of the navicular fractures were not healed in spite of apparently adequate treatment. *Cutler* estimates that "failure of union" is found in 30–40 % of all navicular fractures.

Old non-united navicular fractures present a difficult therapeutic problem. In the comprehensive literature on the subject considerable divergencies of opinion exist as to which methods of treatment from the most conservative to the most actively surgical should be chosen. Among these methods the following may be mentioned:

Prolonged immobilisation. (*Böhler, Schnek, Rehbein, Düben & Gelbke, Troyan, Jahna*).

Beck drilling. (*Schnek, Obletz & Halbstein, Andersen & Therkelsen, Soto-Hall*).

Internal fixation with metal pin. (*Geissendörfer, Gieseking, Lindwall*).

Internal fixation with bone graft. (*Adams & Leonard, Murray, Armstrong, Palmer & Widén, Cobey & White*).

Transplantation of cancellous bone. (*Matti, Russe*).

Intercarpal arthrodesis (between the navicular and lunatum). (*Thornton*).

Radiocarpal arthrodesis. (*Smith Petersen*).

Radial styloidectomy. (*Barnard & Stubbins, Lyman Smith*).

Bentzon's interposition method. (*Bentzon, Randløv, Perey, Bertelsen*).

Excision of proximal carpal row. (*Brittain, Stack, Speed*).

Partial excision of the fragments. (*Aleman, Soto-Hall, Watson Jones, Downing*).

Total excision of navicular. (*Hirsch, Ritter, Davidson & Horwitz, Dwyer*).

Insertion of prosthesis, vitallium or acrylic, after total excision of the navicular. (*Metcalfe, Legge, Waugh & Reuling, Picaud, Merle d'Aubigné*).

It is not the purpose of this study to determine which method produces the best result. For this, large series of cases are required, directly comparable but treated according to each individual method and investigated after a long period of observation. This can hardly be carried out on the basis of the literature available at present.

At the Orthopaedic Hospital in Copenhagen the treatment of old and non-united navicular fractures has developed since 1954 as follows:

Plaster cast when cysts are present indicating reactive processes.

Removal of the proximal fragment in true pseudarthroses if this is sclerosed and forms less than 1/5 of the bone.

Bentzons' interposition operation with wide fracture lines.

Radiocarpal arthrodesis when deforming arthrosis is present.

However, after following up a series of 243 patients with fracture of the os naviculare we found a small group which had been treated by insertion of prosthesis after total excision of the navicular, a method which has produced good results according to the literature. Since this could not be confirmed by our follow-up investigation we thought it would be of interest to publish this, as we believe our results to be a warning against this method.

TABLE

Case no.	Sex	Age	Occupation	Initial treatmant	Time from accident to operation	Primary result	Late result	Evt. later treatment	Complication
1	m	37	worker	Open reduction of semilunar. Plaster cast 12 weeks.	7 months	bad	bad	Arthrodesis 10 months after the operation.	Dislocation of semilunar.
2	m	20	farmer	Plaster cast 6 weeks.	8 months	bad	bad	Arthrodesis 3 years after the operation.	Dislocation of semilunar.
3	f	40	waitress	Plaster cast 17 weeks.	6 months	bad	bad	Arthrodesis 1½ years after the operation.	Arthritis
4	m	33	worker	Plaster cast 8 weeks.	?	bad	bad	Arthrodesis 2¾ years after the operation.	Comminuted fractur Arthritis
5	m	28	worker	Plaster cast 4 weeks. After 2 years drilling.	10 years	fair	bad	Arthrodesis 2 years after the operation.	
6	m	27	sailor	Plaster cast 11 months.	2½ years	fair	fair		Arthritis
7	m	18	clark	Plaster cast 21 weeks.	2½ years	good	good		

Total excision of the navicular was declared by *Hirsch* who gave an account of his first results in 1914. 9 patients were operated on, all with good results. Full working capacity was achieved after an average period of 6 weeks. In later studies *Hirsch* states that the long-term results are good: According to *Hirsch* the operation should be undertaken as early as possible, if possible as soon as the fracture is diagnosed and before arthritis arises in the joints. Moreover, the importance of the following points is emphasised that the whole of the os naviculare is removed that nothing is left and that the operation is executed so as to avoid damaging neighbouring cartilage.

Ritter (1929) prefers excision of the one fragment, when this is dislocated but believes it necessary to remove both fragments in order to achieve good function of the wrist joint when the fracture "has existed some time without being recognised and consequently no attempt at reduction has been made."

In 1938 *Davidson & Horwitz* published 7 cases treated by total excision of the navicular. Pre-operative X-rays showed pseudarthroses in all cases. The observation period following the operation was from ½–15 years; in 5 cases the results were excellent anatomically and functionally, in 2 cases there was moderate limitation of mobility, but no pain. These two were designated as good. *D. & H.* think that the total excision ought to be chosen in 1) fractures which cannot be reduced even in open reduction, 2) severely comminuted fractures, especially when they are caused by other injuries in the wrist joint, e.g. dislocation of the lunate bone and 3) neglected cases with pronounced and irreparable degeneration of the fragments.

Dwyer in 1949 presented the largest series. 19 patients were followed-up. In 12 cases the result was found to be "good", in 4 "fair" and in 3 cases "bad". *Dwyer* points out that the results become worse when arthritis is present and with subluxation of the lunate bone. In some cases progressive dislocation forward of the os lunatum was found on late X-ray control. Radial deviation of the hand was not observed. Mobility in the wrist joint improved in 15 patients,—maximal recovery sometimes took a year or more.

Many authors have advised against the total excision of the navicular (*Böhler, Schnek, Stewart, Aleman, Obletz & Halbstein, Troyan, Düben & Gelbke*). They consider that the navicular is so important for the structure of the hand that its removal will always bring about damage to the wrist joint which will go into radial abduction that function becomes, steadily worse even if some improvement can be obtained im-

mediately after operation. This experience brought total excision of the navicular into discredit in most hospitals,—in recent years, however, the operation has been adopted again by some surgeons who, recognising the importance of the os naviculare for the stability of the hand, replaced the navicular by a prosthesis.

Metcalfe, Legge, Waugh & Reuling have used vitallium as a prosthesis material, *Picaud* and *Merle d'Aubigné* acryl.

Metcalfe operated on 30 patients, all with good results. One patient was observed for 3½ years owing to reflex dystrophia, but the end result was good.

Legge: 7 cases, all good. *Waugh & Reuling:* 3 cases, 2 good, 1 less good.

Picaud inserted acryl in one case with good results. *Merle d'Aubigné & Ramadier* had 2 cases with acryl, the one with good and the other with poor results.

The above-mentioned authors point out the advantages of the method to be: 1) relieving of the pain in the wrist joint, 2) a functionally effective wrist joint, 3) short period of treatment.

In the series published, however, primary results are involved. *Merle d'Aubigné* gives no information about observation time. *Picaud*'s single patient was able to return to work after 2 weeks, *Legge*'s 7 patients after between 3 weeks to 2 months, but in none of these authors does one find information about follow-up investigations. As already stated *Metcalfe* observed one patient for 3½ years, but gives no information about a follow-up of the remaining 29.

Waugh & Reuling followed-up their patients (3) for 7, 15 and 16 months respectively after the operation and conclude: "The use of vitallium replica for replacement after excision of the fragments of an ununited fracture of the carpal scaphoid is in the experimental stage. While the results to date are encouraging, sufficient length of time has not elapsed to determine whether or not the use of these vitallium replica will be of value in solving the problem of the ununited fracture of the carpal scaphoid."

Even if provisional information about a new operation technique is naturally of importance, one must, however, require a thorough postoperative investigation into all the cases operated on, and a long observation period—10–15 years presumably—in order to determine the value of such a method. Several authors have also expressed their scepticism.

In 1959 Troyan stated "substitution operations for navicular frac-

tures are still very new and only the future can show how the late results will be."

The follow-up investigations of *Busch, Bing & Hart Hansen* in 1948, of *Henrichsen, Jansen & Krogh-Poulsen* in 1952 and of *Collins* in 1954 showed that acryl is tolerated to a considerable degree by the tissues. *Newman & Scales* in 1951 and *Scales* in 1956 showed that no tissue reaction was seen when implanting acryl into the muscles of animals; if, however, the substance was exposed to mechanical forces, especially wearing forces, tissue reaction was seen in form of fibrosis.

As far as vitallium is concerned, *Speed* remarks that even if a prosthesis of this material is smooth on the surface this does not hinder the formation of fibrous tissue around such a surface which will gradually narrow the natural gap left by the removal of the bone and thus possibly prevent movement to a normal extent.

Venables points out that the mechanical conditions for a navicular prosthesis are quite different from those for a prosthesis in the hip joint where alloplastics especially have been utilised, and that similar conclusions cannot be drawn. In the hip joint the prosthesis is stabilised, it is present in order to stabilise the joint and takes part in its functions. In contrast to this the navicular prosthesis is applied to a stabilised area, function occurs around the prosthesis, while it is immobile itself.

We have no experience of navicular prostheses of vitallium. On the other hand acrylic prostheses have been used in 7 cases on the initiative of *Sven Kiaer* in Dept. 2 of the Orthopaedic Hospital, Copenhagen. The operations were carried out in the years 1950–52.

All patients had pain in the wrist joint, limited mobility and reduced strength in the hand. 5 had hard work, 2 had lighter work. 3 fractures were in the left wrist, 4 in the right wrist joint. In 1 case the fractures had existed for 10 years, in 2 cases for 2½ years, in 3 cases, 6, 7 and 8 months respectively. In 1 case the patient had suffered an accident 3 months before the operation and swelling of the wrist joint. On X-ray examination, however, a well-developed pseudarthrosis was found with sclerosis of the fracture ends and initial arthrosis in the radiocarpal joint indicating that the original trauma must be sought several years back. In 2 cases in addition to navicular fractures dislocation of the lunate bone was found. (1–2). 1 fracture was comminuted with 3 irregular fragments (4); the others were transverse fractures near the centre of the bone. In 3 cases arthritis was found before the operation. (3, 4, 6).

Operative technique: the operation was carried out in 2 parts. 1) The navicular bone was removed through a dorsoradial incision, an impression of the cavity was taken with a plastic mass and the wound was closed. 2) 1 to 2 days afterward (in case 2, however, 9 days after), the wound was opened again and the prosthesis was inserted. A plaster cast was applied for 3 weeks, afterwards the hand was given physiotherapy.

In cases 1–4 there was constant pain and swelling of the wrist joint, —the mobility was improved immediately after the operation, but became gradually severely limited. None of these patients became fit for work. Case 5 could begin to work 4 months after the operation, he only had slight pain and for a short period better mobility than before. 1 year afterwards the mobility was severely limited, there was increasing, reduced strength and also swelling of the hand. In these 5 cases the prosthesis was removed and arthrodesis was performed. In each case pronounced fibrosis was found around the prosthesis, with thickening of the joint capsule and severe arthritis in the radiocarpal joint.

The prosthesis was not removed in only 2 cases. Case 6 works as a seaman. He has no pain but yet makes use of a wrist joint capsule. Upon the follow-up 10½ years after the operation the joint was found to be slightly deformed, the hand was in radial deviation and the prosthesis was prominent dorsally. The mobility in the damaged right wrist joint is half that in the left and the strength of the hand is reduced. The X-ray examination shows a severely deforming arthritis both the radiocarpal and in the intercarpal joints.

In case 7 the result is good. He works as a clerk and uses a typewriter without pain. Mobility is only slightly limited, the strength of the hand slightly reduced. There is no deformity. X-rays 10 years after operation show good distance between the neighbouring bones. As a sign of initial arthritis there is slight tapering of the radial styloid process while otherwise conditions are the same as directly after the operation.

The results of the 7 substitution operations have thus produced satisfactory results in one case only after 10 years observation. In another case the clinical results was "fair", but the X-ray showed severely deforming arthritis. In 5 cases arthrodesis had to be performed after ½–3 years.

There is scarcely any doubt that the mechanical conditions pointed out by *Venable* had a decisive importance in the poor result. A navi-

cular prosthesis is an unattached foreign body in a preshaped cavity and is not, like the navicular bone, fixed by ligaments. A foreign body reaction must be expected both when using vitallium and acryl and this leads to the formation of fibrous tissue around the whole prosthesis, resulting in limited mobility. Moreover, with acryl prostheses "wearing" occurs producing increased tissue reaction according to *Scales*. This is confirmed by this investigation, since 2 of the 3 patients who went back to their work had hard work and severe deforming changes in the wrist joint resulted, while the 3rd patient who had easy work avoided these changes.

SUMMARY

A series of 7 cases of nonunited navicular fractures was treated by excision of the fragments and insertion of an acrylic prosthesis. The series was followed-up 9-11 years after operation.

In all 7 cases primary improvement of the wrist joint's mobility was obtained, 4 patients remained, however, unfit for work owing to pain. 1 patient was able to return to work after 4 months but a year after the operation the mobility of the wrist joint was severely limited; there was pain, reduced strength and swelling of the wrist joint. In these 5 cases the prosthesis was removed ½-3 years after the operation and radiocarpal arthrodesis was performed. It was only in 2 cases that the prosthesis was not removed,— 10 years after operation one of these has severely deforming arthritis in the radiocarpal joint but no pain, while the other has a good result. Radiologically only a slight arthritis can be found in this patient.

Thus the results of the 7 substitution operations were only satisfactory in one case.

The mechanical conditions for a navicular prosthesis have an important influence on the poor result, since the prosthesis is a loose foreign body in a preshaped cavity and a foreign body reaction must be expected; in addition although acryl has proved in experimental research that it is tolerated by the tissues, this substance provokes a powerful tissue reaction in the form of fibrosis when it is exposed to mechanical forces, especially wearing forces.

RESUME

Une série de 7 cas de fractures du scaphoïde, traités par excision des fragments et mise en place d'une prothèse acrylique, ont été réexaminés entre 9 et 11 ans après l'opération.

Chez tous les 7 on a observé une amélioration primaire de la mobilité du poignet. Toutefois, 4 malades n'ont pas retrouvé leur capacité de travail en raison de douleurs. Un malade avait pu reprendre son travail au bout de 4 mois, mais un an après l'opération la mobilité du poignet était fortement réduite, il y avait des douleurs, une diminution de la force et une enflure du poignet. Dans ces 5 cas, la prothèse avait été enlevée entre 6 mois et 3 ans après l'opération et l'on avait pratiqué l'arthrodèse radio-carpienne. Dans deux cas seulement, la prothèse n'a pas été enlevée. L'un avait 10 ans après l'opération une arthrose déformante prononcée dans l'articulation radio-carpienne, mais pas de douleur, tandis que chez l'autre le résultat était bon. A la radiographie, on n'a trouvé chez ces malades qu'une légère arthrose.

Ainsi, c'est seulement dans un cas que les résultats de cette opération de substitution ont été satisfaisants.

Les facteurs qui entrent en considération par rapport aux mauvais résultats obtenus sont les conditions mécaniques d'une prothèse du scaphoïde qui est un corps étranger introduit sans fixation dans une cavité préformée. Il faut s'attendre à une réaction au corps étranger. A cela s'ajoute que bien que les tissus tolèrent la résine acrylique, l'usure particulière de cette matière lorsqu'elle exposée à des effets mécaniques, provoque une forte réaction des tissus sous forme de fibrose.

ZUSAMMENFASSUNG

Eine Reihe von 7 Fällen nicht geheilter Kahnbeinbrüche wurde mittels Excision der Fragmente und Einsetzung einer Akrylprothese behandelt und 9–11 Jahre nach der Operation nachuntersucht. Bei allen erreichte man primär eine Besserung der Beweglichkeit des Handgelenkes, 4 Patienten wurden jedoch nicht arbeitsfähig wegen Schmerzen. 1 Patient konnte seine Arbeit nach 4 Monaten wiederaufnehmen, ein Jahr nach der Operation war jedoch die Beweglichkeit im Handgelenk stark eingeschränkt. Es bestanden Schmerzen, herabgesetzte Kraft und Schwellung des Handgelenkes. In diesen 5 Fällen wurde die Prothese ½–3 Jahre nach der Operation entfernt und eine radio-carpal Arthrodese vorgenommen. Nur in zwei Fällen wurde die Prothese nicht ent-

fernt -- der eine zeigt 10 Jahre nach der Operation eine schwere deformierende Arthrose im radio-carpal Gelenk, hat aber keine Schmerzen, während der andere ein gutes Resultat aufweist. Röntgenologisch findet man bei diesem Patienten nur leichte Arthrose.

Das Ergebnis in diesen 7 Substitutionsoperationen ist somit nur in einem Falle zufriedenstellend gewesen.

Von Bedeutung für das schlechte Ergebnis sind die mechanischen Verhältnisse im Zusammenhang mit der Navicularеprothese. Indem diese einen lose liegenden Fremdkörper in einem präformierten Hohlraum darstellt, muss eine Fremdkörperreaktion erwartet werden. Dazu kommt, dass obwohl es sich bei experimentellen Untersuchungen zeigte, dass Akryl vom Gewebe gut vertragen wird, dieser Stoff doch, wenn mechanischen Beanspruchungen und besonders Abnutzung ausgesetzt, eine starke fibröse Gewebsreaktion hervorrufen kann.

REFERENCES

Adams, J. D. & Leonard, R. D.: New England J. Med., *198*: 401, 1928.
Aleman, O.: Acta chir. scand., *80*: 217, 1937.
Andersen, K. & Therkelsen, F.: Ugeskr. læger, *112*: 868, 1950.
Armstrong, J. R.: Lancet, *1*: 537, 1941.
Armstrong, J. R.: Bone-Grafting in Treatment of Fractures. Livingstone L. T. D. Edinburg, 1945.
Barnard, L. & Stubbins, S. G.: J. Bone and Joint Surg., *30 A*: 98, 1948.
Barr, J. S., Elliston, W., Musnick, H., Delorme, Th. L., Hanelin, J. & Thibodeau, A.: J. Bone and Joint Surg., *35 A*: 609, 1953.
Bentzon, P. G. K. & Randløv-Madsen, Aa.: Nord. Med., *21*: 524, 1944.
Bentzon, P. G. K. & Randløv-Madsen, Aa.: Acta Orthop. Scand., *16*: 30, 1945.
Bertelsen, A.: Acta Orthop. Scand., *24*: 343, 1954.
Busch, E., Bing, J. & Hart Hansen, E.: Acta chir. scand., *97*: 410, 1948.
Böhler, L.: Die Tecknick der Knochenbruchbehandlung. Maudrich, Wien, 1957.
Cobey, M. C. & White, R. K.: J. Bone & Joint Surg., *28*: 757, 1946.
Collins, D. H.: Proc. royal. soc. med., *46*: 22, 1953.
Couble, A.: These Lyon, 1954–55.
Cutler, C. W.: The Hand, Its Disabilities and Diseases. W. B. Saunders Comp. Philadelphia & London, 1942.
Davidson, A. J. & Horwitz, M. T.: Ann. Surg., *108*: 291, 1938.
Detrie, P.: Mém. Acad. chir., *83*: 396, 1957.
Detrie, P.: Presse Méd., *64*: 1475, 1956.
Downing, F. H.: The Western Journal of Surg., Obstetrics & Gynecology, *59*: 127, 1951.
Dwyer, F. C.: J. Bone & Joint Surg., *31 B*: 572, 1949.
Düben, W. & Gelbke, H.: Acta Orthop. Scand., *26*: 25, 1956.
Geissendörfer, H.: Zbl. Chir., *75*: 906, 1950.
Gieseking, H.: Z. Orthop., *80*: 597, 1951.

Henrichsen, E., Jansen, K. & Krogh-Poulsen, W.: Acta Orthop. Scand., 22: 141, 1952.
Hirsch, M.: Wr. med. Wochr., *85*: 803, 1935.
Hirsch, M.: Wr. med. Wochr., *85*: 1086, 1935.
Legge, R. F.: West. J. Surg., *59*: 468, 1951.
Lindvall, S. B.: Nord. Med., *29*: 351, 1946.
Luck, J. V., Smith, H. M. A., Lacey, H. B. & Shands, A. R.: Arch. Surg., 57: 801, 1948.
Matti, H.: Zbl. Chir., *63*: 1442, 1936.
Matti, H. & Russe, O.: Zbl. Chir., *71*: 1149, 1944.
Merle d'Aubigné, R. & Tubiana, R.: Traumatismes anciens Généralités membre supérieur. Masson, Paris, 1958.
Metcalfe, J. W.: J. internat. College of Surg., 22: 459, 1954.
Murray, G.: J. Bone & Joint Surg., *28*: 749, 1946.
Newman, P.H. & Scales, J. T.: J. Bone & Joint Surg., *33 B*: 392, 1951.
Obletz, B. E. & Halbstein, B. M.: J. Bone & Joint Surg., *20*: 424, 1938.
Palmer, I.: Nord. Med., *16*: 3574, 1942.
Palmer, I. & Widén, A.: Acta chir. scand., *110*: 206, 1955.
Perey, O.: Acta Orthop. Scand., 23: 26, 1954.
Picaud, A.: Mém. Acad. Chir., 79: 200, 1953.
Randløv-Madsen, Aa.: Acta Orthop. Scand., *24*: 341, 1955.
Rasmussen, K. Bang: Personal communication to the author.
Rehbein, F.: Arch. klin. Chir., *260*: 356, 1948.
Rehbein, F. & Düben, W.: Arch. orthop. Unfallchir., *45*: 67, 1952.
Ritter, H. H.: Surg. Gynec. and Obst., *49*: 838, 1929.
Russe, O.: Wiederherst. Traumatol., *2*: 175, 1954.
Scales, J. T.: J. Bone & Joint Surg., *38 B*: 754, 1956.
Schnek, F.: Zbl. Chir., 57: 2600, 1930.
Smith, L. & Friedman, B.: J. Bone & Joint Surg., *38A*: 368, 1956.
Soto-Hall, R.: J.A.M.A., *129*: 335, 1945.
Soto-Hall, R. & Haldeman, K. O.: J. Bone & Joint Surg., 23: 841, 1941.
Speed, K.: Arch. Surg., 57: 251, 1948.
Speed, K.: Amer. J. Surg., 67: 197, 1945.
Stack, J. K.: Arch. Surg., 57: 245, 1948.
Stewart, M. J.: J. Bone & Joint Surg., *36 A*: 998, 1954.
Thornton, L.: South. M. J., *17*: 430, 1924.
Troyan, E. & de Mourgues, G.: Rev. chir. orthop., 45: 614, 1959.
Venable, C. S.: Amer. J. Surg., 67: 197, 1945.
Watson Jones, R.: Tractures and Joint Injuries. Livingstone, Edinburgh, 1956.
Waugh, R. L. & Reuling, L.: Amer. J. Surg., 67: 184, 1945.
Widén, A.: Nord. Med., *48*: 1013, 1952.