CAST-BRACING OF FRACTURES

A REPORT OF A WORKSHOP SPONSORED BY THE
COMMITTEE ON PROSTHETICS RESEARCH AND DEVELOPMENT
DIVISION OF ENGINEERING, NATIONAL RESEARCH COUNCIL

NATIONAL ACADEMY OF SCIENCES

1971

COMMITTEE ON PROSTHETICS RESEARCH AND DEVELOPMENT
DIVISION OF ENGINEERING-NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES--NATIONAL ACADEMY OF ENGINEERING

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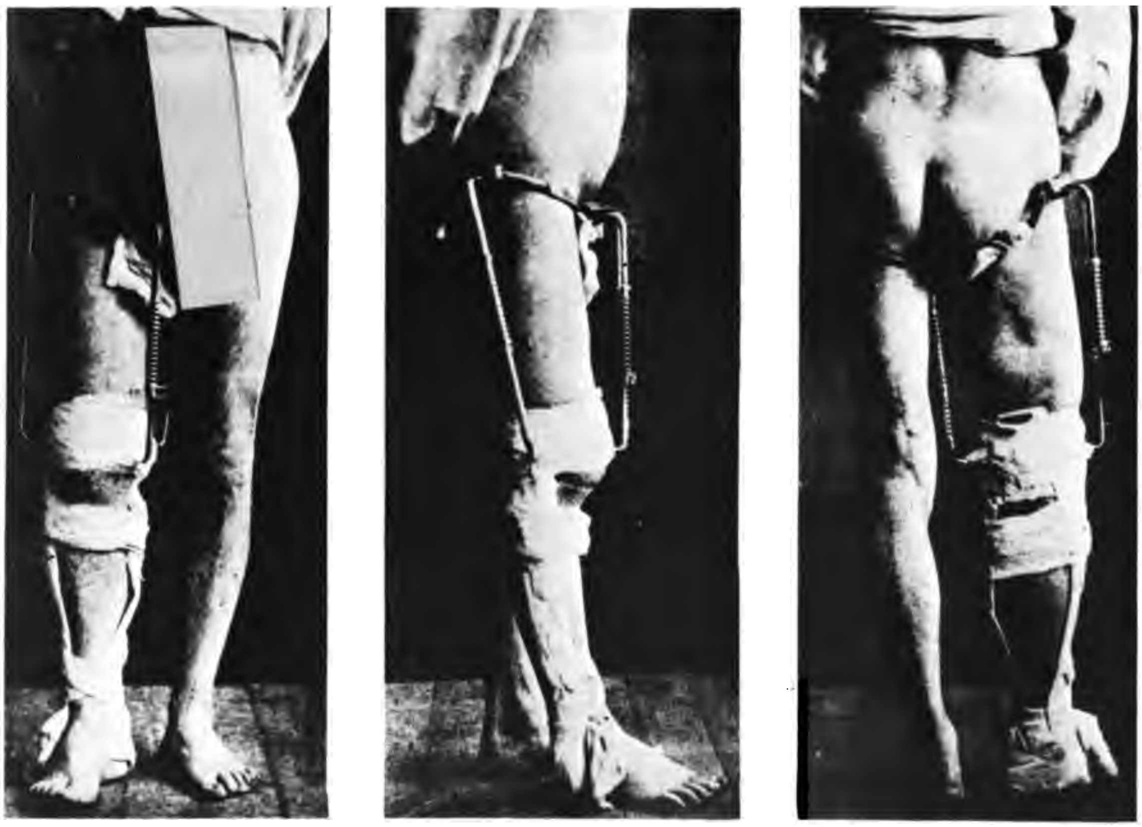

Frontispiece: Delbet's spring-loaded brace for the ambulatory treatment of femoral fractures, *circa* 1900.

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Held at

FITZSIMONS GENERAL HOSPITAL
DENVER, COLORADO
JANUARY 27-28, 1971

NATIONAL ACADEMY OF SCIENCES
Washington, D. C.
1971

This report was prepared as part of the work under Contract V1005M-1914 between the Veterans Administration and the National Academy of Sciences, and Contract No. SRS-71-7 between the Social and Rehabilitation Service, Department of Health, Education, and Welfare, and the National Academy of Sciences.

C O N T E N T S

WORKSHOP ON CAST-BRACING OF FRACTURES OF THE LOWER LIMBS

The Second Workshop Panel on Cast-Bracing of Fractures was held at Fitzsimons General Hospital, Denver, Colo., Wednesday and Thursday, Jan. 27-28, 1971. A copy of the agenda is attached as Appendix I and the list of participants is given in Appendix II. Essentially the program was organized to determine the current status of cast-bracing procedures for fractures of the tibia and femur. To this end, selected research groups working in these areas made formal presentations of their procedures and experiences following which a general discussion ensued.

The meeting was opened by Major General James A. Wier, Commanding General of Fitzsimons Hospital, who extended a hearty welcome to the participants.

The chairman of the meeting, Dr. Robert G. Thompson, in his opening remarks, referred to the first workshop conference on the use of prosthetic and orthotic techniques to promote and ensure healing of lower-extremity long-bone fractures which was held at Duke University February 1969. At that meeting Drs. Sarmiento, Brown, Mooney, and Connolly had presented their techniques of using a cast orthosis in the treatment of tibial and femoral fractures. Some information on the experimental use of cast-braces in fractures of the forearm was also presented. Apparently at that time satisfactory results were being obtained in the use of these techniques for the treatment of both tibial and femoral fractures. However, some problems were being encountered including (1) excessive swelling of the exposed knee area in some cases, particularly in patients with fractures of the femur; (2) variable amounts of ischial weight-bearing from cast to cast; (3) the greater complexity of the above-knee cast orthosis, requiring the services of an experienced orthotist to assist in its application.

The qualified consensus of the Duke meeting was that tibial fractures of any nature, open or closed, could be treated by functional below-knee walking orthoses beginning two to three weeks after the fracture occurred. Furthermore, fractures of the femur (usually of the distal third) could be treated with a long-leg cast orthosis after three to five weeks in balanced skeletal traction.

Since that conference two articles have appeared in the *Journal of Bone and Joint Surgery;* one in March 1970 by Augusto Sarmiento *A Functional Below-Knee Brace for Tibial Fractures*, and a second article in December 1970 by Mooney, Nickel, Harvey, and Snelson *Cast-Brace Treatment for Fractures of the Distal Part of the Femur*, relating their experiences with 150 patients with fractures of the femur. Both articles indicated a greater incidence of fracture healing and the achievement of near normal joint function in patients whose fractures were treated with a weight-bearing orthosis. The major drawback appeared to be the need for persons trained in orthotic techniques, in addition to the services of a knowledgeable orthopaedic surgeon. This requirement might well inhibit the widespread use of the technique.

The present conference was planned to update information in these areas, based on experience accumulated over the last two years. Hopefully, also, the discussions could lead to the development of a set of guidelines in the areas of treatment under consideration. Dr. Thompson mentioned that at the appropriate time the prosthetics-orthotics schools might be interested in the inclusion of cast-bracing material in their courses, which would have the effect of disseminating information to the orthopaedic residency programs.

NARRATIVE REPORT

A. TIBIAL FRACTURES

University of Miami

Speaking on behalf of the University of Miami, Dr. Augusto Sarmiento stated that in his opinion cast-bracing of a tibial fracture would have a permanent place in the treatment armamentarium if its advocates and practitioners did not make any serious mistakes.

The University of Miami group had become interested in fracture-cast-braces as a result of their experience with amputees, particularly the patellar-tendon-bearing prosthesis for the below-knee amputee. They were also aware of Dr. Ernst Dehne's work and it occurred to them that the proximal weight-bearing features of the PTB prosthesis could be incorporated into a brace-cast to bypass a fracture site.

After experimenting with various procedures the routine that they were now using in tibial fracture treatment was the application of a long-leg brace for approximately two or three weeks to allow swelling to subside and some "stickiness" to develop at the fracture site. Patients were then placed in a short-leg walking cast. Similar in proximal configuration to the PTB socket, this walking cast was then worn for a variable time, which might be two, three, or four weeks, depending on the particular patient. The patient was then switched to a plastic brace. The material now being used for this plastic device was Orthoplast, distributed by Johnson & Johnson.

Mr. William Sinclair had experimented with various types of ankle joints for the cast-brace. It had been found that the snugger the calf brace was applied the more critical was the placement of the ankle joint. This experimentation had led eventually to the development of the cable ankle joint now used in Miami.

Dr. Sarmiento emphasized that the amount of shortening initially accepted in the fractured limb did not increase with the use of the cast-brace. However, angulation at the fracture site may increase if an excessive amount is accepted when the cast is applied, and by "excessive" Dr. Sarmiento implied angulation in excess of 10 deg. The formation of large amounts of callus at the fracture site was not unusual in the functional treatment of fractures.

Dr. Sarmiento mentioned the 1855 article by Henry H. Smith *On the Treatment of Ununited Fracture by Means of Artificial Limbs*. Without being aware of this article, Dr. Sarmiento said he had used somewhat similar procedures for nonunion of fractures by applying a Phemister bone graft followed by a functional cast in two weeks. Dr. Sarmiento also mentioned the work of the Frenchman, Delbet, who a hundred years ago had described a functional splint which he recommended as primary treatment for fractures. Dr. Sarmiento indicated that possibly the use of a conventional cast for two to three weeks, followed by the application of the Delbet splint, would be satisfactory.

With regard to the ankle joint, further experimental work had involved the use of Orthoplast with a hole at the malleolus but no cable. The group had also gone one step further and used Orthoplast with a separate footpiece connected to the Orthoplast brace by a pivot at the ankle.

At Jackson Memorial Hospital and the Veterans Administration Hospital in Miami, 190 tibial fractures had been treated by the functional method. According to Dr. Sarmiento, not all fractures could be treated by this method and there was a place for use of Rush nails, plates, and other methods of treatment.

Fracture healing time for the series at the University of Miami was: average 15 weeks, longest 28 weeks, shortest 8 weeks. These data would indicate that functional treatment does not cause the fracture to heal faster. Little difference in healing time was noted regardless of which third of the tibia was fractured. In the Miami series the median shortening was one centimeter, maximum was 3.8 centimeters. It was Dr. Sarmiento's opinion that function not compression caused fractures to heal.

The Miami group was of the opinion, which seemed to be supported by pressure studies, that the patellar tendon does not contribute significantly to weight-bearing support, nor does the medial flare of the tibia as previously thought. Nevertheless the cast is still compressed at the patellar tendon and in the popliteal area, and the lateral and medial wings of the cast are contoured to the femoral condyles. It is now believed that pressures are distributed throughout the cast and that support is on the basis of hydraulic principles, i.e., the noncompressibility of the fluid constituents of the limb. It appeared that most pressure was taken on the gastrocnemius soleus muscle mass.

Dr. Sarmiento concluded by saying that the Miami experience had been written up a short time ago in the *Journal of Bone and Joint Surgery* (March 1970). He also reported that he was writing a manual on the procedures used at Jackson Memorial Hospital.

Mr. Sinclair continued the report on behalf of Miami. He stated that the ankle joints initially used were of the Klenzak type. However, with these joints patients could not remove their shoes readily. Moreover, the bars for the joint had to be bent and the whole procedure was quite time-consuming. This situation had led to experimentation with cables, many types and thicknesses being tried. The cable which had been found to be the most satisfactory was 3/8 in., six strands, six leads to the strand, with the cable fitting into a female tube for ready application and disconnect. The tubes were tapped with setscrews and inversion-eversion adjustments could be made.

An attempt was made to eliminate the lateral bars by using a posterior rod with a ball joint at the heel and a cable at the top. However, this had not been found to be satisfactory. Various distal applications of Orthoplast had been tried culminating in the design shown by Dr. Sarmiento with an Orthoplast saddle or shoe insert which allowed plantar- and dorsiflexion through a nut-and-bolt ankle joint. The patient could wear this device inside a shoe half a size larger than normal.

For fractures of the tibial plateau the cable ankle joint was used with an orthotic knee joint and an Orthoplast thigh cuff.

To conclude the University of Miami presentation, a movie showing the techniques for the bracing of tibial fractures at that institution was shown.

In the question period following the presentation some of the points made were: in the treatment of open fractures, debridement, irrigation, and immobilization in a long-leg cast were the initial procedures used with most of the open fractures left open, thanks to the influence of Dehne and Brown.

In answering the question as to the purpose and value of the Orthoplast cast-brace as compared to the plaster-of-Paris, Dr. Sarmiento cited the factors of lightness and comfort, especially for the elderly, and the facts that they were able to clean their feet and remove their shoes at night.

Further description of the Miami procedures may be found in Appendix III and in the reference cited.

Fitzsimons General Hospital

Dr. Paul Brown, formerly at Fitzsimons but now at the University of Colorado, stated that he had found civilian tibiae no different from Army tibiae and in his practice now is using essentially the same procedures he had followed at Fitzsimons. This practice had been greatly influenced by the work of Dehne and Sarmiento. He still believed in a long-leg cast to start with, but then moved to a Sarmiento-type short-leg walking cast. He stated that he didn't like the flexed-knee position in the initial cast but preferred an extended knee suspended with the foot up, which he felt relieved pain. With the long-leg cast and crutches, patients were able to stand the next day. Dr. Brown expressed the opinion that patients could safely take as much weight as they were willing to since at the beginning there were frequently crepitus, discomfort, and apprehension to prevent their overdoing it. Weight-bearing was increased according to the patient's tolerance, first with crutches and then with a cane and then without any supplementary support. Dr. Brown also emphasized the point that was implied by many other speakers to the effect that in the functional treatment of tibial fractures nonunions did not occur in contrast to the conventional treatment methods where such results were not uncommon.

Dr. Brown also discussed the treatment of open fractures. He spoke of debridement procedures involving removal of foreign matter and devitalized tissue and essentially leaving the wounds open with a covering of fine mesh gauze, sponges, etc. Dr. Brown mentioned that in some instances there was a greater amount of discharge resulting in sodden casts and a situation that was not good aesthetically. However, the wounds typically developed a granulation cover eventually and then epithelium. It was his opinion that cross leg graft flaps or similar procedures were unnecessary. Dr. Brown showed a picture from Delbet's book printed in 1916 which showed a group of patients in casts and with one or more crutches.

In general Dr. Brown's position, which is described more fully in Appendix IV and in his article in the *Journal of Bone and Joint Surgery* (January 1969), was to return the patients to function and to avoid "meddlesome, metalsome" surgery.

Following Dr. Brown's presentation Dr. Burkhalter presented five Fitzsimons Hospital patients who were ambulatory in casts. Dr. Burkhalter emphasized a number of points: (1) that patients were not received at Fitzsimons until two or three weeks or longer after injury; (2) that generally his patients were sick patients, i.e., they had weight loss, infection, malaria, or other debilitating conditions as well as the fracture, hence, his concern was to rehabilitate them as human beings; and (3) that the procedures followed were very much like those described by Dr. Sarmiento except that there was less tendency to free the knee for ambulation.

In the discussion following the presentations by Drs. Brown and Burkhalter, Dr. Thompson mentioned that it was his practice to close all open fractures as he felt that this procedure spared most patients the drainage that ensued from open treatment. Dr. Brown asked whether all closed fractures stayed closed, but received no unequivocal reply.

Rancho Los Amigos Hospital

In opening the presentation on behalf of Rancho Los Amigos Hospital, Dr. Mooney mentioned that so far all the focus had been on some method of providing function to fracture patients. This modern concept had derived from the work of Dehne, Brown, and Sarmiento who had found that it was not essential to immobilize the joints above and below the fracture site. With regard to the patients seen at Rancho Los Amigos Hospital, Dr. Mooney emphasized that many of them represented bottom-of-the-barrel cases who had been seen elsewhere initially and then referred to his care.

Dr. Mooney showed slides of patients treated at Rancho Los Amigos Hospital, Los Angeles Community Hospital, and in private practice. His remarks are summarized in Appendix V. Some of the key points made were:

1. Treatment considerations in institutions such as military hospitals or developmental laboratories are somewhat different from those that apply in private community practice. In the latter situation such considerations as availability of materials, time, and expense involved in application were quite critical. Hence, after trying various plastic fracture braces and making trials with the Sinclair-cable ankle joint the current practice was to rely primarily on full plaster casts.

2. In earlier experiences with the VAPC-PTB brace for nonunions of the tibia, attempts had been made to increase the amount of weight borne by the brace. However, patients had found such efforts to increase proximal weight-bearing intolerable. It was Dr. Mooney's current view that the brace maintained position of the fracture rather than contributed significantly to unloading the limb--at best the amount of unloading did not exceed approximately 10 per cent.

3. The control of edema by the fracture brace favored wound healing.

4. The current treatment of tibial-shaft fractures essentially involved application of a long-leg cast until the patient could walk with crutches only, followed by the use of the Sarmiento short-leg (plaster) brace using crutches, and then use of the gaiter à la Delbet. The healing times of his patients were similar to those reported by Dr. Sarmiento.

Also speaking on behalf of Rancho Los Amigos Hospital, Mr. Snelson reinforced Dr. Mooney's remarks concerning the difference in practice between community hospitals and other centers, remarking that sometimes plaster of Paris was the only material available. Mr. Snelson then went on to discuss procedures used from the point of view of the orthotist.

Northwestern University

Dr. Robert G. Thompson opened the presentation on behalf of Northwestern University but reported that, although some of his colleagues in private practice had had some experience at fracture cast-bracing, his own experience was limited.

Dr. Robert G. Addison, also associated with Northwestern University, indicated that his experience was limited primarily to private patients. In treating these patients he had principally used plaster-of-Paris casts, although one or two patients had been provided with cable ankle joints. Dr. Addison then went on to present some of the patients he had treated. In several of these cases the treatment of the fracture had been complicated by the presence of other problems.

A summary of the Northwestern University experience is included as Appendix VI.

In discussing the orthotic aspects of treatment, Mr. Fred Hampton reported that he had used Tubigrip between the proximofemoral segment and distal cast to reduce knee swelling. He had made several attempts to reduce the weight of the plaster-of-Paris cast but had not been very successful.

Vanderbilt University

Dr. John Connolly, reporting on behalf of Vanderbilt University, observed that all that were present at the workshop obviously were of the Dehne or Trueta school. Dr. Connolly then briefly reviewed some aspects of surgical history with particular emphasis on the open and closed treatment of fractures.

Dr. Connolly's paper is presented as Appendix VII.

Veterans Administration Hospital, Memphis

In opening his remarks Dr. Ernst Dehne stated that a fracture was a structural catastrophe, but it was also a physiological phenomenon in that a certain amount of effective stimulation of the fracture site was necessary for maximum healing. Commenting on the number of cast changes reported by other speakers, Dr. Dehne remarked that he tried not to change casts for nine to ten weeks unless there was a very good reason for doing so. Dr. Dehne also warned against the risk of overlooking vascular injuries in treating fracture cases.

One particular advantage of the functional treatment of braces that he had noted was that activity was contagious in that when some patients are ambulatory others desired to be ambulatory also.

Dr. Dehne's remarks on tibial-fracture treatment are amplified in Appendix VIII.

Valley Forge General Hospital

Dr. Philip Deffer reported that he had not done internal metal fixation in the treatment of tibial fractures since 1953. He reported that at Valley Forge only one trained orthotist was available to assist so that he had to apply his own plaster and train his own assistants to do so. His procedures were similar to those previously described in that he began with a long-leg plaster cast and then transferred to a short-leg plaster device. In his most recent series of patients, 91 had had open fractures, and 28 closed. His data on time lapse from injury to return to duty were: less than three months--nine patients; three to six months--63 patients; six to nine months--38; nine months or longer--19. Only six patients had leg-length losses of more than one inch and these were massively comminuted fractures.

Dr. Deffer's paper on tibial fractures is presented as Appendix IX.

B. FEMORAL FRACTURES

University of Miami

Speaking on behalf of the University of Miami, Dr. Sarmiento remarked that he had serious doubts as to the value of bracing for fractures of the femur. To be of real value the procedures must be practical. Dr. Sarmiento stated that he was aware of the possible complications with internal fixation methods of treatment. However, he was of the opinion that open reduction was the treatment of choice for a good percentage of the complicated cases. In his experience the morbidity in such cases had been very low. However, comminuted fractures of the lower end of the femur might present an area for the development of a cast-brace. A high percentage of fractures above the middle third tend to angulate.

After variable periods of traction, patients fitted with cast-braces and ambulated frequently developed excessive swelling at the knee joint.

Mr. Sinclair described the procedures used at the University of Miami for fabricating cast-braces for femoral fractures. He stated that he had first tried the VAPC-AK casting jig. However, this had not been practical as patients who had spent six weeks or more in bed would faint after being brought to the vertical position for application of the jig. Therefore, a switch had been made to the Seattle jig which could be applied with a patient in a horizontal position in bed.

Subsequently a change had been made to Orthoplast. Mr. Sinclair then described the fabrication procedures for this material. Two layers of stockinette were pulled over the leg, the Orthoplast was then measured and cut; after heating in water at 140 deg., it was wrapped around the thigh and secured with a lap joint. Trichloroethylene or carbon tetrachloride was used to enhance the self-adhesive qualities of the Orthoplast. An Ace bandage which had been dipped in cold water was then wrapped around the Orthoplast to expedite setting. Aluminum uprights had been used in the early stages with two 3/16 in. x 5/8 in. bars the preferred size, although the heavier bars had been used initially. In some few instances only the medial bar had been used and more recently only a lateral bar had been applied as in the VAPC single-bar brace application.

At the conclusion of the University of Miami presentation, a question was asked as to the purpose of the brace, whether it was simply to hold the thigh socket in place. Dr. Sarmiento stated that various conjectures could be made but they didn't really know what the brace actually accomplished.

Further discussion of the University of Miami procedures may be found in Appendix X.

Fitzsimons General Hospital

Colonel Burkhalter presented slides and a movie depicting patients treated at Fitzsimons General Hospital. Col. Burkhalter also presented two patients who were in Fitzsimons Hospital at the time. One had a right below-knee prosthesis as well as a long-leg brace for the fracture on the left limb. He was ambulatory without crutches.

Col. Burkhalter's remarks are amplified in Appendix XI.

Dr. Brown reported on the use of the cast-brace for fractured femurs as shown in Appendix XII.

Rancho Los Amigos Hospital

Dr. Mooney opened his remarks by observing that it was evident that the University of Miami group was in love with Orthoplast while the group at Rancho was enamored with plaster of Paris.

With regard to the shaping of the proximal brim area of the thigh section, Dr. Mooney reported that one of his prosthetists liked to use the Seattle jig. Various types of joints had been used including polycentric, single-axis, and posterior offset. Functionally, these various types of units were found to make little difference. However, the current tendency at Rancho was to use the polycentric hinges which provided more margin for error in obtaining coincidence with the anatomic knee joint. Other features of the RLAH fittings were the use of six in. stockinette or Spandex under the plaster and an elastic cage to prevent swelling at the knee, and a jig for location of the knee joints which was held in place with a temporary hose-clamp attachment for checking position as the knee joint was taken through its range of motion. A relatively conventional fracture-cast boot with a rubber sole was used. The foot was cast in the neutral position with respect to plantar- and dorsiflexion, but with some valgus.

Dr. Mooney expressed the opinion that taking off the shoe, as in plastic applications, was inadvisable in that it contributed to swelling of the foot and ankle. Pressures between the thigh and the cast of 1½ to 1 psi had been measured. It was estimated that initially the leg was unweighted by approximately 50 per cent, but in a week of walking, with loosening of the cast, this unweighting was often down to 10 per cent.

Mr. Snelson stressed the importance of the elastic sock under the cast and indicated that he preferred the geared polycentric joint which provided a greater margin for error. He mentioned that it took about an hour, with a helper, to apply a fracture femoral cast-brace in the Community hospital. He stressed the importance of "ranging" the knee during the fitting so that the patient could fully extend the knee in functioning with the brace.

The RLAH procedures and results are described in an article in the *Journal of Bone and Joint Surgery* (December 1970). Additional information may be found in Appendix XIII.

Northwestern University

Drs. Thompson and Addison spoke on behalf of Northwestern University and indicated that their experience in femoral fracture cast-bracing had been limited to fractures of the distal third of the femur. They had made one unsuccessful effort to use a cable ankle joint. However, the cable was of large diameter and long.

With regard to the question frequently raised as to whether the proximal segment of the brace actually took ischial weight-bearing, Northwestern's slides showed one aged female with decubitus ulcers at the ischium indicating that she <u>must</u> have had pressure in this area.

The Northwestern experience is more fully described in Appendix XIV.

In the discussion following the Northwestern University presentation, Mr. Berger asked why cable wasn't used as a knee joint if it had proven to be satisfactory as an ankle-joint material. Mr. Snelson replied that cable won't take the vertical loads imposed and wobbles when loaded. Cable also would rotate. Speaking from an engineering design viewpoint, Mr. Staros suggested that somebody had to specify what the joint should do, to which Dr. Thompson replied that primarily it should provide flexion and extension. Dr. Mooney again emphasized the need for the brace to provide stability against rotation.

Vanderbilt University

Reporting on behalf of Vanderbilt University, Dr. Connolly stated that he was sure that motion occurred at the fracture site and that the cast needed to be well molded to provide maximum support. He stated that he routinely used a pelvic band although there was some doubt as to whether this was needed except in fractures of the proximal third. If applied snugly the band does cut down on pelvic and trunk rotations.

Dr. Connolly reported that in the Vanderbilt series they had had no nonunions but had had two refractures, and a number of pressure sores had occurred.

Dr. Connolly's remarks are elaborated upon in the paper which appears as Appendix XV.

In discussion following Dr. Connolly's presentation, Dr. Habermann of New York University asked whether refractures were common. He also raised the question concerning the bayonet apposition which had appeared in some of the slides. Dr. Mooney replied that he had not had any refractures in 250 cases and had had only one nonunion. He did not correct bayonet apposition. Dr. Sarmiento stated that he had had some refractures but thought that this occurred in cases where the previous fracture had not fully healed.

Dr. Addison remarked that in the presentations thus far no common denominator had been found to account for the fracture healing that occurred. Dr. Sarmiento suggested that we should not give credit to the cast as much as to the "scarring" which occurred.

Veterans Administration Hospital, Memphis

In his presentation Dr. Dehne again spoke of the work of Delbet in using distraction springs and walking fracture patients in five to seven days. Dr. Dehne emphasized that in his own fracture-brace work he used a Steinmann pin in the tibia as a second line of defense. If he did not like the results of ambulatory treatment he could put the leg back in traction. Dr. Dehne mentioned that in later applications of the cast-brace he applied the device with the patient in a sitting position, made an X on the epicondyles of the knee, and located the hinges as close as he could to the knee centers.

Dr. Dehne mentioned that sometimes he could not apply the cast-brace immediately because of patients' brain damage or other injuries. However, in general, he preferred to apply the cast-brace as soon as he received the patient.

An elaboration of Dr. Dehne's remarks is attached as Appendix XVI.

Valley Forge General Hospital

In his remarks Dr. Deffer stated that the prime concern at Valley Forge in the treatment of fracture cases had been a reduction in hospitalization time, particularly in relation to the World War II experience. This goal had been achieved and his patients healed on an average of 5.7 months as compared to the time lapse of 13 months reported by DeLorme. Moreover, patients had been permitted to go home on leave well before the completion of healing.

Dr. Deffer described the procedures used in applying femoral cast-braces at Valley Forge, which are somewhat similar to those described by Dr. Mooney but with some variations.

Dr. Deffer's remarks are amplified in Appendix XVII.

C. GENERAL DISCUSSIONS

Following the presentations previously described, Dr. Thompson, as chairman of the meeting, sought to establish some consensus among the participants as to the role and effectiveness of cast-bracing. He proposed an opening statement to the effect that "evidence available to date has indicated that the use of cast orthoses (braces), with early ambulation, has been shown to provide effective treatment of fractures of the tibia and distal third (or half) of the femur with great assurance of bone healing and less detrimental effect on the body physiology."

Considerable discussion ensued following Dr. Thompson's opening statement during which it became evident that: 1) the orthopaedic surgeons present were not ready to reach a consensus on any aspect of the cast-brace treatment program; and 2) some of the participants questioned the advisability of formal courses to teach fracture cast-bracing procedures. An opinion was expressed that the procedures could be best taught at the centers where there was the greatest experience.

As the lack of consensus became evident, Dr. Paul Brown proposed a modified statement on which agreement might be reached. This statement read "Several orthopaedists have demonstrated in a significant number of cases that many fractures of the femur and tibia can be successfully treated by ambulation of the patient in some type of cast or cast-brace before a fracture is united." This statement was not debated but it did seem to summarize the evidence of the presentations given at the meeting.

D. RESEARCH NEEDS AND AIDS

In the final portion of the meeting consideration was given to areas in the cast-bracing procedures where further research is needed. Numerous items which require further study were identified, as listed below:

1. Brim shape and/or weight-bearing characteristics of the cast-brace. It was suggested by some that the emphasis in this area be on clinical research but with some prior basic research.

Specific questions raised were "should a thigh cast be ischial weight-bearing, and if so how much?" Specific needs cited in the brim area were: a socket to finish off a cast which would reduce its thickness to about 1/16 in. in the perineum; and better provision for maintaining personal hygiene.

2. Does the proximal socket stabilize the femur and if so what are the requirements to achieve this stabilization?

3. How can we control angulation and rotation of the femur, particularly with respect to fractures in the proximal third?

4. How can we prevent or control swelling in the knee and ankle joints?

5. How can we control recurvatum, varus, and valgus of the tibia?

6. In tibial fractures, is it possible to reduce the period of time the long-leg cast is worn before transferring the patient to a short-leg walking cast?

7. The measurement of pressures inside the leg and between the leg and the cast-brace; specifically, what is the significance of myostatic or hydrostatic pressures in the stabilization of bone?

8. Improved knee joints are needed. These should be easy to apply and provide ready conformity to the thigh and shank sections of the limb. Accessory suggestions in this area were for a simple, practical, knee-joint alignment jig and a self-adjusting or self-aligning knee joint.

9. A cast material, as convenient and easy to apply as plaster of Paris but much lighter, is needed.

10. How critical is it to have the socket or cuff fit closely to the limb, and if close fit is important what are the relative merits of plaster-of-Paris and plastic materials in this regard?

11. What are the effects of alignment on the outcomes of bracing (angulation, rotation, etc.)?

12. In the femoral cast-brace, how much calf material is necessary to provide adequate support and stabilization during ambulation, and in fact is a shank cuff necessary at all in this application?

It was emphasized that the solutions for all the items listed and problems raised must be practical.

E. EPILOGUE

(by Robert G. Thompson, M.D.
Chairman of the Workshop)

It had been the chairman's opinion that, at the conclusion of this workshop on fracture cast-bracing, a set of guidelines could be formulated to aid others of the orthopaedic community in the safe use of these techniques. However, after extended discussion, no general agreement could be reached by the major contributors. Nevertheless, your chairman, who has observed these developments from the beginning, and has had a limited personal experience with the several methods promulgated, has set down what he believes to be a reasonable and safe set of guiding principles in the use of orthotic-type fixations for long-bone fractures of the lower extremities with early ambulation. These guidelines follow.

General Statement

The use of a cast-orthosis (brace) with early ambulation has shown early promise to provide effective treatment of fractures of the tibia and the distal half of the femur with greater assurance of bone healing and with less detrimental effect on the body physiology than treatment methods previously used. The effective use of this method depends greatly on observance of the following considerations:

I. Personnel

A knowledgeable orthopaedic surgeon and a trained orthotist or prosthetist are needed.

II. Types of Fractures Treated

a. Closed or open tibial-shaft fractures (transverse, oblique, or comminuted), including selected proximal condylar area fractures and selected fracture dislocations of the ankle area.

b. Closed or open fractures of the distal half of the femur down to and including the supracondylar area.

III. Tibia

a. Closed fractures (initial treatment)

All participants agreed that the fracture (transverse, oblique, or comminuted) should be reduced with attention to alignment, rotation, and length, with or without general anesthesia.

1. A long-leg, minimally padded plaster cast with the knee in zero degrees of extension, or in only a few degrees of flexion, is then applied to remain a variable time from two to four weeks.

2. Cast-brace treatment. After the initial edema has subsided with beginning evidence of fracture stability noted, and physician acceptance of the alignment, reduction, and bone length obtained, a below-knee plaster cast of the patellar-tendon-bearing type is applied to allow early weight-bearing function. (If excessive bone shortening has developed, a decision has to be made at this time whether to allow the length discrepancy to remain or to do open surgery with internal fixation.)

(a) The foot and ankle joint may be included in the cast, and a walking heel applied to the bottom of the cast.

(b) Alternatively, the foot and ankle joint may be freed by use of a removable shoe attached to the cast by a brace joint. (For details see *A Functional Below-the-Knee Brace for Tibial Fractures* by A. Sarmiento, J. Bone Joint Surg., 52A:295-311, March 1970.)

3. Rehabilitation activities. Ambulation on cast or orthosis progressing to full weight-bearing two to five weeks postinjury.

b. Open fractures of the tibia

The consensus of the conference was minimal debridement of skin with maximal debridement of devitalized muscle tissue. The skin is then closed primarily, or allowed to remain open, depending on the decision of the surgeon. Subsequent treatment of the fracture (either open or closed) is as discussed under a. above.

NOTE: The decision to use a patellar-tendon-bearing weight-bearing plaster cast with foot included, or to use a below-knee orthosis of Orthoplast (Polysar) material with proximal patellar-tendon-bearing trim line with or without attached ankle portion, is a point of discretion in the technique, depending on the availability of an orthotist. It seems that nearly identical results may be obtained by either technique.

IV. Femur (Initial Treatment)

a. Closed fractures

Reduction of the fracture of the mid-shaft or distal third (transverse or oblique), either by manipulation or reduction traction (skeletal traction preferred).

1. Use of floating Thomas splint or some such modified traction device. Maintenance of said traction, and fracture length and alignment, for a few days to four to six weeks.

2. Application of cast brace (orthosis)

(a) Leg removed from traction apparatus when fractured area reveals early stability with traction weight removed, and with usually minimal pain experienced on fracture area manipulation. X-ray may show early bony callus. (If the bone shortening present is unacceptable, an open reduction may be required.)

3. Application of the thigh portion of the orthosis using principles of quadrilateral above-knee socket shape at the outlet. A Spandex stump sock with toe removed is used over the skin.

(a) Rigid material may be plaster of Paris or Orthoplast (Polysar).

(b) Preformed plastic brims may be used.

(c) Seattle casting fixture (to form quadrilateral shape in proximal plaster-thigh portion) is used by some.

4. Knee

Fixed hinge joint (four varieties available). Alignment of hinges is important to provide maximum knee range of motion.

(a) Alignment jig for knee hinges is essential.

5. Lower leg portion

(a) Material may be plaster of Paris or Orthoplast.

(b) Proximal end to be trimmed in accordance with patellar-tendon-bearing trim line techniques.

6. Foot and ankle

(a) Continuation of below-knee plaster cast to include foot at right angles to the tibia, or

(b) Shoe orthosis attachment with removable shoe (similar to that used on a below-knee orthosis).

7. Rehabilitation activities

(a) Ambulation with crutches progressing to full weight-bearing one to two weeks post-orthosis application, and

(b) Continuation of cast-brace and ambulation to definitive fracture healing.

(1) Observation for angulation deformities of the femoral shaft during this period is essential and correction of excessive angulation is important. A general consensus was that no more than ten degrees of angulation of the femoral shaft should be tolerated.

b. Open fractures

Minimal skin resection but adequate debridement of devitalized muscle tissue. Skin closed primarily or allowed to remain open at the discretion of the operating surgeon.

1. Application of cast orthosis to be identical to that used for closed femur fractures.

NOTE: It is to be emphasized that the above guidelines do not represent a set of principles <u>agreed to</u> by the major participants in the workshop, but do indicate the chairman's evaluation of the various opinions and techniques presented. Anyone wishing to use an approach of this nature (cast-bracing) would do well to make a personal visit to one of the facilities with wide experience in the technique and observe the procedures at first hand.

June 30, 1971

A G E N D A

SECOND WORKSHOP ON CAST-BRACING OF FRACTURES

Committee on Prosthetics Research and Development
Division of Engineering-National Research Council
National Academy of Sciences--National Academy of Engineering

Fitzsimons General Hospital, Denver, Colorado

9:00 a.m., January 27-28, 1971

Wednesday, January 27

ORIENTATION	Robert G. Thompson, Chairman
NARRATIVE REPORT	
A. TIBIAL FRACTURES	
University of Miami	Augusto Sarmiento
Fitzsimons General Hospital	William E. Burkhalter et al.
Rancho Los Amigos Hospital	Vert Mooney
Northwestern University	Robert G. Addison and Robert G. Thompson
Vanderbilt University	John Connolly
Veterans Administration Hospital	Ernst Dehne
Valley Forge General Hospital	Philip Deffer

Thursday, January 28

B. FEMORAL FRACTURES	
University of Miami	Augusto Sarmiento
Fitzsimons General Hospital	William E. Burkhalter et al.
Rancho Los Amigos Hospital	Vert Mooney
Northwestern University	Robert G. Addison and Robert G. Thompson
Vanderbilt University	John Connolly
Veterans Administration Hospital	Ernst Dehne
Valley Forge General Hospital	Philip Deffer
C. GENERAL DISCUSSIONS	
D. RESEARCH NEEDS AND AIDS	
E. EPILOGUE	Robert G. Thompson

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TIBIAL

FRACTURES

TIBIAL FRACTURES

Augusto Sarmiento, M.D., and William Sinclair, C.P.O.
University of Miami School of Medicine, Miami, Fla.

The investigators reported on their experiences with functional casting and bracing of tibial fractures since their first studies were conducted in 1963[2]. The initial success with a below-the-knee cast, molded in the manner of a total-contact PTB prosthesis (Fig. 1), soon led to experimentation with methods of treatment that would free the ankle and knee joints as well[3].

Fig. 1. Functional short-leg total-contact cast for tibial fractures usually applied 2 weeks after the initial injury.

They presented statistical data on 190 tibial fractures treated with functional braces applied after a period of stabilization in plaster-of-Paris casts. They concluded that bracing is applicable to most tibial fractures providing that certain prerequisites are met. Alignment of the fracture fragments must be obtained as early as possible, followed by immobilization of the limb in a toe-to-groin cast. This is the critical time when restoration of length and alignment is best obtained. It is possible in most instances to replace the toe-to-groin cast for a below-the-knee functional cast two weeks after the initial injury. Massive soft-tissue damage, excessive swelling or other associated problems might make it necessary to delay the application of the short-leg cast. It was reported that in a few instances excessively large soft-tissue masses around the fracture fragments precluded the obtaining of satisfactory alignment of the fragments and required subsequent internal stabilization procedures. During the period of immobilization in the toe-to-groin cast, weight-bearing ambulation may be permitted provided that the alignment of the fragments is adequate, swelling is not excessive, and activity is not accompanied by pain.

After this average two-week period of immobilization in the toe-to-groin cast and following the application of the below-the-knee functional cast, the patient is allowed to bear weight on the injured limb. In most cases, it is possible to discard all types of external support within the following two weeks. Pain at the fracture site calls for the use of crutches and gradual progression to greater weight-bearing. Alignment of the fragments may be improved during the application of the below-the-knee cast. Angulatory deformities cannot be accepted because of the likelihood of increased deformity upon resumption of weight-bearing ambulation. This is more likely to occur in fractures of the distal tibia with angulation present on the lateral plane. Shortening does not seem to increase over that accepted at the time of application of the first below-the-knee cast.

After the two-week period of activity and ambulation in the below-the-knee functional cast, it has been possible to transfer patients to functional braces that permit motion of the ankle and knee joints. Attempts to bypass or shorten this period of time have been generally accompanied by the development of ankle and foot swelling of varying degrees of significance. Once the brace is completed, it is best to advise the patient to avoid prolonged periods of ambulation for the first few days and to elevate the limb while sitting. It may be anticipated that, in most instances, discomfort of the ankle will subside after that initial period of time. The rate of success with this method of treatment has been encouraging. In 190 instances when this regimen was carefully followed and no more than six weeks had elapsed since the initial injury and the application of the first brace, no nonunions were encountered. The average shortening was 6.5 millimeters and the maximum was 2 centimeters. As in the case of tibial fractures treated by the functional below-the-knee cast, no additional shortening was observed following the onset of weight-bearing ambulation (Figs. 2 and 3). Similarly angulatory deformities did not increase over the ones accepted at the time of application of the first brace.

Fig. 2. Roentgenogram of oblique fracture of the tibia and fibula taken through Orthoplast functional below-the-knee brace.

Fig. 3. (Same patient) Final roentgenogram illustrating the satisfactory alignment of the healed tibial and fibular fractures.

The investigators also reported on their experiences with the use of thermoplastic materials as a substitute for plaster of Paris[1,4] and demonstrated the technique of application of Orthoplast braces (Fig. 4). The technology seems to have developed to the point that bracing with this material is practical and expeditious. The material is durable, cooler, and lighter than plaster, and it can be cleaned easily. Results from the use of this material in 95 cases revealed that the healing time and behavior of tibial fractures are not influenced by the material used in the fabrication of the brace.

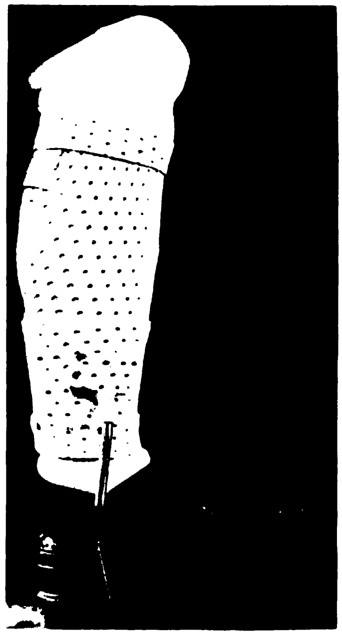

Fig. 4. Orthoplast short-leg functional brace with the flexible cable joint.

The investigators also reported and demonstrated a flexion cable ankle joint which they have used in 120 consecutive cases. This joint permits flexion and extension of the ankle and eliminates the need for great precision in its placement in relation to the anatomical joint. The donning and removal of the shoe is rapid and simple (Fig. 5).

They stated that their experiences with other pathological situations, such as delayed unions of the tibia, bone grafts, and osteotomies, served to demonstrate that in order to obtain maximum benefits from functional bracing it is best to institute functional activity during the first few weeks after the initial insult. Satisfactory results from these methods are otherwise likely to be less consistent.

Fig. 5. Illustration of a disassembled flexible cable joint.

They discussed their ideas regarding the favorable effects of function in the healing of fractures and the possibilities that the successful application of the principle of incompressibility of fluids[1,4]--

by the compression of soft tissue masses with high water content--may be partially responsible for the maintenance of length of the fractured extremity despite the vertical loading brought about during ambulation (Fig. 6).

Encouraging experiences with nonarticulated plastic splints seem to strengthen the validity of this hypothesis (Figs. 7, 8, and 9).

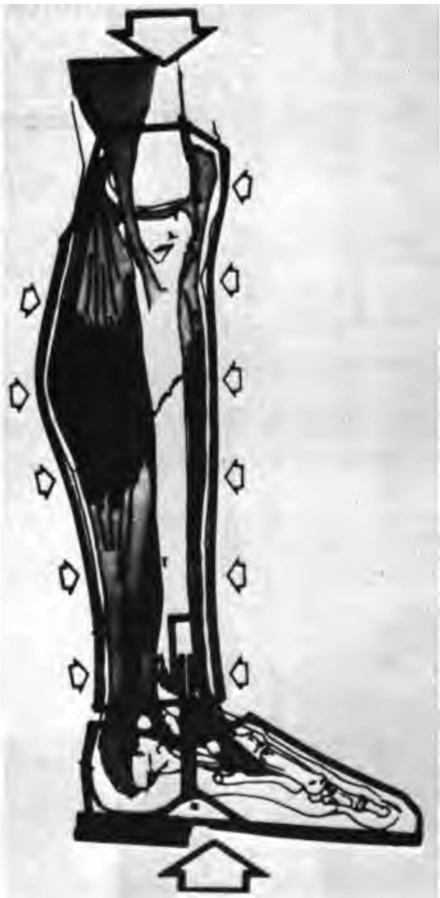

Fig. 6. Schematic drawing of proposed theory concerning the distribution of pressures in the injured limb based on the principles of incompressibility of fluids.

Fig. 7. Nonarticulated Orthoplast splint used in several instances with encouraging results.

Fig. 8, *left*. A roentgenogram of comminuted fracture of the tibia and fibula taken through Orthoplast nonarticulated splint obtained four weeks after the initial injury.

Fig. 9, *right*. (Same patient) The roentgenogram illustrating the fractures of the tibia and fibula healed with satisfactory alignment.

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1. Committee on Prosthetics Research and Development, National Academy of Sciences, *Fracture bracing*, February 1969.

2. Sarmiento, Augusto, *A functional below-the-knee cast for tibial fractures*, J. Bone Joint Surg., 49-A:5:855-875, July 1967.

3. Sarmiento, A., and W. F. Sinclair, *Application of prosthetics-orthotics principles to treatment of fractures*, Artif. Limbs, 11:2:28-32, Autumn 1967.

4. Sarmiento, Augusto, *A functional below-the-knee brace for tibial fractures*, J. Bone Joint Surg., 52-A:2:295-311, March 1970.

THE EARLY WEIGHT-BEARING MANAGEMENT OF TIBIAL FRACTURES, OPEN AND CLOSED

by Paul W. Brown, M.D.*
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Since my transition to civilian practice a year and a half ago, I have had the opportunity to apply so-called military methods of treatment to approximately 60 nonmilitary fractures of the tibia. The basic method, as previously described, was the immediate application of a straight-knee long-leg cast (Figs. 1-A and 1-B), followed by graduated weight-bearing in the cast as soon as possible following the injury and preferably within a day or two of onset. As with the military fractures, these fractures have healed well with some cost in angulation (up to ten deg.), shortening of up to 1.5 cm., an occasional bony protuberance under the skin, and some rather grotesque x-rays. However, the primary goal has been achieved without exception: bony union without surgical complication and functional extremities in functioning patients. Patients with closed uncomplicated fractures

Fig. 1-A. Application of the Cast. Most tibial fractures can be reduced in this position with time, patience, gentle manipulation and manual traction. Following reduction, one layer of sheet wadding is placed from toes to knee followed by two 6-in. rolls of plaster.

Fig. 1-B. When the short-leg cast is set the knee is extended fully (0 deg.) and a reinforced closely molded long-leg cast is applied.

*formerly at Fitzsimons General Hospital usually spent five or six days in the hospital and most obtained full weight bearing on the injured extremity in two to three weeks from the time of injury. Less discomfort was experienced and earlier weight-bearing was accomplished if the fracture was reduced, i.e., aligned, within 12 hours of injury, and placed in a straight-knee nonpadded cast which was then suspended from a traction frame overnight. The next day the patient was encouraged to get up on crutches and to take as much weight on the plaster cast as could be comfortably tolerated. Guidance, crutch training, patience, encouragement, and sympathy were essential if the patient was to progress in weight-bearing.

Many patients had been placed in bent-knee long-leg casts prior to admission to our hospital. We promptly changed the casts to straight-knee plaster casts and most of these patients immediately volunteered the information that they were much more comfortable with the knee in the straight position (Figs. 2-A, 2-B, and 2-C). While learning to ambulate during the first two weeks, patients were instructed to avoid dependency of the extremity, and to keep the plaster cast supported or elevated between walking sessions. They were told to keep the extremity elevated when not actually up and in motion. Sitting or standing around was discouraged. With this regimen painful swelling was rare and it was seldom necessary to bivalve or change a plaster cast because of swelling, particularly if the plaster cast was applied within 12 hours of injury. The plaster cast was changed only if it became loose or if the patient stated it was uncomfortable. It was our feeling that the fewer the number of plaster changes the more prompt was the union, and conversely that multiple plaster changes prolonged the healing time of the fracture.

Since the publication of Sarmiento's work, I have gradually adopted his short-leg cast as an adjunct to our method, at least with the simpler types of tibial fractures. I still start with the long-leg cast, but if the fracture is inherently stable at about six weeks the plaster cast is converted to the Sarmiento type. Freeing the knee adds much to the convenience of living. For the badly comminuted or the extremely unstable or complicated types of fractures, I prefer to remain with the long-leg plaster cast until the fracture is healed.

Fig. 2-A, *top*. This patient incurred a closed oblique midshaft fracture of the tibia while skiing. The fracture was reduced 18 hr. prior to this photo and a bent-knee plaster dressing applied. He complained of pain.

Fig. 2-B, *middle*. The plaster cast has been changed to a straight knee plaster cast and the patient is now comfortable.

Fig. 2-C, *left*. Three days postinjury the patient was bearing approximately 40 per cent of body weight on the injured extremity.

Control of angulation is still a difficult problem with many tibial fractures. How effectively we control it is generally a measure of good plaster discipline, and we cling to the concept of a nonpadded closely conforming total-contact plaster cast carefully molded about the knee. Most of the angulation should be corrected at the time of initial reduction, but in some oblique fractures, particularly of the lower third of the shaft, a residual or recurrent angulation of 10 to 15 deg. may be apparent and this is best corrected by either a change of plaster during the first two weeks or by wedging of the plaster cast (Figs. 3-A and 3-B).

Age, weight, sex, bilaterality or comminution have not proven to be deterrents to this treatment (Figs. 4-A and 4-B). Personality factors may be deterrents; the timid, fearful, or poorly motivated patient is much more difficult to convince that he may safely and comfortably bear weight on the injured extremity than is the patient who is anxious to get back to work. I have found that elderly or even very aged patients do very well with this method (Figs. 5-A and 5-B).

OPEN FRACTURES

The presence of large wounds accompanying the fracture has not contraindicated this treatment, and it is our impression that healing has been facilitated by returning the extremity to active motion and weight-bearing. The healing of large wounds of 100 sq. cm. or more may be expedited by the use of split-thickness skin grafts, but in no case have drastic and often damaging surgical procedures such as cross-leg pedicle flaps, rotation flaps, tubed pedicles, or relaxing incisions been necessary. In our experience at Fitzsimons with over 400 open fractures of the tibia, often associated with massive wounds and soft-tissue loss, none of these procedures to obtain skin coverage has been used. We are now successfully applying the same technique of ignoring the wound in our civilian cases at the University of Colorado Medical Center (Figs. 6-A through 6-E). There is nothing new about this approach as it is simply a further modification of the Orr-Trueta method of open-fracture management.

Fig. 3-A. A closed oblique fracture of the lower tibia and fibula 11 days after a skiing accident. Weight-bearing started during the first week.

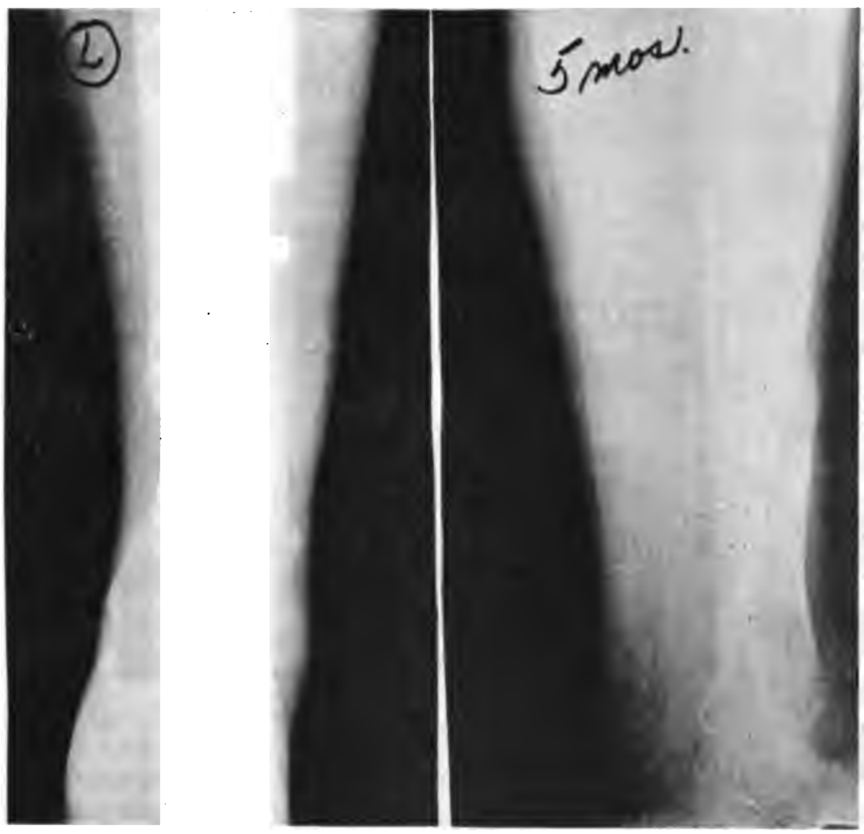

Fig. 3-B. Five months postinjury. No disability. Less than 1 cm. of shortening. Total time in plaster ten weeks.

Fig. 4-A. Open comminuted fracture of lower tibia and fibula incurred in combat: three weeks after injury. Weight-bearing in plaster started at this time.

Fig. 4-B. Ten months postinjury. No disability and no drainage: 1.2 cm. of shortening. Total time in plaster five months.

Fig. 5-A. A 63-year-old woman incurred this spiral fracture while skiing. Proximal to this fracture was a healed tibial fracture treated over 40 years previously.

Fig. 5-B. Four years later. Patient was treated by immediate ambulation in a long-leg straight-knee cast. She is again an active skier.

Fig. 6-A. Day of injury. Tractor rolled over on leg causing a displaced transverse fracture of the tibial and fibular metaphysis; grossly contaminated with large wounds on medial and lateral aspects of leg. Debrided, copiously irrigated, wounds left open and long-leg plaster cast applied. Weight-bearing started on fifth day.

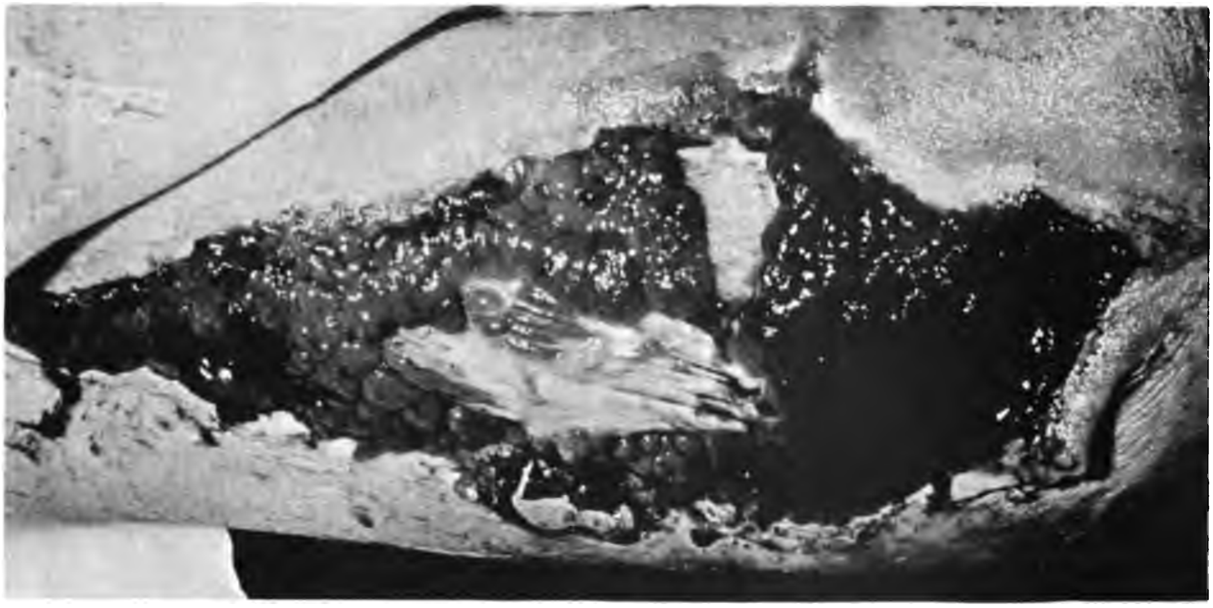

Fig. 6-B. Five weeks after injury. Granulations are beginning to cover the exposed bone and fracture site.

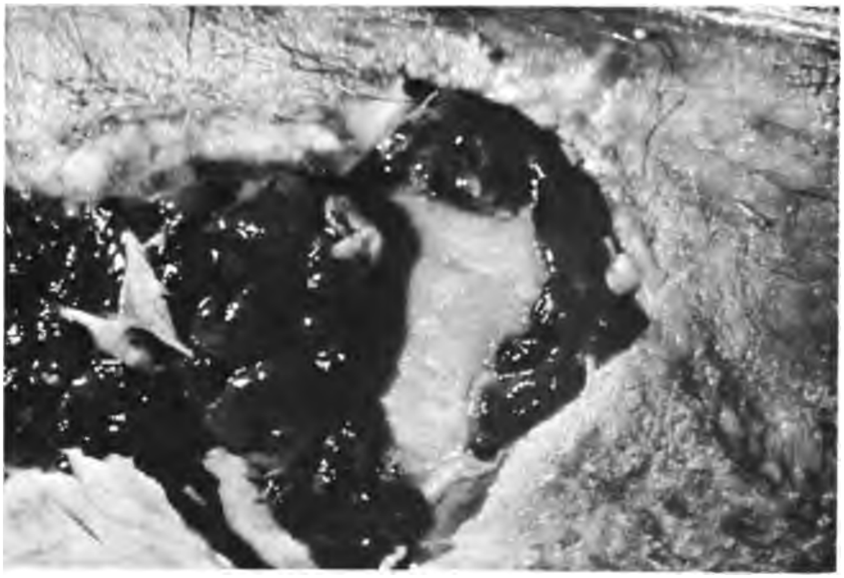

Fig. 6-C. Twelve weeks after injury. Close-up of granulations. Gross motion at fracture site. Copious pus. Patient walking comfortably without crutches or cane.

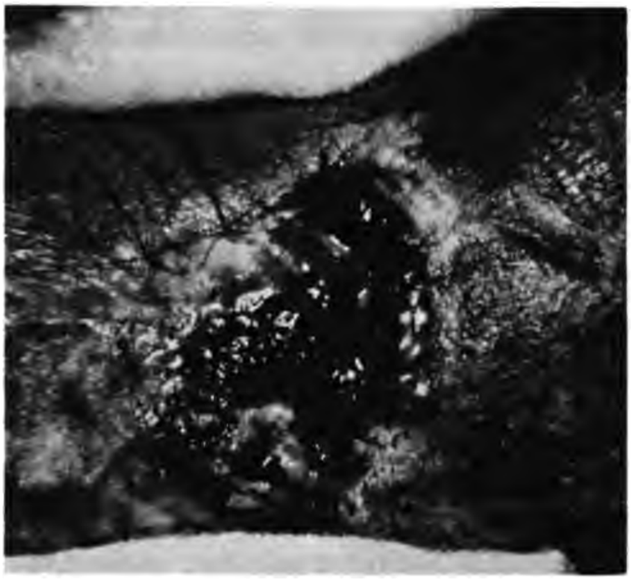

Fig. 6-D. Sixteen weeks after injury. Granulations are now covering the bone. Less motion at fracture site.

Fig. 6-E. Eighteen weeks after injury. Wound closed. Drainage has ceased. Fracture is solid.

A large segment of the surgical establishment believes in the "morbidity of the open wound," and open wounds with exposed bone seem particularly offensive to this group. It is widely believed and actively practiced that exposed bone is a very bad thing and that something, regardless of cost, must be done to cover the bone. As corollaries to this doctrine it is said that exposed bone is dead bone and that exposed bone is infected bone. Our experiences lead us to believe that while it is better to have bone covered than exposed, it is not such a bad situation that harmful procedures must be done in order to cover that bone, and most such procedures often turn out to be harmful. We have demonstrated in many hundreds of cases that if the extremity is made to function, if the muscles regularly contract and relax, if circulation is stimulated through function, and if edema is decreased by avoidance of static dependency, exposed bone will ultimately be covered by granulations and then by epithelium, and in a way which is quite compatible with the normal function of the extremity.

Is exposed bone dead bone? The point has never been proven, but it has certainly been assumed. We are attempting to find this out with controlled animal experiments and our initial investigations indicate that, if the periosteum is removed and the bone left exposed, the superficial layers of bone will become necrotic. How deeply this layer of necrosis will extend apparently depends on the condition of the surrounding bone and underlying tissues and many other factors which we have yet to define. Whether dead or not is not too important from a clinical point of view as we have found that unless this exposed bone is completely devascularized or massively infected, when it is covered with granulations it ultimately becomes revascularized and does not sequestrate. To say that exposed bone is dead bone presents a half truth which distorts or overstates its clinical significance.

The second assumed corollary is that exposed bone is infected bone. In most cases this is fallacious as no attempt has been made to delineate contamination from infection or to distinguish saprophytic from pathogenic organisms. All open wounds drain, and often they drain pus; but the presence of pus does not necessarily mean the wound is infected. It is the nature, appearance, and response of the tissues in and around the wound that determine whether or not there is infection. It is the progress of events in that wound that tells us whether or not the wound is coping with the situation and whether or not it is dealing with the contaminating organisms. The medieval concept of laudable pus perhaps was not so laughable, and we have tended to confuse aesthetics with bacteriology. It is a shock to the uninitiated to remove a sodden, malodorous plaster cast from an extremity with a fractured tibia overlain by a large wound and find the wound awash with copious amounts of frank pus. The sight is unappetizing and the stench may be staggering but, when the pus is washed away and the deodorizer has been sprayed around the room by the offended attending nurse, examination of this "infected" wound shows healthy granulations about the wound margins or perhaps covering the wound, and comparison with previous examinations invariably shows the size of the wound to have decreased.

Vigorous cleansing of such a wound, application of topical antibiotics or other medications, prying, probing, undermining or operating on such a wound will simply delay the wound-healing process. If the fracture site is exposed it too will cover spontaneously with these granulations, and if left undisturbed and the extremity supported with a plaster cast and returned to function the fracture will heal, as I have observed many times. These observations have convinced me that wounds and open fracture sites are quite tolerant of exposure. They very definitely are not tolerant of attempts to close the wound prematurely, and it has been my undeviating policy for many years to leave an open fracture open: debride it, irrigate it, and reduce it, but don't close it. With this approach, wound breakdowns, prolonged infection, pain, and osteomyelitis are far less common than with primary closure of open fractures.

The principles of debridement and nonclosure, or at least delayed closure, of wounds and open fractures have been proven and reproven in military practice in all the wars of the past century. They have been most successfully applied during the present Vietnam conflict. There has been an unfortunate and sometimes tragic tendency on the part of the medical profession to separate military from civilian practice, and it is ironic that in civilian practice I see proportionately many more complications, such as wound breakdown, as a result of inadequate debridement and premature closure than I saw in the military where the nature of these wounds and the environment in which they were incurred were so much more severe.

The incidence of clostridial infections in my military practice was extremely low; two cases, I believe, in my last ten years of military duty. I have seen three cases in my past year of civilian practice, all following primary closure of wounds. During and for several years after World War II our military hospitals had hundreds of cases of delayed or non-union of the tibia with sinuses, continuous drainage and osteomyelitis, and many of these ultimately were treated by amputation. Many of these fractures had been subjected to open internal fixation, bone grafts, cross-leg pedicle flaps, and premature closure. Our military hospitals today, dealing with the same type of injuries, do not have this experience as these fractures are seldom operated upon and they are usually not closed until late. Today these fractures are uniting without infection and the net results are functional extremities and functional patients.

THE USE OF CAST-BRACE FOR TIBIAL FRACTURES

by Vert Mooney, M.D.
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FRACTURE BRACING FOR TIBIAL SHAFT FRACTURES

In our experience we have not found it generally practical to use fracture bracing for tibial shaft fractures. We have been advocates of the ambulatory methods of fracture care, and the approach used has been a combination of the methods advocated by Paul Brown and Augusto Sarmiento. We believe that symptomatic status is one of the best guides as to progress of stresses applied to the fracture site. Thus, the initial form of care for the reduced tibial shaft fracture would be a long-leg cast in which the patient continued ambulating till he could perform full weight-bearing without distress. This cast would then be converted to a Sarmiento-designed, short-leg cast in which the patient would continue ambulation until, again, no distress occurred on full weight-bearing. Generally, we find this period to take two to three months post-fracture. At this point, after the patient has been ambulatory in the Sarmiento short-leg cast for at least a month, probably six weeks, we have converted this support device to a "gaiter" which leaves both knee and ankle free.

In our earlier developmental work, we tried placing the patients in braces at this time, believing it was appropriate to partially unweight the fracture site. Thus, the braces were fitted as PT-molded plastic or leather cuffs attached to the shoe by double-upright metal supports. We used free ankle joints, locked ankle joints with SACH heel, and sole roll off; and also have used flexible cables according to the Miami design. In none of our testing could we verify a prolonged unweighting effect of the brace and thus interpreted the function of the brace uprights as the method used to keep the support material (plastic, leather, or plaster) from sliding distally. In that the short-leg bracing did not effectively unweight the fracture site, we decided that the additional efforts required to build a true brace were unwarranted.

Thus, at our present level of development, we construct a plaster gaiter applied skintight from just at the malleolar level distally to above the patella proximally. At first we tried using a plastic material and heat, molding this material over the contour of the leg, but gave this procedure up as being too cumbersome. Clinically, this plaster gaiter is usually worn for about a month and in that it gives freedom to both ankle and knee seems to offer the anticipated benefits of more traditional fracture bracing.

FRACTURE BRACING FOR TIBIAL PLATEAU FRACTURES

Of all the potential locations for the use of fracture bracing, I believe that interarticular fractures at the knee offer the site which has the greatest potential benefit. Our method of care is as follows:

Tibial plateau fractures always imply some degree of disruption and collapse of either medial or lateral tibial plateaus, or both. It has been our impression that approximately five millimeters of collapse is the maximum that can be allowed to persist if we expect to obtain reasonable knee function. Thus, if a plateau collapse is greater than this and comminution is not too severe, it should be opened, elevated, and internally fixed with whatever method seems appropriate at the time.

In those fractures of less than five millimeters of collapse, it is generally not necessary to have an open reduction and elevation of the plateau. These fractures are usually treated in suspension or traction until such time as effusion at the knee is reduced and relatively pain-free motion at the knee can be performed through an arc of about 20 deg. This point is usually about one to three weeks postinjury--depending upon the severity of the comminution.

Thus, following healing of the skin incision for surgical repair (about ten days postoperation) or the arrival of some pain-free motion at the knee, the cast brace is applied. It is important that the physician and the orthotist be aware of the point of bony stability and that of instability when the cast brace is applied. The brace can be applied either in varus or valgus position to unload the fractured plateau. Frequently this alignment can be determined very easily clinically by ranging the knee in either varus or valgus. When the fracture site is unloaded and stresses reduced, pain-free range is available. However, when the fracture is allowed to fall back into the neutral position, pain recurs. This point confirms the effectiveness of unloading the fracture site by varus or valgus alignment.

The techniques for cast-brace application are the same as those used for application for fractures of the distal femoral shaft. Before application of the cast-brace in the knee fractures, effusion should be reduced--occasionally aspiration is necessary to accomplish this. The elastic wrap about the knee is always necessary to avoid recurrence of effusion.

Experience with tibial plateaus now exceeds 120 cases and the general result leads us to believe that has been the application location for cast-braces least troublesome to the clinicians. In addition, the concept of supplying motion to a healing interarticular fracture is more readily accepted than the equally valid concept of applying axial loads to an incompletely healed femoral or tibial shaft fracture. Unfortunately, we have not accomplished a prospective control study of the use of cast-braces in tibial plateau fractures compared to traditional methods. Our only documentation are those cases done at Los Angeles County General Hospital which identified a healing rate of 100 per cent and a functional range available in 90 per cent of the patients treated.

EXPERIENCES AT NORTHWESTERN UNIVERSITY

by Robert G. Addison, M.D.,S.C.
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After much consideration, I feel that we could only reiterate the limited experience that we have had at Northwestern University with the cast-brace as compared to the larger experience of the other members of our workshop. However, our group has attempted to illustrate four fairly unrelated conditions with a similar objective in mind, that being the encouragement of and preservation of knee motion.

Sometime ago, during my training years, one of the attending men predicted that we would be using less and less casting, not only because of the newer methods of internal fixation, however. It was his strong feeling that too often joint motion was seriously hampered by prolonged immobilization.

Vert Mooney, in his article in the *Journal of Bone and Joint Surgery*, December 1970, stated that his purpose was to show that early ambulation while a fracture was healing also permitted the preservation of joint motion and muscle function. This also minimized the rehabilitation period in the post-fracture healing.

I feel that this is particularly true in our series. In addition to fractures, we have had opportunity to use cast-bracing for a random selection of other problems. In one patient, it was used for an upper tibial giant cell tumor postoperatively. This patient had the tumor excised and the area packed with bone. After the initial wound-healing, he was placed in a cast-brace, and this worked out successfully.

Another instance is the case of a post-burn heterotopic bony fixation of multiple joints. After excision of the heterotopic bone from the knee area, the cast-brace was used with successful rehabilitation in this area.

Two types of plateau fractures are included in our series: one following open reduction and the other in which I felt the cast-brace helped in the performance of a closed reduction.

Although the use of many similar devices has been described, it has been the products of our prosthetic and orthotic laboratories and the use of skilled workers that has made the present cast-brace more readily and rapidly available.

I feel that the principal contributions are those of (1) early and maximal weight-bearing, (2) maintenance of the rhythm of gait, (3) the possibility of the patient returning to work earlier by decreasing the rehabilitation time post-injury and post-removal of support, (4) multiple uses other than for fractures, (5) the possibility of re-evaluating fracture healing, this because of the really poor immobilization of the cast-brace, although healing, nevertheless, does occur.

We have been particularly impressed in the tibial-plateau fractures and joint fractures from condyles with the use of the cast-brace especially when the opposing femoral condyle and tibial plateau are intact. There is often very little reason why these patients cannot be ambulated extremely early in their treatment.

I cannot help but feel that we have a valuable adjunct in the cast-brace, and that its further refinement is in prospect for all of us.

THE MANAGEMENT OF OPEN TIBIAL FRACTURES

by John Connolly, M.D.
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Since Lister's introduction of antiseptic techniques 100 years ago reduced mortality rates from open tibial fractures to levels permitting treatment other than primary amputation to be considered, a number of methods have been advocated. Most of these approaches were stimulated by the major casualties generated from the catastrophes of war. In 1872, during the Franco-Prussian War, Ollier utilized the technique of plaster immobilization or occlusive dressings to the injured limb to maintain constant compression on the wound, forerunning the Orr method. Carrel, in 1916, introduced Dakin's solution as a continuous irrigant of open wounds. French surgeons, especially Duval, in World War I, demonstrated the necessity of debridement in order to remove destroyed tissue as well as foreign bodies to allow for wound healing. Orr found that rigid immobilization of the limb was necessary to promote bony union and secondary soft-tissue healing. His results reported after World War I were impressive, but the method was accepted not for the treatment of open fractures but for chronic osteomyelitis in which no other method seemed applicable. Trueta resuscitated the Orr method in the Spanish Civil War and reemphasized the importance of wound debridement prior to using the closed-plaster treatment. In 1961, Dehne pointed out the value of ambulatory closed-plaster treatment for open tibial fractures, and subsequent reports have demonstrated that early weight-bearing is effective in treating these injuries.

Despite the demonstrated effectiveness of closed-plaster treatment for open fractures under wartime conditions, a number of reports challenge the reliability or applicability of the Orr-Trueta method for civilian injuries. Essex-Lopresti in 1950 reported that all ten fractures treated by Trueta's closed-plaster technique at the Birmingham Accident Hospital became infected while only five per cent of the 85 open fractures treated by immediate closure developed infections. In reporting results from Malmo, Sweden, Edwards indicated that no one has demonstrated that the Trueta closed-plaster method is either effective or necessary in managing open fractures of the tibia in civilian injuries. He felt that conversion of the open fracture to a closed wound is of paramount importance to treat these injuries safely. In his excellent monograph on the subject, Edwards compiled an abstract of 17 previously reported studies of tibial fractures and found an infection rate of 15 per cent in 723 open tibial fractures treated by closed reduction. In addition, in 191 reported cases of open tibial fractures treated by plating and primary closure, the infection rate increased to 26 per cent. In a prospective study at Malmo, using blind intramedullary nailing and primary closure of the wound, Edwards reduced the infection rate to 2 per cent in 47 open displaced tibial fractures. These results supported Lottes' previously reported technique of blind intramedullary nailing and were also felt to have demonstrated the necessity of primary wound closure in open tibial fractures by whatever means necessary, including local flaps or skin grafts.

There exists today then two main schools of thought regarding the management of open tibial fractures with a compromise school somewhere in between. One philosophy insists that the wound must be closed primarily by whatever means necessary in order to convert the open fracture into a closed one[2,3,5,6]. The second philosophy emphasizes that the wound should never be closed, especially when there is any doubt as to the extent of injury, and that bone is actually quite resistant to any secondary infection if properly immobilized by the Orr-Trueta closed-plaster method[1,4,8,10]. Somewhere in between these two schools is a compromise approach, which neither completely closes nor completely leaves the wound open. The area around the fracture site is inspected frequently, usually through a window in the cast in order to change dressings or apply antiseptic solution designed to diminish infection or possibly promote granulation.

ORR-TRUETA TECHNIQUE

In regard to the Orr-Trueta closed-plaster treatment, the chief objection has always been that one should not risk the danger of secondary contamination of open fractures. The ideal should be to convert the open fracture to a closed wound as early as possible, especially within the golden six-hour period after injury. This objection seems reasonable for a number of civilian open fractures in which the wound over the fracture is usually less than 1 or 2 cm. Closure can usually be accomplished soon after injury without risking skin necrosis or deep infections. Difficulty arises, however, in managing the grossly contaminated, motorcycle-type civilian injury with large areas of skin loss and considerable contamination of the fracture. In caring for this problem type of injury, a familiarity with the rationale and technique of the Orr-Trueta-Dehne method has been found useful in our experience.

Essentially, the Orr-Trueta method emphasizes the importance of rigid immobilization and rest of the open fracture to achieve bony healing and promote wound healing. Trueta points out that to permit this complete immobilization the plaster should not be padded, the cast should not be windowed to inspect the wound, and the cast should not be changed during the first two weeks merely because of unpleasant odor. Inspection of the wound every day through a cast window may satisfy the surgeon's "good-grooming" instinct, but should definitely not be considered treatment by the Orr-Trueta-Dehne method. The value of this complete immobilization as pointed out by Trueta is that it promotes small capillary and venous thrombus formation and proliferation of new capillaries in the wound. Also maintenance of constant, evenly distributed pressure on the fracture site diminishes edema and lymphatic spread of infection. Trueta does not deny the presence of bacteria in the wound and, in fact, points out that eventually the bacteria become predominately Pseudomonas-type organisms. However, the presence of these organisms in a healthy granulation tissue is by no means of the same significance as is the presence of bacteria underneath a necrotic, closed wound. All the authors on the subject of open fractures seem to agree that wound necrosis is the chief problem to be avoided in order to prevent deep infection. The advocates of closed-plaster treatment avoid this complication by leaving the wound open. Those favoring primary closure attempt to eliminate wound necrosis by the use of local flaps or skin grafts when necessary.

CONTRIBUTION OF WEIGHT BEARING TO SOFT-TISSUE HEALING

In addition to the advantages of rigid immobilization for open wounds as proposed by Trueta, the use of early weight-bearing as described by Dehne seems to add an additional stimulus to wound granulation. In our observation, the use of early ambulation promotes wound drainage probably by the pumping activity of the muscle about the fracture massaging out any fluid collection from the depths of the wound. Another possible explanation of weight-bearing effect on soft-tissue healing may be related to a Wolff's law applicable to soft tissues as proposed by Forrester and his associates at the University of California. By the use of the scanning electron microscope, Forrester experimentally showed that tensile strength and alignment of collagen fibers in a healing skin wound can be improved by moderate distracting forces. It was his conclusion that the healing skin, like bone, adapts to external stresses by internal architectural changes. The beneficial stimulus of weight-bearing and rigid plaster immobilization on soft-tissue healing has also been evident in the numerous studies on the immediate prosthetic fit of amputees.

MANAGEMENT OF OPEN TIBIAL FRACTURES ON THE VANDERBILT ORTHOPEDIC SERVICE

A review was carried out of the last 45 open tibial fractures treated on the Vanderbilt Orthopedic Service by a number of different orthopedic surgeons using a variety of techniques. The majority of wounds associated with these open fractures was described as small, ranging from 1 to 2 cm. in size. Thirty-five of the 45 wounds were closed primarily. In regard to internal fracture fixation, screws were utilized in eight cases without complications and plates in four fractures. The only deep infection and chronic osteomyelitis developed in one of the four patients treated by plate fixation and primary wound closure. This limited experience with plating and primary closure supports other evidence from the literature that the incidence of osteomyelitis from this method approaches 25 per cent. Pins above and below the fracture site were utilized to immobilize four open tibial fractures with a surprisingly high rate of three delayed unions. One of these nonunions occurred in a six-year-old boy, necessitating bone grafting.

The closed-plaster treatment method was found particularly useful in the more severely injured limbs as demonstrated by the following cases:

Case 1. A 15-year-old boy was injured in a motor-scooter accident and sustained an extensive soft-tissue injury to his limb associated with an open tibial fracture (Fig. 1-A). The damaged limb was treated by the closed-plaster method for two weeks after which time the bone was still exposed in the wound but was being surrounded by granulation tissue (Fig. 1-B). Three weeks later the bone had become completely covered by granulation when skin grafts were applied to the multiple areas on the calf and the leg (Fig. 1-C).

Fig. 1-A. AP and lateral roentgenogram of open tibial fracture in 15-year-old boy.

Case 2. A 19-year-old man sustained a motorcycle-type fracture of his tibia with a small 2- to 3-cm. wound adjacent to the fracture (Fig. 2-A). The wound was debrided and closed, and was felt to be healing satisfactorily enough for the patient to be discharged ten days after injury. Two weeks after injury, the patient returned with fever, pain, and an obviously infected, draining wound which required debridement and tube irrigation for one

Fig. 1-B. Granulations forming about exposed bone after two weeks of closed-plaster treatment.

Fig. 1-C. Granulations after five weeks of closed-plaster ambulation had completely covered exposed bone.

week (Fig. 2-B). The patient was then allowed to ambulate in a short-leg, skintight cast while the wound granulated over the bone without further treatment. The fracture healed uneventfully seven months after injury (Figs. 2-C and 2-D).

Fig. 2-A. AP and lateral roentgenogram of open tibial fracture in 19-year-old man.

Fig. 2-B. Open wound with exposed bone four weeks after injury, prior to application of walking cast.

Fig. 2-C. Healed wound seven months after injury--granulation tissue had completely covered exposed bone.

Fig. 2-D. Healed fracture seven months after injury.

Case 3. A 40-year-old man had previously had an infected distal tibial fracture treated elsewhere with a pantalar arthrodesis because of chronic infection and inability to bear weight on the foot. He was admitted to the Nashville Veterans Hospital where amputation was strongly considered because of the equinovarus position of the ankle and the wound which had been chronically draining for two years (Figs. 3-A and 3-B). However, at the recommendation of Dr. E. Dehne, the equinovarus position was corrected by an osteotomy through the infected distal tibia and the patient was allowed to bear weight in a short-leg, skintight cast. Six months later his wound had granulated down to a 1-cm. size and he could bear weight without external support and with the aid of a shoe lift (Figs. 3-C and 3-D).

Fig. 3-A. Infected chronically draining wound in 40-year-old man with ankle fused in equinovarus position.

Fig. 3-B. AP and lateral roentgenograms showing equinovarus position prior to osteotomy.

Figs. 3-C and 3-D. Six months after osteotomy and weight-bearing in plaster cast--the wound had granulated down to 1-cm. size and the foot could now be used as a weight-bearing end organ.

SUMMARY

Open tibial fractures from civilian injuries can be successfully managed by the Orr-Trueta-Dehne method without necessarily requiring closure of the wound. The majority of civilian fractures will probably continue to be treated by primary wound closure. The closed-plaster ambulatory method has been found valuable as primary treatment for the more serious injuries or secondarily when the surgeon gets into difficulties by primarily closing the open fracture.

The beneficial effect of weight-bearing in promoting granulation tissue about the open fracture site suggests that Wolff's law may be applicable to soft tissue as well as to bone.

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WEIGHT-BEARING TREATMENT OF THE FRACTURED TIBIA

by Ernst Dehne, M.D., Col., MC, Ret.
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Henry Smith of Philadelphia wrote about treatment of ununited fracture by means of artificial limbs combining the principles of pressure and motion at the seat of the fracture. This was in 1855, before the days of aseptic surgery or x-ray. The results were spectacular. Not only did ambulation in this early orthosis revert the course of cachexia and debilitation but infection subsided readily and the bones united. Gesundgehen was the reaction in the German literature, a term not readily translated in its implications but carrying overtones of "faith healing" or cure-all.

I believe that the teachings of activity advocated for the past century by Lucas Championnière, Delbet, Böhler, and myself stem ultimately from this early Philadelphia report. The weight-bearing management for the fractured tibia is an art rather than a method. It is readily transmitted by preceptorships, but I do not believe that it lends itself for relation by writing or manual since it breaks with a number of well-accepted traditions such as the act of reduction performed as a maneuver, sometimes under the protective screen of anesthesia. It takes empathy, experience, and confidence to get a patient to relax in a sitting position to the point that his fragments line up spontaneously and without maneuver, without rotatory or angulatory deformity and no shortening in excess of one centimeter in spiral, oblique, or butterfly fractures--shortening in excess of one centimeter is desirable in primary bone defects (Fig. 1). If these statements offend or cause skepticism my point is made: preceptorship is the only effective mode of transmission. Lucas Championnière, one hundred years ago, said everything I teach now, but his teachings failed to take hold because he relied on the written word only for transmission.

The rewards of weight-bearing management are far-reaching:

rapid and consistent union--elimination of nonunion (Fig. 2);

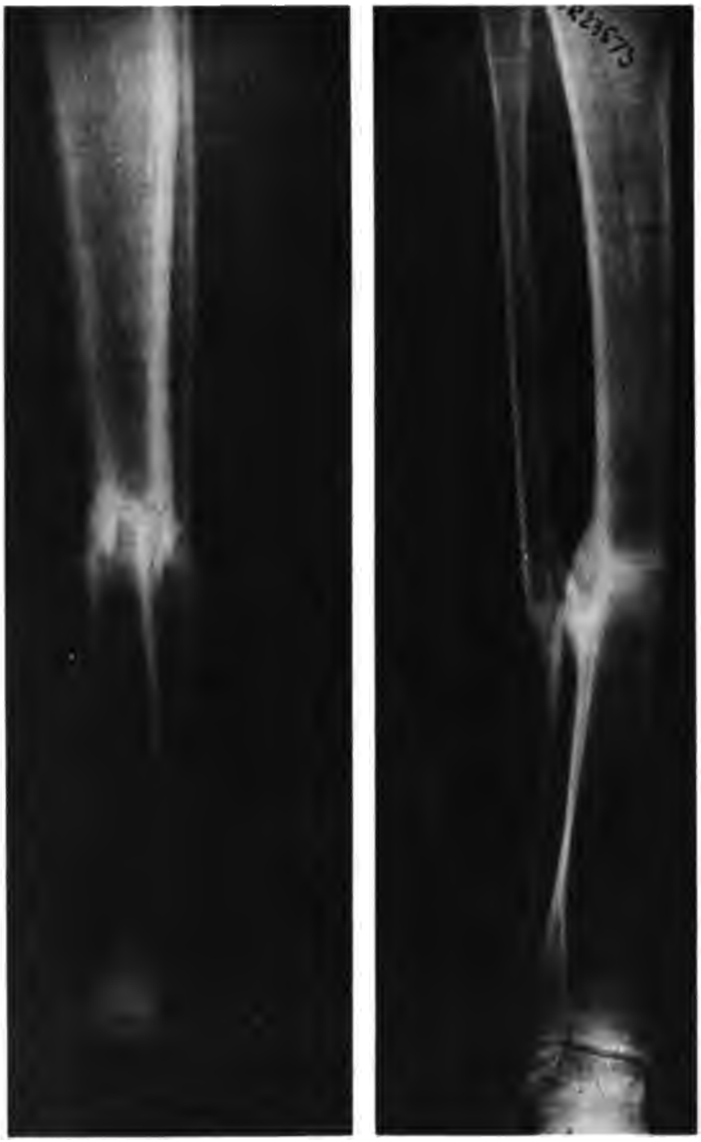

Fig. 1. Healing at full length is the rule, but valgus angulation could have been corrected by wedging long-leg cast.

Fig. 2 (*top right*). Segmental compound fracture that became infected. (*Bottom right*). Eight months and two parachute descents later--position less than desirable, union strong.

low incidence and bland course of infection--elimination of amputation for chronic or acute osteomyelitis (Fig. 3);

minimal general morbidity and early return to social and economic function.

Fig. 3. Descent six months after fractured tibia.

ALTERNATE TECHNIQUES

The Sarmiento cast has the advantage of a freely movable knee joint with probably greater comfort for the patient. However, I think that I can control angulation better by wedging a long-leg cast, but this may be an unimportant detail. The Sarmiento brace has the additional advantage for the patient of a free ankle joint and movable foot. My concern that the necessary change from long-leg cast to short-leg cast to brace may delay union by injuring the young callus is entirely speculative. The knowledge gained by the investigation of the Sarmiento brace is a real asset.

THEORETICAL CONCLUSIONS

It appears that feedback exposure (in the case of the fractured tibia--graded weight-bearing) within the daily tolerance of the patient is an essential prerequisite for optimum healing.

If this is correct all previous experiences gathered from treatment by immobilization and more radically reduced activity may require re-evaluation and revision (Fig. 4).

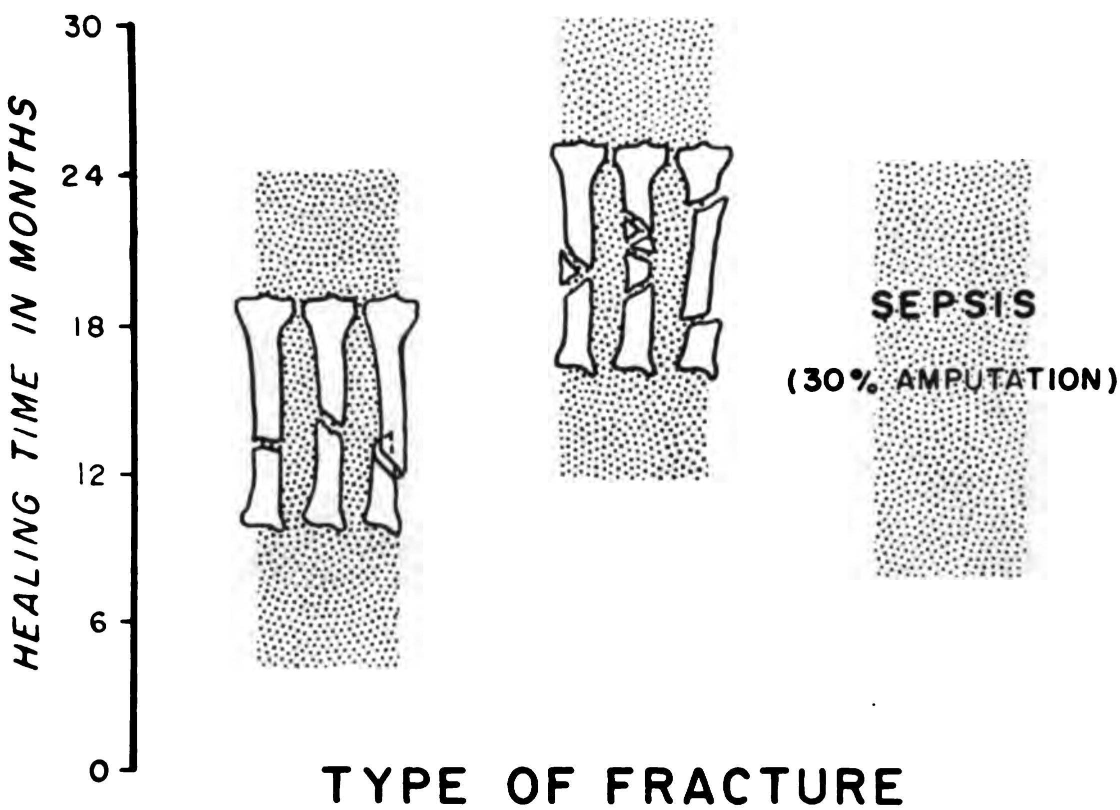

Fig. 4. Note wide variation in healing time, incidence of sepsis, and amputation rate in <u>nonweight</u>-bearing management.

TREATMENT OF FRACTURES OF THE SHAFT OF THE TIBIA BY IMMEDIATE AMBULATION

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Fractures of the shaft of the tibia have a notoriously high complication rate. These complications include infection, nonunion, delayed union, stiffness of the foot and ankle, persistent edema of the leg and foot, and stress-sensitivity. They are more often directly related to the treatment used rather than to the injury. Surgical intervention to achieve exact anatomical reposition of the fracture with internal fixation results most commonly in these disastrous complications, the culmination of which all too often results in the necessity for amputation. To prevent complications due to surgery it was necessary to discontinue the use of open reduction. However, if closed reduction were to be used, it was necessary to devise a method that would permit good alignment, reliable fixation, a short immobilization time, and the earliest possible restoration of the normal functional use of the extremity.

Fig. 1. Initial long-leg cast with knee in full extension.

In 1950 at the 97th General Hospital, Munich, Germany, Dehne introduced the method of immediate ambulation in a long-leg cast for the fractured tibia with the knee in complete extension (Fig. 1). This procedure has been reported in previous publications[1,2].

Since 1953 the author has used this method without exception for all fractures of the shaft of the tibia. The only modification has been the use of the Sarmiento PTB cast-brace after some stability of the fracture has

Fig. 2. Sarmiento-type cast-brace applied after some stability of fracture has been obtained.

been obtained (Fig. 2). This technique has been universally successful in the management of closed fractures of the tibia, stable and unstable (Figs. 3-A, 3-B, 4-A, and 4-B).

Fig. 3-A. At time of injury.

Fig. 3-B. At seven months.

Fig. 4-A. Initial x-ray.

Fig. 4-B. X-ray at 14 weeks.

In addition, it is uniquely suited to the management of high-velocity-missile, combat-incurred fractures of the tibia (Figs. 5-A, 5-B, and 5-C). For these cases the method has revolutionized the management of this particular fracture.

METHOD

Closed Fracture

Anesthesia is rarely required except in the case of displaced transverse fractures where spinal anesthesia is the method of choice. With the patient in the sitting position the legs are allowed to hang over the end of the table with the knees in 90-deg. flexion. Length is restored by the effect of gravity on the affected extremity. Occasionally, a little gentle pull is required. Angulation and rotation are corrected and a snug,

Fig. 2. Sarmiento-type cast-brace applied after some stability of fracture has been obtained.

been obtained (Fig. 2). This technique has been universally successful in the management of closed fractures of the tibia, stable and unstable (Figs. 3-A, 3-B, 4-A, and 4-B).

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Fig. 5. *A*, two and one-half weeks after wounding with attempt at delayed primary closure. Condition on arrival at Valley Forge General Hospital. *B*, Injury film showing bone loss, healed fracture, no drainage at nine months. *C*, External appearance of leg at nine months, bone covered by scar, no drainage.

well-molded short-leg cast is applied. Only one thickness of Webril is used. No attempt is made to hold the foot at 90 deg. for this often produces recurvatum at the fracture site. When the cast has hardened sufficiently to prevent indentation from holding, the patient is placed supine, the knee is fully extended, and the cast is extended to the groin. Great care is taken to mold the cast well around the knee, patella, and thigh. X-rays are taken at this time and any angulation is corrected by wedging the cast. Undue discomfort after wedging is thoroughly investigated to prevent pressure sores at the wedging site.

The patient is returned to bed and the leg is elevated. He is started on a modified Bueger-Allen exercise program with active elevation of the extremity to restore motor control.

The following day the patient is ambulated on crutches, with a three-point gait. As much weight is borne on the affected extremity as can be tolerated. Meticulous attention is given to instructing the patient in proper crutch gait so that normal gait rhythm is established. He may progress to full weight-bearing as rapidly as he wishes within the limitation of increasing pain and swelling. These two conditions should not be accepted. The patient is usually full weight-bearing in ten days. Within the limitation of excessive loosening, I prefer to leave this original cast on for six to eight weeks. At this time the cast is removed and x-rays are taken, the fracture tested for spring-tenderness and local heat. Although some few may be clinically solid at this time, a new long-leg cast is applied. It is changed at intervals of four weeks until clinical union is achieved. In closed fractures without extensive soft-tissue injury, this union is usually achieved at about 13 weeks. At this time the cast is removed and the patient put to bed for several days until knee motion to 90-deg. flexion and usable ankle motion are obtained, and muscular control of these joints is regained. Then full ambulation without support is permitted.

Open Injuries

Open fractures are managed by appropriate initial wound surgery. Primary closure is never attempted. Delayed primary closure of wounds that are not due to high-velocity missiles is occasionally done, but never just to cover exposed bone. Delayed primary closure of wounds due to missile fragments invariably fails leading to skin loss (Fig. 5-A) and disastrous infection. Wounds of the calf and other areas of the leg where bone is not exposed are covered with layon split-thickness graft. I want to reemphasize that exposed bone is of no consequence (Fig. 5-A). It is no bar to union.

The patient with a combat injury usually arrives at Valley Forge General Hospital within five to ten days after wounding. Upon arrival the cast is removed, the wound inspected, and new x-rays obtained. Any necessary re-debridement is done, but fragments of bone are never removed. It may be necessary to use moist Saline dressings for a few days to create a clean wound. The wounds and the exposed bone are covered with fine mesh gauze and a single layer of Webril, and a long-leg cast is applied as previously described. The patient is ambulated the following day or as soon as other wounds that he may have will permit.

The tibial injury, regardless of state of comminution or sequestration, is never a bar to ambulation. The casts are changed at intervals of four weeks or when dictated by the amount of drainage. Any skin grafting that is deemed necessary is done through windows in the cast. The grafts are laid on, never sutured. This procedure only interrupts ambulation for a period of two to three days. At six to eight weeks the long-leg cast is changed to a short-leg Sarmiento-type cast. Immobilization is continued until union is achieved. With union, scar tissue will cover the bone and drainage will cease (Figs. 5-A and 5-B).

For the purpose of this paper, 123 patients with 129 fractured tibiae were reviewed. Six patients had bilateral injuries, 73 had both tibia and fibula fractured, 56 had only the tibia fractured. Ninety-one were open fractures and only 38 were closed. Eighty-four were due to missiles, and 22 to vehicular accidents. The remainder were due to a variety of reasons (falls, athletics).

Delayed primary closure was attempted in 56 cases and it failed in 32 (Fig. 6). Those cases in which it failed resulted in skin and muscle loss with infection.

Fig. 6. Five days after delayed primary suture.

When wounds were left open without suture, healing occurred rapidly without infection (Figs. 7-A and 7-B).

Primary closure failed 100 per cent of the time.

After arrival at Valley Forge General Hospital, all patients were managed by immediate ambulation as described.

Fibular osteotomy performed in four cases developed tenuous union because of loss of bone substance. Selective shortening is necessary for union of these fractures (Fig. 5-C).

Bone grafts through a posterolateral approach were done in seven cases. These were not done because of nonunion or delayed union, but to provide bulk to a united fracture that had limited bony substance at the fracture site. Wounds open anteriorly are no bar to posterior bone grafting (Fig. 8).

In nine cases sequestrectomies were done. These were all minor procedures, the bony fragment easily delineated. None was done before unequivocal bony union was obtained (Fig. 9).

No saucerizations were done. No amputations were necessary.

All wounds healed and only one cross-leg flap was utilized. This case required 23 months for union.

Fig. 7-A, *above*. Nine months post-high-velocity-missile wound. Skin healed without suture.

Fig. 7-B, *left*. External appearance at nine months.

Fig. 8, *right*. Fusion at proximal tibiofibular joint with posterolateral bone graft.

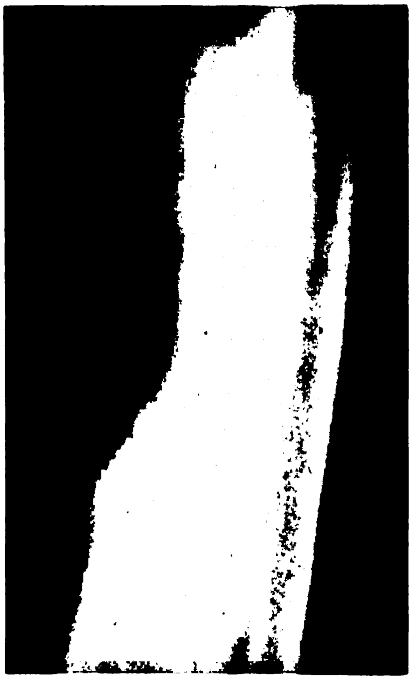

Fig. 9. Clearly delineated sequestra, which was removed after bony union had been achieved.

In four cases there was minimal intermittent drainage at the time of return to duty. Antibiotics were not used except to control evidence of systemic infection. This was necessary only in those cases that developed infection after delayed primary closure.

All patients in this series returned to duty. Since it is difficult for me to delineate exactly when a fracture healed, I have utilized a time frame that is from time of injury to discharge from the hospital to productive duty. It includes all rehabilitation and administrative time.

Injury to	Duty
0-3 months	9
3-6 months	63
6-9 months	38
9 months +	19

Six patients had shortening of 1 in., the remainder from 0-2 cm. None required a shoe lift. Upon return to duty none required any external support.

The goal in treating tibial shaft fractures is to achieve the earliest possible union of the fracture, without complications, and an extremity whose functioning is essentially normal. The immediate ambulation method as described achieves this goal.

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F E M O R A L

F R A C T U R E S

FEMORAL FRACTURES

Augusto Sarmiento, M.D., and William Sinclair, C.P.O.
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The University of Miami investigators related their experiences with femoral fracture bracing in 75 patients. They stated that the applicability of bracing techniques to the treatment of femoral fractures was not as yet developed to the point of justifying routine use. They have encountered, with frequency, undesirable complications because of failure of the orthotic device to maintain adequate alignment of the fragments. They illustrated examples of fractures at various levels of the femur where alignment was lost and angulatory deformities developed following the onset of weight-bearing ambulation. These complications were seen more frequently in fractures above the middle third of the femoral shaft (Figs. 1 and 2).

Fig. 1. Roentgenogram of a comminuted fracture at the distal end of the femur obtained shortly after the application of the Orthoplast femoral brace five weeks after the initial injury.

Fig. 2. Roentgenogram of same patient demonstrating the healed fracture in satisfactory alignment.

At this time the use of bracing techniques requires a preliminary period of bed rest and stabilization in traction for an average of five weeks and the confirmation of intrinsic stability at the fracture site (Figs. 3 and 4).

Fig. 3. Roentgenogram of a comminuted fracture at the junction of the middle and proximal third of the femur obtained shortly after the application of the first Orthoplast femoral brace. Notice the presence of callus and satisfactory alignment.

Fig. 4. Roentgenogram demonstrating the angulatory deformity that occurred shortly after the resumption of weight-bearing ambulation.

They discussed their observations concerning the effect of femoral braces in the restoration of knee motion. They suspect that swelling and effusion in the knee joint respectively are unavoidable with certain fractures, particularly those close to the knee joint. Increase of these undesirable phenomena may be brought about by the tourniquet-like effect of the thigh portion of the brace which is placed close to the knee joint. Preservation and/or restoration of motion is best accomplished by the early institution of passive or active exercises to the knee joint during the period of compulsory recumbency. The likelihood of swelling, edema, and joint stiffness is indirectly related to the degree of motion present at the time of application of the brace.

They illustrated their plastic femoral shaft brace (Orthoplast) and discussed the technique of application. This brace, which is lighter than plaster of Paris, encases the thigh but leaves the leg free. It maintains a level pelvis, permits the wearing of shoes, and allows motion on all joints of the extremity (Figs. 5 and 6).

Figs. 5 and 6. Front and side views of the Orthoplast femoral brace with free knee and ankle joints.

Following the application of the brace, several weeks after the initial injury, patients are allowed to ambulate on crutches gradually increasing the amount of weight on the injured limb. The knee joint is mobilized as soon as possible and roentgenographic studies are repeated at frequent intervals to confirm the maintenance of adequate alignment.

Angulatory deformities are corrected by standard orthopaedic methods.

They stated finally that in the light of our present knowledge the bracing of femoral fractures must be undertaken with extreme care and full awareness of its potential dangers. Bracing techniques should be applied only to those patients suffering from fractures which are not amenable to internal fixation and early rehabilitation, especially those located in the most distal portion of the femur.

EXPERIENCE WITH BRACE-CAST FOR FEMORAL FRACTURES

by William E. Burkhalter, Col., MC
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At the present time our experience with the brace-cast treatment of lower-extremity injuries involves 125 cases. Of these 125 cases, 50 were fractures of the femur secondary to penetrating injuries of the thigh. These fractures are associated with high-velocity-bullet or fragment wounds and should be considered as open, comminuted fractures. In these cases the soft-tissue injury may be of considerable magnitude and may be accompanied by varying degrees of bone loss.

In addition, we have 40 closed, comminuted femoral-shaft fractures without knee-joint involvement. The remainder of the cases consists of ten fractures of the proximal third of the femur; ten fractures of the distal third of the femur; five distal-third fractures with knee-joint injury; five tibial-plateau fractures, and five knee-joint wounds associated with both tibial and femoral injury. The latter groups are so small that very little in the way of conclusions can be drawn regarding the use of the brace-cast in these instances.

INDICATIONS

Our current feeling is that all fractures of the lower half of the femur, including those involving the knee joint, may be satisfactorily treated in a brace-cast providing a reasonable reduction is obtained prior to application of the cast. Because we are attempting to apply the brace-cast earlier and earlier in fracture treatment, we have felt that upper-third fractures present too much of a problem and have not attempted the early application of the cast in these cases. Our earliest application of a brace-cast has been three days post-fracture and our latest six months. The latter was associated with marked degrees of bone loss and required several months to obtain skin closure and pedicle-flap coverage.

The ideal patient for the brace-cast would have a well-muscled thigh with a minimum of subcutaneous fat. The contraindications that we have seen are certainly not absolute but should be considered more as relative contraindications or calculated risks. As previously stated, early application, that is, earlier than six to eight weeks post-fracture, is probably not indicated in proximal third fractures. Even the application of a minispica or pelvic band to the brace-cast will not completely avoid varus angulation at the fracture site. Neither will wedging the cast completely eliminate the problem. So this type of fracture, i.e., proximal third, is best avoided in using the method of early brace-cast treatment.

The patient with a heavy thigh or a thigh with much subcutaneous fat is not well suited for this method of treatment, regardless of the fracture location or geography. Total contact and compression of the muscle proximally is a necessity in this type of treatment and if these requirements cannot be met because of body habitus, angulation of the fracture is likely to occur.

The presence of injury to the sciatic nerve in the thigh or buttocks, we feel, is another relative contraindication to brace-cast treatment. Extreme care in padding the more distal bony areas about the knee, ankle, and foot is required in order to ambulate a patient with anaesthetic skin in a walking-type cast (Fig. 1). We have been successful in five patients with sciatic-nerve injuries and femoral fractures without causing skin breakdown in the area of anaesthesia.

Fig. 1. Padding technique utilizing split felt.

The presence of wounds about the leg is no contraindication to the use of the brace-cast nor is a below-knee amputation or tibial fracture (Fig. 2). Wounds in the proximal thigh, however, create some difficult problems. Total contact is necessary here and the healing of wounds may be slowed considerably with ambulation. Again this is a relative contraindication and requires cast changes during the treatment of the fracture. In certain cases, grafting of the wound or the burn may be delayed until union of the fracture has occurred.

Fig. 2. The association of a below-knee amputation or tibial fracture with the femoral fracture does not in any way prevent the use of the brace-cast. In those cases with distal BKs, a Steinmann pin through the tibia supports the brace-cast.

TECHNIQUE

In fractures of the distal half of the femur with involvement of the knee joint, we attempt to apply the brace as soon as possible after the patient is admitted to the hospital. In many combat casualties this application may be three or four weeks post-injury, but in patients generated in the local environs it may be only three to four days. We feel that early application requires reduction with skeletal traction within 24 to 48 hours following fracture. Additional Kirschner wires or Steinmann pins should be used to obtain as anatomical a reduction as possible. With the pins in place and traction on the leg, and the fracture reduced as anatomically as possible as demonstrated by satisfactory x-rays, the brace-cast is applied. The hip must be maintained in extension during application of the proximal portion of the cast and the pins are incorporated in the cast during its application. At the conclusion of the procedure then, we have a well-fitting, long-leg cast, with the portion about the root of the leg shaped into a quadrilateral configuration by an NYU casting jig (Fig. 3). If x-rays through this cast reveal satisfactory position of the fracture, a single-axis, drop-lock knee joint is applied and the pins previously used for reduction are removed (Figs. 4-A and 4-B). With the application of the knee joint, the area about the knee is open and is free of the supportive effects of the plaster cast. Initially, we used an elastic knee support applied at the time of cast application to control swelling in this area. As we have expanded to include patients with open, draining wounds and those with early reduction and therefore skeletal pins in place, we have discarded this elastic knee support. Instead we have used rubberized Ace bandages in the area to control subcutaneous edema and knee-joint effusion (Fig. 5). Ambulation is begun either in parallel bars or with crutches as soon as the cast has dried satisfactorily. If the patient has been recumbent in traction for a period of time, the use of a circelectric bed or tilt-table may be necessary. During this ambulation, the knee joints are kept locked and the knee is maintained in full extension. Ambulation with minimal external support is encouraged as soon as possible, but generally all patients ambulate with at least one crutch or cane.

Fig. 3. The proximal femur is shaped into a quadrilateral configuration using the NYU casting brim.

Range-of-knee motion is encouraged several times a day when the patient is nonweight-bearing. Active and assistive exercises are used. Our single-axis knee joint limits knee flexion to a range of 45 to 60 deg. from

Figs. 4-A and 4-B. Using single-axis knee joint only, 60 deg. of flexion are possible unless the proximal portion of the cast moves distally.

Fig. 5, *right*. Elastic Ace bandage controls edema and joint effusion. Without support in this area, a definite problem exists with swelling.

full extension, no more being possible unless the cast around the thigh moves distally when the knee is flexed. Generally our cast is so tight proximally that this distal migration does not occur. We have felt that as long as approximately 60-deg. range of knee motion is possible in the cast, doubling the range following removal generally presents no problem and is usually achieved fairly rapidly. As ambulation and knee-joint exercises continue, check x-rays are taken periodically to be certain that alignment of the fracture is being maintained by the brace-cast. If at any time during the ambulatory period angulation occurs, it can generally be corrected by wedging of the plaster cast. Cast changes may be necessary because of wound drainage or excessive loosening of the cast but, if at all possible, the brace-cast should not be changed for eight to ten weeks from fracture. The reinstitution of traction is not necessary and the increased stability noted after eight or ten weeks is generally enough to allow use of an elastic knee support and a regular examining table for the application of the brace-cast.

Treatment is discontinued when it is felt by clinical examination and x-ray that union has occurred.

RESULTS

Union of the fracture occurred in all but five of the cases presented. Nonunion secondary to bone loss was present in three and required extensive surgery in order to obtain union of the fracture. The two other nonunions were associated with excessive skeletal traction and attempts to maintain leg lengths. Both of these latter cases would have best been managed by allowing controlled shortening of the fracture to occur. These cases required bone graft in order to obtain union.

The greatest shortening that we have encountered in our femoral fractures was 2½ inches. The greatest shortening that occurred after application of the brace-cast and the initiation of ambulation was one inch. The average shortening has been less than one-half inch following application of the brace-cast.

Angulation in this group of patients presented no problem. The greatest angulation noted in any of the fractures was 27 deg. posterior which was present at the time of cast application. The greatest total increase in the fracture brace was ten deg. of varus.

In our 50 patients with penetrating femoral fractures, the range of motion of the knee was greater than 90 deg. in 24 patients, and less than 90 deg. in 20. Six had 20 deg. or less, and all of these had extensive soft-tissue damage about the knee, and septic arthritis. All of the remaining 40 femoral-shaft fractures were closed injuries and had more than 90 deg. of motion except for five. One had an associated septic arthritis of the knee and four had less than 90 deg. of knee motion.

CONCLUSIONS

We feel that the ideal patient for a brace-cast is a thin, muscular adult with the fracture involving the distal half of the femur. Proximal fractures, or those associated with sciatic nerve injury or open wounds, may be treated in the fracture brace if certain special problems are recognized. This method of treatment decreases the total time in bed, improves the state of the soft tissues in the injured extremity, and improves the general body physiology. Shortening and angulation of the fracture have not been problems with this method of treatment. A satisfactory range of knee motion is generally achieved in all patients and is certainly commensurate with that that would be obtained by prolonged treatment in skeletal traction.

The application of the brace-cast, especially early in the fracture management, requires skilled plaster technicians with a knowledge of orthotic principles. Because of this requirement the method may have limited applicability in the average practitioner's hands.

CAST-BRACING FOR FRACTURED FEMURS

By Paul W. Brown, M.D.*
University of Colorado Medical Center
Denver, Colorado

We began using the cast-brace for fractured femurs in 1968 after learning of the concept and technique from Colonel Charles Metz at Walter Reed General Hospital. Over the next year we treated approximately 125 patients with this device and, even though we proceeded gingerly and with caution, we made many errors along the way. The technique will be described in detail and more expertly by others at this meeting, so I will not dwell on it, but simply outline our conclusions and some of our experiences with it (Figs. 1-A through 1-D).

Fig. 1-A. Open gunshot fracture of femur two weeks after injury.

Fig. 1-B. Cast-brace applied six weeks after injury. Note degree of flexion possible in knee.

*formerly at Fitzsimons General Hospital

Fig. 1-C. Full weight-bearing in cast-brace at eight weeks.

Fig. 1-D. Fracture well healed at six months.

We found from the outset, as others have, that proper application of the cast-brace was critical and time-consuming. Molding of the plaster and placement of the knee joints were best accomplished by a trained orthotist and the entire job took one to two hours. As our devices improved and as our experience grew, we became bolder in our use of them and moved to earlier application. This was particularly true with fractures at or distal to the midshaft of the femur. Some fractures of the upper third of the femoral shaft tended to angulate in varus though this proved to be quite unpredictable as a few went into valgus and most did not angulate at all. Many of these quickly angulated up to 25 deg. and then progressed no further. As we became more expert at applying the cast-brace and in teaching patients to walk in it, the incidence of angulation in these high fractures decreased noticeably and our preliminary evaluation at the end of a year's experience was that angulation of up to 20 deg. might be expected in approximately 20 per cent of high femoral-shaft fractures ambulated in a cast-brace before there was any bony stability (Fig. 2).

Fig. 2. Gunshot wound. Grossly contaminated high femoral fracture in cast-brace ten weeks after injury and four weeks after application of cast-brace.

Five patients had below-knee amputations on the side of the fractured femur and were managed with the cast-brace, and in three of these cases the cast-brace was combined with a modification of the immediate fitting technique for the amputation. In these instances, weight-bearing was started on a pylon fitted to a plaster thigh cast with a quadrilateral fit (Figs. 3-A, 3-B, and 3-C).

Despite the difficulties encountered in applying a satisfactory and comfortable cast-brace, and the angulations and swelling of the knee in many of these patients, several marked advantages were gained. These patients had a much better general course on an ambulatory basis than those who had previously been confined to bed in plaster spicas or in traction. Their morale was better, they gained weight and developed better musculature, and they took an earlier active interest in their rehabilitation and return to normal living. None rejected the cast-brace and all thought that its use had contributed to an earlier recovery. In only four was ultimate union in question.

In my civilian experiences of the past year, I have only had occasion to use this technique in three cases. Each of these was an extremely

A B C

Fig. 3. *A*, gunshot wound. Femoral fracture and open below-knee amputation on same side. *B*, eight months after injury; amputation stump healed. *C*, ten months after injury; fracture healed; knee motion 0 to 90 deg.

complex fracture. One was associated with a contralateral above-knee amputation and refracture of an open comminuted fracture of the midshaft of the femur which had previously united in traction. Another was an 8-in. segmental fracture of the femur in a 76-year-old man. The third was a refracture of a femur which had been treated in traction but in which there were only 30 deg. of knee flexion. All were treated in cast-braces before there was any skeletal stability and all went to solid union.

My conclusion is that this is a potentially valuable technique which follows the principle of seeking an early return to function of the injured extremity and of the patient. It has shortcomings, we have much to learn about its proper usage, and it should be used only when proper control and expert application of the cast-brace are possible.

CAST-BRACE TREATMENT FOR FRACTURES OF THE DISTAL PART OF THE FEMUR

By Vert Mooney, M.D.,* Vernon L. Nickel, M.D.,** J. Paul Harvey, Jr., M.D.,+ and Roy Snelson, C.P.O.ϒ

In a prospective study conducted at the Los Angeles County University of Southern California Medical Center in June 1967 through June 1969, two hundred fractures of the distal portion of the femur were treated initially with skeletal traction and, once the fracture was stable, placed in cast immobilization. Fifty cases were treated with the standard one-and-one-half spica cast while 150 cases were treated with an ambulatory cast-brace device. In the spica-cast group, mean traction time was 8.7 weeks and mean immobilization time in cast was 16 weeks, totalling 24.7 weeks of mean treatment time. In the cast-brace group, mean traction time was 7.3 weeks, mean cast time was 7.2 weeks, totalling 14.5 weeks of mean treatment time. There were three refractures and three nonunions in those treated with spica casts while in the 150 cast-brace patients there were no nonunions or refractures. All patients selected for this study had fractures of the distal femur deemed inappropriate for internal fixation, and selection for either cast-brace or spica was during the first year of the study by odd and even hospital-numbers selection. During the second year of the study all fractures were treated consecutively with the cast-brace.

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Supported by SRS Project Number RD 2580 MPO 78 Cl: Final Report, Application of Lower Extremity Orthotics to Weight-Bearing Relief, Vert Mooney and J. Paul Harvey, Jr.

Abstracted from *The Journal of Bone and Joint Surgery*, 52-A:8:1563-1578, December 1970.

The critical features of the device are a total-contact cast applied as proximal as possible upon the leg with brace joints at the knee (Figs. 1 through 7). Foot and ankle are incorporated in the cast chiefly for reasons of suspension. The proximal brim is constructed of an adjustable quadrilateral socket of the same design as an above-knee prosthesis. The cast, however, is not expected to be ischial weight-bearing; and the brim construction is the most convenient shape to contour the cast at the root of the leg. Standard brace joints are incorporated in the plaster at the knee, but alignment and attachment to plaster are achieved most efficiently using equipment common to orthotic-prosthetic practice. All devices in this series were applied by orthotists-prosthetists.

Figs. 1 and 2. Joint placement and plaster trim lines permit range of knee motion from 90-deg. flexion to full extension.

The results of this study indicate that functional stresses applied to a healing fracture are beneficial and probably enhance healing potential. This point has been well demonstrated with the ambulatory care of tibia fractures. Experience has also indicated that functional stability of the healing fracture cannot be defined adequately by radiographic appearance--and cast-brace support can be discontinued once full weight-bearing and functional knee range are available to the limb. Support to the incompletely healed





Figs. 3 through 7. Views of fracture cast-brace with and without cast walking shoe.

fracture during the period of ambulatory care is thought to be achieved by conversion of the thigh into a semirigid hydraulic tube by means of the total-contact plaster encasement.

Deterrents to the successful utilization of this technique will be the lack of available personnel and equipment. A more significant deterrent, however, is the hesitancy of clinicians to view the application of functional stresses to healing fractures as a positive rather than a destructive element in wound healing. The value of functional stresses has been well demonstrated in the healing of hernia repairs, etc., but the principle is not well accepted when bone repair is considered.

CAST-BRACING

By Robert G. Thompson, M.D.
Northwestern University--McGaw Medical Center
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The Northwestern University--McGaw Medical Center consists of a number of hospitals which are largely concerned with the private practice of medicine. In addition, most of the patients with orthopaedic disabilities are not suffering from acute trauma, but rather from the problems encountered following trauma that may have been treated elsewhere and which had resulted in delayed unions or nonunions. Moreover, in the Center, most of the acute fractures of the femur and tibia are treated by surgical methods rather than by more conservative techniques such as traction. The total number of patients treated with the cast-brace technique has thus been rather small. Nevertheless, the participating surgeons have judged the experience to be relatively successful.

Doctors Robert Addison, Robert Keagy, Paul Meyer, and Robert Thompson have all participated in the cast-bracing experience at the Northwestern University--McGaw Medical Center. The prosthetist-orthotist group has included Mr. Fred Hampton, Mr. James Russ, and Mr. Michael Quigley, all associated with the Prosthetics and Orthotics Research Laboratory of Northwestern University--McGaw Medical Center.

TYPES OF BONE INJURIES TREATED

Acute Fractures

Patients with fractures involving the mid or distal third of the femur, oblique or transverse

Fractures involving the proximal tibia, including the condylar area--transverse, comminuted, and oblique.

Delayed Healing Fractures: the distal third of the femur

Patients with Pathological Lesions of the Distal Femur and Proximal Tibia Requiring Protection following Bone Grafting

PRECAST-BRACE TREATMENT

When a patient presents with a fresh fracture in the distal half of the femur, our routine practice has been to maintain this patient in skeletal traction for a period of four to six weeks, or until clinical stability of the fracture site is present and/or initial callus formation is noted in the x-ray. The patient then has a cast-brace applied. In the patient who has a fracture of the proximal tibia involving one or both condyles or the proximal half of the tibia, the custom has been to maintain this patient in a long-leg plaster cast for two to four weeks until the acute reaction has subsided and some initial stability is present. At this stage a cast-brace is then applied and maintained until evidence of healing is present both clinically and by x-ray. Patients with nonunions of the femur and/or the proximal tibia are treated as soon as arrangements can be made to fit them with a cast-brace. For those who have had surgical lesions of the bone treated by excision and grafting, the cast-brace may be applied after the sutures are removed.

APPLICATION OF CAST-BRACE

The patient is usually transported to the cast-room of the hospital where he will be treated by both the attending surgeon and the prosthetist or orthotist who will fabricate the cast-brace. The proximal thigh portion of the cast-brace is applied by first drawing a Spandex stump sock (with toe removed) over the thigh. A preformed adjustable plastic brim which is roughly the size of the patient's proximal thigh is then applied, following which the plastic brim is incorporated in the thigh portion of the plaster cast. The below-knee section of the plaster cast is then applied. Either a complete below-knee cast incorporating the foot and ankle or a plaster cylinder is used. The attachment to the shoe (if used) is made through a cable extension with stirrup attachment.

The thigh portion and below-knee section of the brace are joined at the knee by means of polycentric knee joints. These joints have been slightly modified by shortening the joint extensions, and a strip of metal is usually riveted to the ends of these joint bars for better anchorage to the plaster cast. The two knee joints are joined by a special jig which allows the joints to be aligned so that on knee flexion the alignment of the fracture is maintained. The hinges are temporarily fastened to the plaster cast and the knee is put through a range of motion to make sure that adequate knee flexion and extension are available. The proximal thigh portion of the brace is snugged up to the ischial-seat area, following which the knee joints are then incorporated by means of additional plaster onto both the thigh and below-knee portions of the cast. To minimize postcast-brace swelling in the knee area, a Tubi-grip stockinette is used. This stockinette maintains firm pressure over the exposed knee and controls the swelling and edema in the knee area to some degree. The foot and ankle portions of the cast-brace are solidly incorporated into the below-knee portion of the cast, following which a walking heel may be applied, or perhaps a Molypedic boot is attached to the foot piece of the cast. If a shoe is to be used, a cable extension from the below-knee leg cylinder is applied, and is attached to a stirrup for application to the shoe. This technique is very similar to that used by Dr. Augusto Sarmiento. The patient begins ambulation between parallel bars in physical therapy (after the cast has thoroughly dried), and is graduated to a walker and to crutches. If he is able to take full weight-bearing with security, he then may graduate to a cane.

The cast-brace has been maintained for a period of time anywhere from six to twelve weeks depending on, first, how well the brace stands up under patient usage, and, second, whether bone healing is evident before the end of the twelve-week period.

RESULTS AND DISCUSSIONS

The Northwestern University--McGaw Medical Center group has used the cast-brace in something less than 25 patients, a series too small to draw definite conclusions. However, it has been the impression of the surgeons, as well as the prosthetists and orthotists that have worked with these patients, that the patient has been quite comfortable in his cast-brace. We have felt that varying amounts of ischial weight-bearing have been present since, in one instance, we have been able to document a pressure decubitus immediately over the ischial tuberosity in a patient who was wearing a cast-brace. Acute fractures and nonunions of the femur have been maintained in excellent alignment, and accelerated bone healing has been present in a few of the acute injuries. The fracture nonunions have shown the usual delay in their healing, but the cast-brace has provided a conservative means of treating nonunions of the distal femur in which open surgery and bone grafting might be contraindicated. Fractures of the proximal tibia have, in almost all instances, healed with preservation of considerable knee motion. In several of the patients it was noted that they had 90 deg. of knee flexion very quickly after the cast-brace was removed. This is in contrast to perhaps only 20 to 30 deg. noted in patients who had been treated in long-leg plaster casts without knee joints. It is believed that the principal contributions of the cast-brace are: 1) early and progressive weight-bearing; 2) maintenance of the rhythm of gait; 3) the ability to return to productive work at an earlier period; 4) the avoidance of surgery in patients in whom surgery would be poorly tolerated; 5) the preservation of joint motion; and 6) the minimizing of muscle atrophy.

It is to be noted that the majority of acute injuries to the middle and distal femur in private patients treated by the above group of surgeons are usually handled by surgical means, but there is an occasional patient in whom surgery would be contraindicated; and the cast-brace thus offers a real possibility for very adequate treatment. In the patients with proximal tibial fractures which are too comminuted or in whom surgery would not be feasible, the use of a cast-brace offers definite advantages. The only discernible drawback noted in the present program has been the necessity of a team approach, namely, not only the use of a surgeon and/or his assistant, but also a prosthetist or orthotist, or one who is knowledgeable in the techniques of knee-joint hinge alignment and fabrication of the preformed portions of the cast-brace. This last factor may well set definite limitations on the widespread use of this technique.

THE EVALUATION AND USE OF EARLY CAST-BRACE AMBULATION FOR FEMORAL SHAFT FRACTURES

By John Connolly, M.D.
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As is prudent with any untried method, most of the advocates of cast-brace treatment procedures have conservatively advised that the femoral shaft fracture be maintained in traction for six to eight weeks prior to application of the cast-brace in order for the fracture to "become sticky." How less likely the fracture would be to angulate at six to eight weeks than at one or two weeks after injury has not been documented. Femoral shaft fractures are not necessarily "sticky" at six weeks and have frequently been known to angulate when taken out of traction and placed in a poorly applied or heavily padded spica cast at six or even twelve weeks after injury. As Mooney and his associates[1] have pointed out, one basic reason for the success of the cast-brace appears to be the method by which the cast is form-fitted or contoured to the thigh in order to compress rigidly the soft tissue about the fracture in the manner of a semirigid hydraulic tube. This molding could be accomplished as readily at one week as it could at six for most shaft fractures. It has been my experience that most femoral fractures, from the mid-shaft down, can be maintained in alignment by cast-brace application to allow weight-bearing as soon as the patient's general condition stabilizes, usually within the first three weeks after injury. Our general approach has been to reduce the fracture to as anatomically satisfactory a condition as possible with skeletal traction and apply the cast-brace while traction is maintained. The traction pin is then left in place until it is evident by cineroentgenogram or plain x-ray that weight-bearing does not displace or angulate the reduced fracture. I do not maintain that rigid fracture immobilization is accomplished by the cast-brace application in the first few weeks after injury, but that this degree of immobilization is sufficient to promote union and prevent deformity. Whatever motion does occur at the fracture site does not appear to be detrimental, as pointed out by Dr. Sarmiento: "Since the motion that necessarily takes place at the fracture site during the early reparative process is the result of function, it is not detrimental to fracture healing."[2] The following case presentations are offered to demonstrate some of the results of this early ambulatory treatment of femoral shaft fractures.

Early in this study we treated a 53-year-old man with an extremely segmented fracture by application of the cast-brace seven weeks after injury, and achieved satisfactory union with no shortening five months after the injury. This man's fracture was by no means stable at the time of the cast-brace application and caused us to wonder whether other unstable fractures might be made sufficiently stable by cast-brace application to allow earlier ambulation. We cautiously began to decrease the time in traction prior to the cast-brace application.

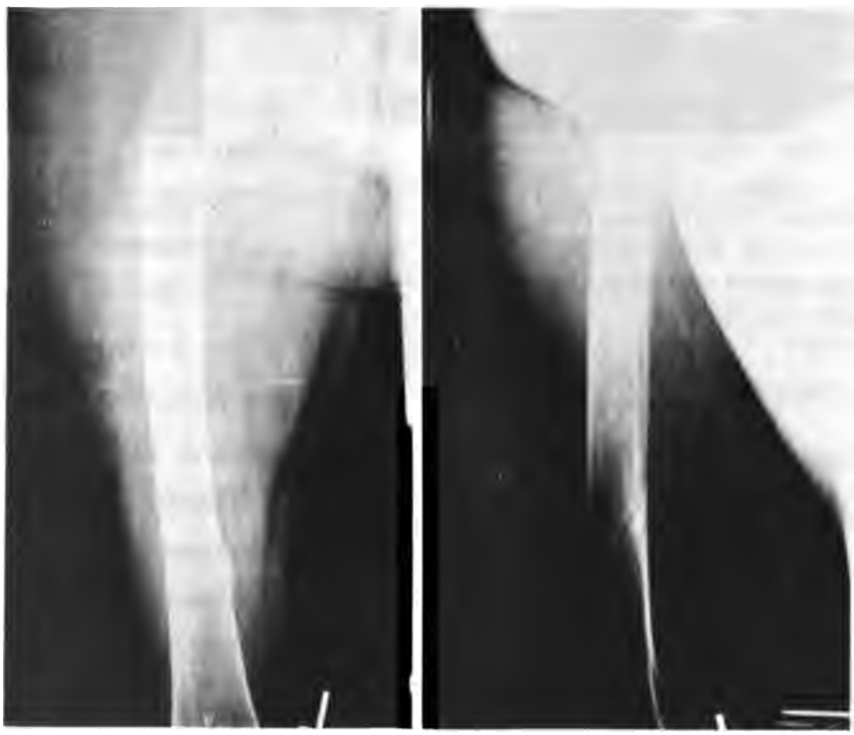
A 32-year-old man with a distal femoral fracture was allowed to ambulate 3½ weeks after injury and went on to satisfactory union of his fracture 14 weeks after injury (Figs. 1-A, 1-B, and 1-C).

Fig. 1. *Left*, A-P roentgenogram of 32-year-old man with distal femoral fracture treated with cast-brace 3½ weeks after injury. *Middle* and *right*, A-P and lateral roentgenogram of healed fracture 14 weeks after injury.

A 45-year-old woman with rheumatoid arthritis sustained a linear, undisplaced fracture of the distal femur. Encouraged by previous results, we allowed her to ambulate on the second day after injury with satisfactory union at 11 weeks (Figs. 2-A through 2-D).

Figs. 2-A and 2-B (*left*). A-P and lateral roentgenogram of 45-year-old woman's fracture treated with cast-brace two days after injury.

Figs. 2-C and 2-D (*below*). A-P and lateral roentgenogram showing healed fracture at 11 weeks.



A 53-year-old man with a mid-shaft fracture was ambulating in the cast-brace two weeks after injury and was out of the cast-brace 18 weeks after sustaining his fracture (Figs. 3-A through 3-D). At the time of cast-brace removal his knee motion went from 10 deg. short of full extension to 80 deg. of flexion with ¼ inch shortening. The extreme amount of callus formation on this man's healed fracture was reminiscent of that seen about healed rib or clavicular fractures which heal despite the necessity of regular motion.

Figs. 3-A and 3-B. A-P and lateral roentgenograms of 53-year-old man's fracture treated by cast-brace ambulation two weeks after injury.

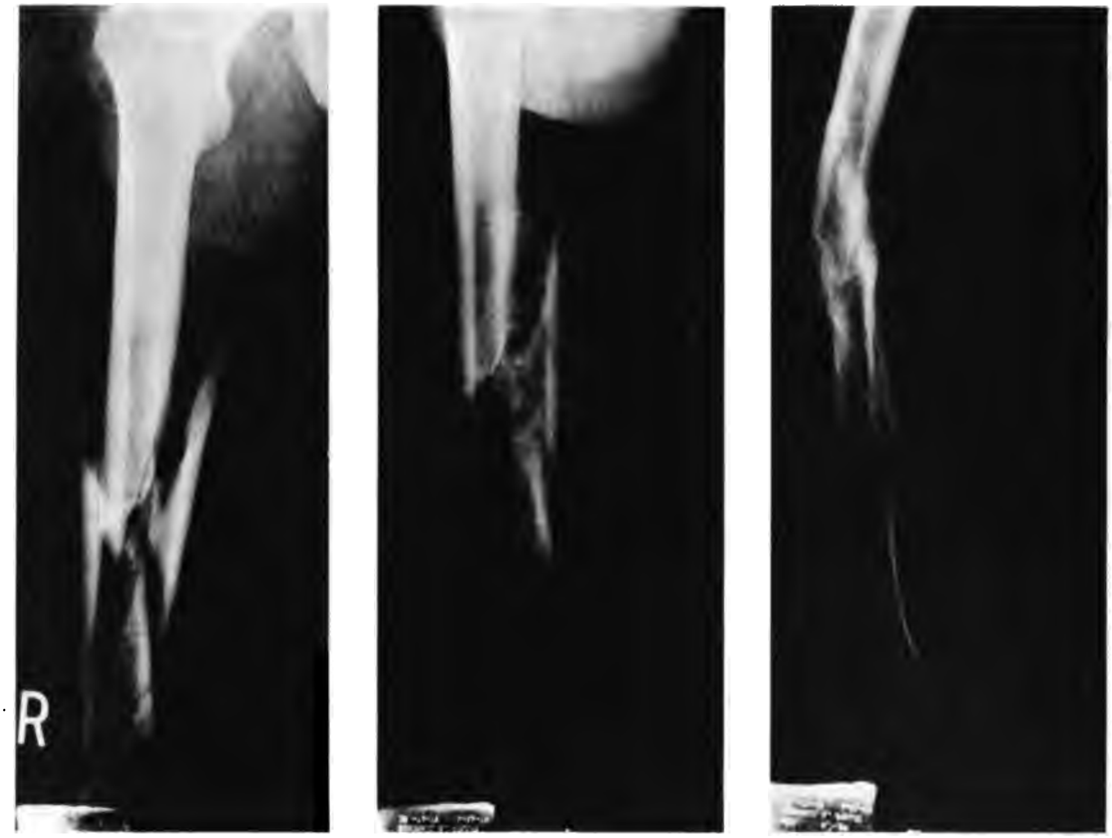
Figs. 3-C and 3-D. Healed fracture with pronounced callus formation at 18 weeks.

A 16-year-old boy injured in a motorcycle accident sustained a fracture of the mid-third of his right femur and a Monteggia fracture of his right elbow which was treated by screw fixation. He was kept in traction for two-and-one-half weeks until his symptoms subsided from the elbow operation and was then ambulated in the cast-brace. The fracture was united at 13 weeks with ½ inch shortening of the limb (Figs. 4-A through 4-D).

Figs. 4-A and 4-B. A-P and lateral roentgenogram of comminuted mid-shaft fracture in 16-year-old boy treated with ambulation at 2½ weeks.

Figs. 4-C and 4-D. Healed fracture 17 weeks after injury.

A 38-year-old man sustained a shaft fracture of his right femur in a logging accident, together with fractures of the transverse processes of his lumbar spine. He had sustained a right below-knee amputation from a similar accident five years before. He was kept in traction until his back pain decreased enough to allow a cast-brace to be applied, which was done three weeks after injury. The fractures solidified 17 weeks after injury, and after he was fitted with a new prosthesis he returned to work as a logger six months following the accident (Figs. 5-A, 5-B, and 5-C).



A B C

Fig. 5. *A*, mid-shaft fracture in 38-year-old man treated with cast-brace three weeks after injury. *B* and *C*, healed fracture at 17 weeks.

DIRECT MEASUREMENTS OF FRACTURE MOTION

Over the past 18 months we have been attempting to measure motion occurring about femoral shaft fractures with patients immobilized in traction and with them walking in the cast-brace. This has been done by cineroentgenograms as well as by an electrogoniometer designed by Dr. Paul King of the Biomedical Engineering Department. This device consists of transducers designed to measure rotation and translation between pins inserted into the femur above and below the fracture. One of these pins is the skeletal traction pin inserted in the distal femur and the second is a pin inserted proximal to the fracture in the region of the greater trochanter (Figs. 6-A and 6-B). Motion about these two pins is felt to be due primarily

Fig. 6-A. Electrogoniometer measuring fracture motion with patient in traction.

Fig. 6-B. Electrogoniometer measuring motion with patient walking in cast-brace.

fracture motion, although soft-tissue pull also applies a limited amount of force on the pins. Initially this device was designed in an attempt to determine at what point fractures were sufficiently stable to allow weight-bearing and what fractures might be treated by early weight-bearing. Sufficient data have not been accumulated as yet to employ the device as a prognosticator in the way it was originally designed. However, it has demonstrated that a surprising amount of motion, particularly rotational motion, occurs when the fracture is "immobilized" in traction. Rotation occurs especially when the patient turns in bed, gets on a bed pan, or reaches to his bedside table. With all these activities, the distal fragment remains fixed in skeletal traction while the proximal fragment rotates with the trunk. This rotation appears to be relatively painless to the patient but did measure as much as 25 deg. in some fractures. This rotation may help to explain some of the poor results that have been reported in the past with the usual nonoperative methods of treating femoral shaft fractures. (Stryker[3] and his associates at San Diego Naval Hospital, for example, reported a 20.7-per-cent incidence of delayed or nonunion in their patients with diaphyseal femoral fractures treated in traction and a spica cast.) Our measurements have demonstrated consistently that the well-molded cast-brace can diminish rotation of a fracture but not necessarily affect the translation or pistoning motion (Figs. 7-A and 7-B). This pistoning motion does not appear to be detrimental to fracture healing and may actually be associated with the excess callus noted on several occasions in fractures treated by early ambulation.

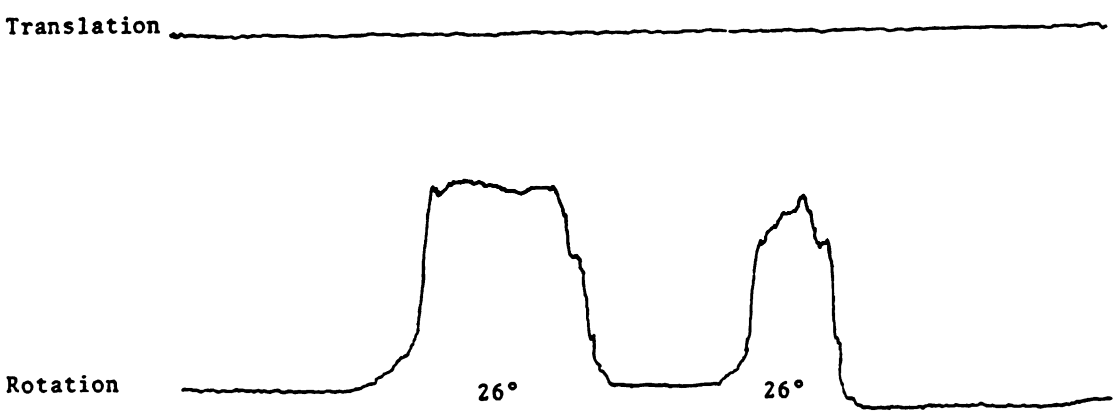


Fig. 7-A. Fracture site relative motion occurring during torso twisting (in traction).

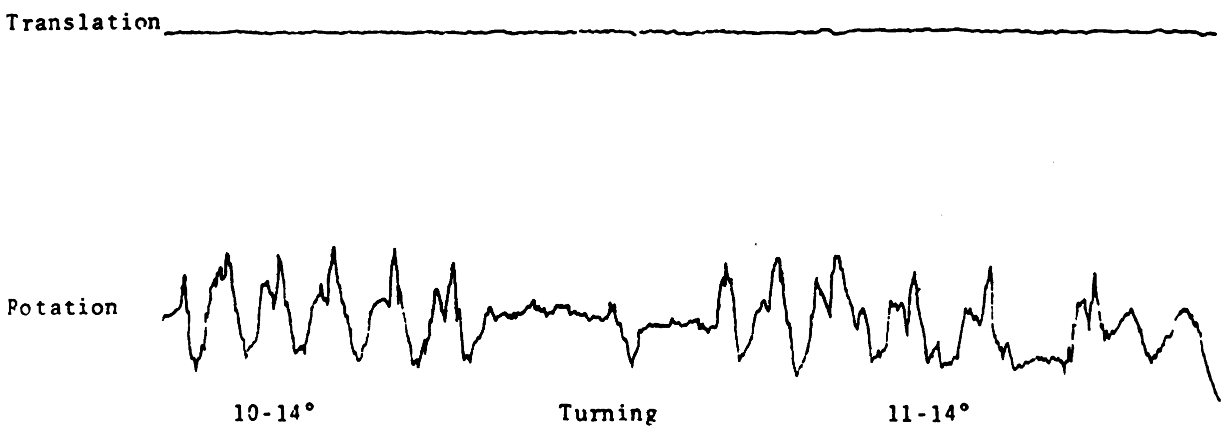


Fig. 7-B. Fracture site relative motion occurring during walking between parallel bars (in cast-brace).

The effect of the cast-brace on fracture rotation was measured in a 39-year-old man who sustained a gunshot wound fracturing the mid-shaft of his femur (Figs. 8-A through 8-D). The previously described electrogoniometer

Figs. 8-A and 8-B. A-P and lateral roentgenograms of mid-shaft fracture in 39-year-old man treated by cast-brace ambulation at one week. Rotation measured 12.5 deg.

Fig. 8-C. Alignment was improved by application of cast-brace. Rotation measured 7 deg.

Fig. 8-D. Fracture had healed when cast-brace was removed at 12 weeks.

demonstrated that in traction the amount of rotation about the fracture site averaged 12.5 deg. A repeat measurement with the patient walking in the cast-brace six days after injury indicated that rotation had decreased to 7 deg. The patient continued in the cast-brace, which was changed once three weeks after injury because of diminished swelling. Twelve weeks after injury the cast-brace was removed and the patient discarded all external support at 16 weeks. The oblique, comminuted type of fracture appears to be especially suited for the early ambulatory treatment since reduction and alignment as demonstrated in this last patient can frequently be improved by a well-applied cast-brace in comparison to the alignment achieved with traction.

SUMMARY OF PRESENT SERIES

Of the last 58 fractures treated by cast-brace application, the majority (or 35 patients) have been ambulatory within one month after injury (Fig. 9). Those in the group kept in traction eight or more weeks were either treated earlier in the study, had multiple injuries, or were referred from other hospitals. In regard to complications, our chief problem with the technique has been the development of pressure sores at the edges of the cast, usually beneath the ischial fold or above the knee. In addition, one other major complication has been two cases of refracture, both occurring in fractures that were felt to be clinically and radiographically united. One patient sustained a mid-shaft femoral fracture and was kept in traction for four weeks prior to application of the cast-brace. The device was removed 18 weeks after injury and the patient had no complaints of pain on weight-

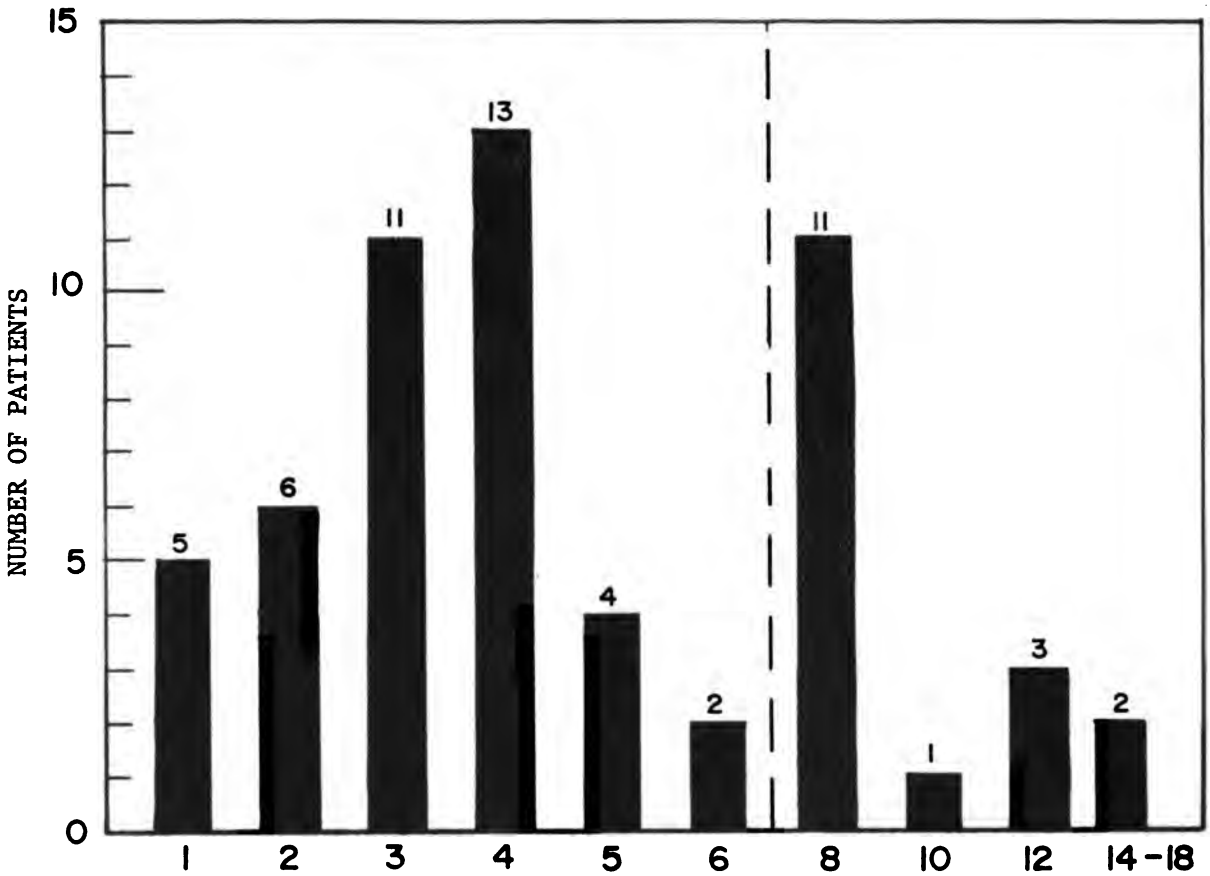


Fig. 9. Weeks in traction prior to cast-brace.

bearing with adequate callus evident on x-rays (Figs. 10-A through 10-E). He was maintained on crutches after removal of the cast-brace but two weeks later he either fell or was pushed while on crutches and sustained a bending of the fracture site. This was not felt to be a complete fracture but was definitely painful and consequently was treated by reapplication of the cast-brace for ten more weeks at which time satisfactory union was achieved.

The freedom provided by the cast-brace may sometimes be a detriment when the device is removed. The patient must be cautioned against overstressing the limb since freedom from pain on weight-bearing may not be an absolute index of healing. Caution seems especially called for when the fracture heals in bayonet apposition as was the case in both of our refractures.

Figs. 10-A and 10-B. Mid-shaft fracture was felt to have healed with satisfactory callus despite bayonet apposition.
Fig. 10-C. Fracture became painful and slightly bent two weeks after cast-brace removed.

Figs. 10-D and 10-E. A-P and lateral roentgenogram showing healed fracture after 10 more weeks in cast-brace.

CONCLUSION

This preliminary study indicates that early cast-brace treatment can be utilized for most mid- and distal-third femoral shaft fractures, usually within the first month after injury. In our limited experience the more comminuted or oblique fractures are especially suited for closed reduction and early cast-brace ambulation, while transverse mid-shaft fractures are best treated primarily by an intramedullary rod. Direct electrogoniometric and cineroentgenographic measurement of fracture motion indicate that application of the cast-brace considerably diminishes rotation but does not reduce translation at the fracture site. No fracture in our series failed to unite. Refracture or bending of a partially healed fracture occurred in two femurs which had healed in bayonet apposition.

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CAST-BRACE FOR TREATMENT OF FRESH FRACTURE OF THE FEMUR AND OTHER CONDITIONS

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Vert Mooney, combining unusual empathy for the patient, technical ingenuity, and conservative scientific processes of evaluation, has added a movable exoskeleton to our armamentarium for treatment of the fractured femur and other conditions. At first I thought it would not work for initial treatment and that it was not worthwhile for convalescent management. I was wrong on both counts.

The cast-brace immediately applied can accomplish all that the Thomas splint does during the initial treatment, even better, since Connolly has shown that it gives more rotatory stability than the splint.

Thus, the procedure for immediate ambulation of the fractured femur starts with a Steinmann pin through the tibial tuberosity, and traction is used while the cast-brace is applied, incorporating the Steinmann pin with the cast while arbitrarily using 35-lb. traction. After application of the plaster and the hinges, the weights are released, x-rays are taken, and the patient is ambulated immediately. If review of the x-rays reveals shortening or angulation, the Steinmann pin can be used for traction to correct these deformities. So far, however, this has never been necessary.

It is important to emphasize that this treatment is carried out under my personal supervision. It is not delegated to a resident or a therapist. It is considered a project of clinical investigation and daily efforts are made to facilitate self-help for the patient since his cooperation and progress depend entirely on his comfort and his feeling of progressive accomplishment. His activities are determined by his tolerance which is gauged by his ease of performance from day to day. This is a matter of empathy and art rather than method or manual.

The Steinmann pin remains in place as a second line of defense. Should undesirable shortening or angulation occur, it can be corrected at any time. Preservation of acceptable position and rapid consolidation are the rule so far (Figs. 1 and 2).

Fig. 1. Immediate ambulation in cast-brace.

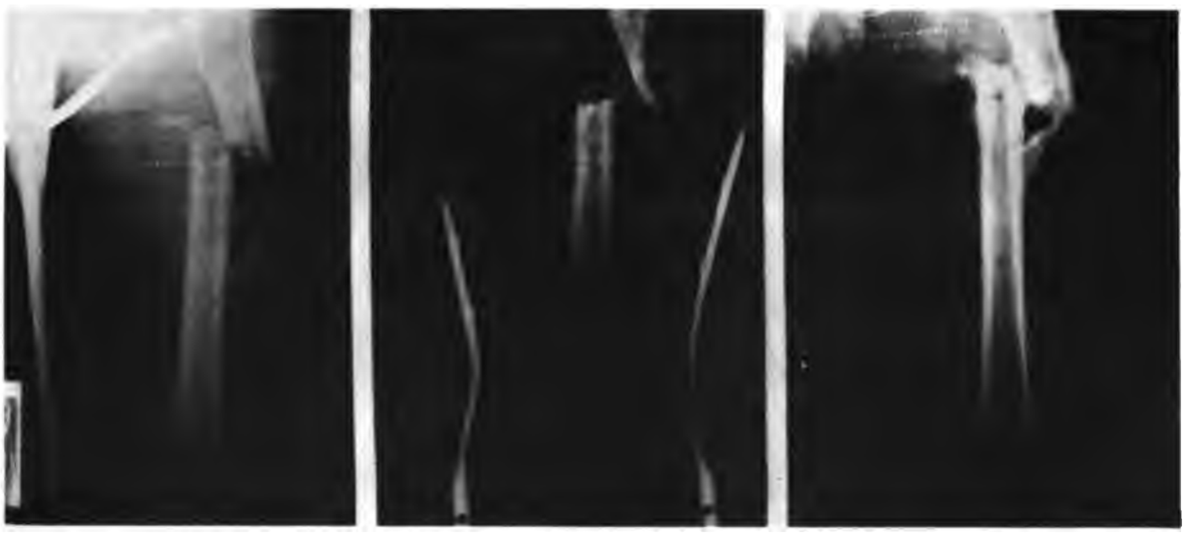
I believe that intramedullary fixation still is the ideal method in rigorously selected cases, but wherever an open wound of one or two days' duration prevents intramedullary fixation, the cast-brace is an excellent alternative. After a wound is healed the alternative of open reduction is still open if doctor or patient so desires. Usually, the healed bone, even in less than ideal position, is accepted by the patient (Figs. 3 and 4). The greatest applicability of the cast-brace is in compound injuries, missile wounds, and fractures complicated by medical or other conditions.

Other applications--correction of flexion contractures of the knee by dynamic rubber-tube traction from an outrigger applied to a cast-brace. The response is rapid and painless since the system permits motion. I have also found the cast-brace useful in the nonoperative management of injuries to the ligaments of the knee, after initial period of rehabilitation of muscles and reestablishment of kinetic balance at bedrest.

Why and how does the cast-brace work? This is a matter of great puzzlement as long as we think in terms of mechanical support, ischial weight-bearing, or external control of the fragments. The problem loses its mystery if we can see the cast-brace for what it is--a device which can be used for the patient's comfort for a relatively brief period of local and regional repair of his injury.

1 wk. 5 wk. 10 wk.

Fig. 2. Subtrochanteric fracture treated by cast-brace: note a) alignment; b) relation of cast to ischial tuberosity or rather lack thereof; and c) rapidity of healing.



0 wk. 6 wk. 12 wk.

Fig. 3. Compound fracture, two days old, treated in cast-brace with rapid union.

3 weeks after injury

Fig. 4. Immediate ambulation. Note Steinmann pin which could be used for traction should degree of angulation or shortening be undesirable.

THE MANAGEMENT OF FRACTURES OF THE FEMUR BY EARLY AMBULATION UTILIZING A MINISPICA CAST-BRACE

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There are certain fractures of the femur that are particularly amenable to treatment by intramedullary fixation. However, comminuted fractures, fractures of the distal and proximal thirds, and open fractures are not. The use of any form of internal fixation is particularly contraindicated in fractures of the femur due to high-velocity missiles such as occur in combat. These fractures traditionally have been managed by prolonged periods of skeletal traction with the occasional use of a hip spica once union was obtained. The prolonged period of skeletal traction in bed led to general inanition, atrophy of thigh muscles, knee-joint stiffness, and an increased incidence of renal calculus. The use of the hip spica after traction added further to the muscle atrophy and joint stiffness. Knee-joint stiffness is the greatest cause of disability after femoral fractures.

To avoid these complications, Dehne advised that immediate quadriceps exercise and a general exercise program should be instituted as soon as the extremity was placed in skeletal traction. This had the benefit of improving knee motion and promoting earlier union of the fracture, and markedly improving the general condition of the patient. However, the prolonged period of lack of ambulation was not diminished, there were still problems with restoration of knee motion, and time until return to duty was unduly prolonged.

The average time before ambulation as reported by Brav[1] was 24 weeks. The average time before return to duty in a study by DeLorme[2] was 13 months.

A significantly large proportion of these patients developed less than 90 deg. of active knee flexion. In Brav's report, only 30 per cent had 90 deg. or more of knee flexion. DeLorme found only 60 per cent got more than 70 deg. of motion.

The key to improving these results seemed to lie in some method of earlier ambulation with knee motion which would avoid the complications of intramedullary nailing. Based on our experience with the early ambulation of tibial fractures that led to early union, and early functional restoration of the extremity, a similar approach to the femur was sought.

I became aware of the work of Dr. Vert Mooney utilizing a cast-brace orthosis for the early ambulation of the distal femur. This seemed to be the answer. Dr. Floyd Goodman, a member of our staff, modified the Mooney cast by adding a pelvic portion and discontinuing the foot portion. This he termed the "minispica." This cast has been used on the Orthopedic Service at Valley Forge General Hospital since 1968. It was reported by Dr. Goodman at the Annual Meeting of the Society of Military Orthopedic Surgeons in November 1969.

METHOD

The patient usually arrives at Valley Forge General Hospital five to ten days after the wound has been received. He arrives in a bilateral hip spica, usually with a Steinmann pin transfixing the proximal tibia. If one is not already in place it is inserted and the extremity suspended in balanced traction. We usually use a large felt sling (Fig. 1) rather than a Thomas splint. Appropriate wound care is given. The patient is immediately started on a general reconditioning program. Active quadriceps exercise with active knee motion is pushed aggressively (Figs. 1 and 2). When motor control of the extremity has been achieved and the fracture has a measure of clinical stability, the minispica is applied.

The technique used is that described by Dr. Floyd Goodman and is given below.

An appropriate size stockinette is fitted from the chest to the ankle of the involved extremity. The patient is placed on a standard fracture table with malleable iron bars form-fitted to the patient's back (Fig. 3). The frequently used sacral rest leaves excess room tending toward a sloppy fit. The bars are overlaid with strips of ¼-in. felt, 6 in. wide,

Fig. 1. Skeletal traction with Steinmann pin through tibia, and felt slings.

Fig. 2. Amount of knee flexion that can be obtained by early motion.

for the patient's comfort. The fractured lower extremity is placed in slight adduction which allows the patient to ambulate later with a normal base gait. The hip and knee are placed in 30-deg. flexion (Fig. 4). The

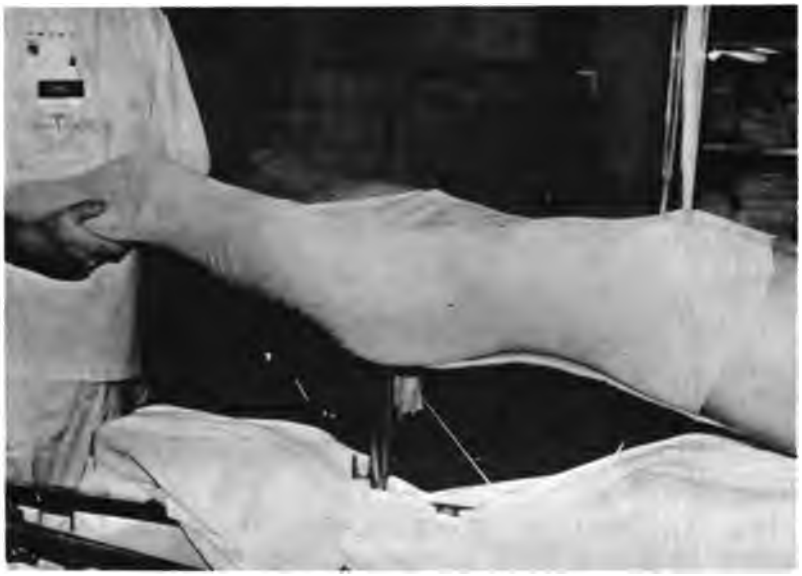


Fig. 3. Use of malleable bars rather than sacral rest. Stockinette applied.

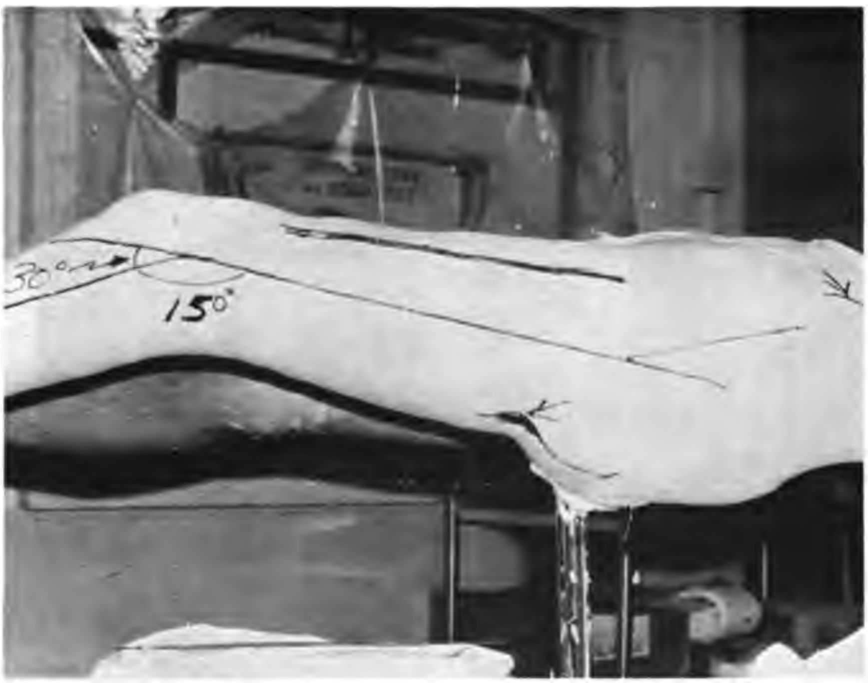


Fig. 4. Knee and hip in 30-deg. flexion. Gluteal fold and iliac crests well molded.

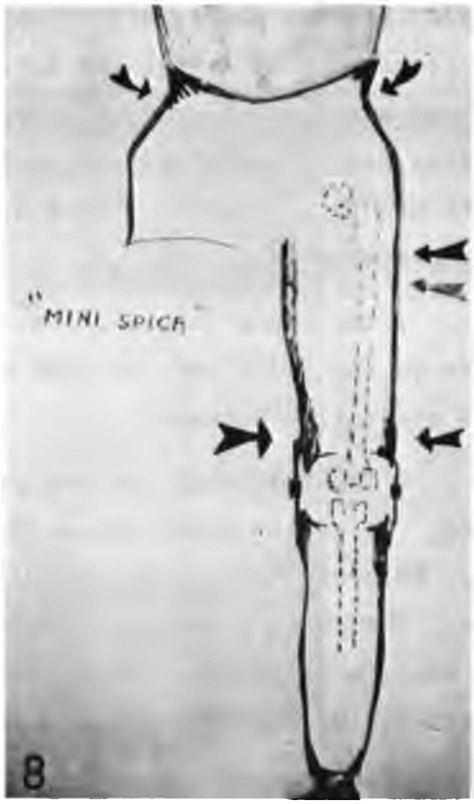
hip flexion allows the patient to sit adequately, walk comfortably (Figs. 5, 6, and 7), and take care of his hygienic needs. The knee flexion allows control of rotation and comfort during application of the cast, and facilitates placement of the knee hinges. After the patient has been positioned on the table, three layers of Webril are applied from rib cage to ankle with six layers over the iliac crest and at the cast edges. The upper portion of the spica cast is then applied with molding above the iliac crests, as in fitting a Milwaukee brace. The upper thigh is wrapped with snug, even compression. The gluteal fold is accentuated, and the lateral wall is flattened from the greater trochanter to mid-thigh.

If the circumference of the cast at the upper-thigh and groin area is excessive, an elliptical section is removed laterally. The slack is taken up with a 4-in. muslin strip and the upper portion of the plaster is completed. This creation of a firm, lateral, total-contact support with the thigh in some adduction is most important (Fig. 8). Final positioning of the fracture is then accomplished and the remainder of the cast is applied to the ankle level. It is well-molded medially and laterally in the supracondylar area of the femur. X-rays are obtained and wedging is carried out if necessary. The medial and lateral surfaces at the level of the knee are then cut away so that the collateral ligament attachments to the femoral condyles can be palpated. Using these as the center of rotation, the knee joints are then applied. These are single-axis joints and must be accurately centered (Fig. 8).

The upper margin of the cast is trimmed just above the iliac crests on the sides and one inch below the umbilicus anteriorly. Sharp cast edges are rolled outward.

The following day the patient is ambulatory with the knee hinges locked. He starts first in the Physical Therapy Clinic between parallel bars. He progresses to crutches, cane, and no support as rapidly as possible. When he has standing control, the knee hinges are unlocked and remain so. He continues on a knee-exercise program with strenuous resistance exercises. He is continued in plaster until he has firm clinical and radiological union.

Fig. 5. Minispica with hinges applied.
Fig. 6. Hip- and knee-flexion angles permit comfortable sitting.
Fig. 7. Walking comfortably.
Fig. 8. Note molding at iliac crests and lateral thigh.



MATERIAL

For the purpose of this paper we have reviewed our first 45 cases treated by the minispica. This is a consecutive, unselected series.

There were 39 open fractures and 6 closed.

The average time from injury to the application of the minispica was 8.4 weeks. In the first 20 cases the average time to cast was 9 weeks, in the last 25 it was six weeks. At the present time the average time is between 3 to 5 weeks.

Our criterion for healing is when the fracture is capable of unsupported weight-bearing without the cast. This has been 5.7 months. The average time for return to duty is 7.7 months (Figs. 9-A, 9-B, and 9-C).

There was one nonunion. This was a soldier who had a 7-in. bone defect in the femur due to a high-velocity-missile injury. He had been held in traction with sufficient weight to restore normal length for 5 weeks prior to arrival at Valley Forge General Hospital. After 4 months in a minispica there was still gross motion at the fracture site. At surgery there was a large mass of muscle interposed in the fracture site. An intramedullary nail was inserted with autogenous bone graft and the wound has since healed. One patient had a shortening of 1½ inches, another 1 inch. The remainder had shortening of 0 to 3/4 in.

All had 90 deg. or more of knee flexion at the time of return to duty.

All wounds healed without meddlesome surgery and no patient had any draining sinuses when returned to duty.

The use of the minispica in our hands has been eminently successful in treating fractures of the femur.

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Fig. 9-A, *upper left*. At time of wounding.

Fig. 9-B, *upper right*. At 4 months.

Fig. 9-C, *right*. Upon return to duty at 7 months, 3 weeks.

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