Constructive Lay-up Technique for Lower-limb Orthoses[1]

RALF UHLIG, O.M.[2]

It is probably because Engineer Scallas and Prosthetist Passerini reported their lower-limb orthotic techniques at the INTERBOR meeting held in Karlsruhe, Germany, 1969, that new emphasis has been placed on orthotics. Their techniques, which have been published, led professional discussions somewhat away from prosthetics, which had overshadowed orthotics for some time. This, of course, resulted in extensive discussions, bringing forth agreement, indifference, or controversy. This paper is intended to document an approach developed by me, and to state opinions different in part from the Karlsruhe discussions.

Fabrication of lower-limb orthoses intended for fixation, correction, weight-bearing, or extension, relates considerably more to the etiology or therapy to be applied than, for example, the principles involved in limb prosthetics. Therefore, frequently the fabrication of leg orthoses is considered a task for a hospital-owned or affiliated orthotics facility. However, manufacturing of lower-limb prostheses is much more frequently the responsibility of independent facilities.

A tuberculosis treatment center cannot be compared with an outpatient department of a general hospital since hospital days per patient, overall costs, and economizing of treatment vary greatly. Nor could one compare orthotic and prosthetic rehabilitation tasks.

Both tasks of rehabilitation differentiate for the Orthotist-Prosthetist economically and structurally during the fabrication process. However, they also vary as to the cause of impairment, course of treatment, and dynamic-static principles.

I hope that my interpretation of the Karlsruhe discussions is correct in reviewing the most interesting topics covered.

Mr. Scallas (Italy) compared prosthetic advances with those of orthotics and

---

[1] This paper is published under the auspices of INTERBOR's Publication Committee. (Translation by Siegfried W. Paul, C.P.O.)

[2] Director, Professional School for Technical Orthopaedics, Frankfurt/ Main, Germany

concluded that impressive progress was made in prosthetics but only little or none in orthotics. At present, orthotists are inclined to use time-consuming and much too complicated methods in fabricating lower limb orthoses. Present systems (1969) can be considered empiric and results of doubtful congruity. Supine positioning of the patient during tracing complicates the design of an orthosis intended for an upright position. The numerous modifications at time of, or after fitting the device, can, according to Scallas, be avoided and are most debatable.

Conclusions of the Karlsruhe meeting resulted in the introduction of a new system and I quote Mr. Scallas:

> "Our new development provides for a rational obtaining of body measurements resulting in most accurate fabrication data. These measurements truly correspond with any given anatomical circumstances representing a cost cutting factor which will permit a lowering of the 'sale price.' Another important advantage is elimination of any fitting. This alone saves time and travel expense in particular for patients coming from some distance."

I would like to express my own thoughts on the same subject:

(1) Comparison of technical advances made in prosthetics with those of orthotics cannot be made. Today's lower limb amputation can be managed with principles and components which are of such different magnitude that they could not be related to the impaired but, in general, preserved lower limb considered for an orthosis.

(2) There exist distinct biomechanical differences between a body supporting device and a limb-replacing prosthesis. One utilizes the stump as a functional part of the body created by the surgeon; and the other a body or joint function directing stabilization of the impaired, but still present, extremity. Combining the orthosis with this extremity will result in the desired function. Today's orthotic technology is frequently forced to make use of complicated and time-consuming principles based on many facts considering the medical circumstances. Construction of an orthosis is often ruled by the function anticipated, and therefore, dependent on existing conditions.

(3) All of the currently applied orthotic systems or working procedures are and will always be empiric in principles of their technology and precision. Body outlines remain within doubtful congruity in relation to anatomical and mechanical joint functions. In fact, they frequently must be fashioned incongruent in order to correct functions as desired by the prescribing physician.

(4) Measuring and casting techniques of extremities in effective positions will always create pro's and con's regardless of whether a vertical or horizontal approach is utilized. Personally, I believe that in most cases the vertical system is more difficult than the horizontal approach. After all, it will be the final product, the leg orthosis, which is supposed to control positioning and support of the extremity. I do not consider shifting of soft tissue during horizontal projecting as decisive, nor does this shifting have any bearing on function, statics, or the mechanics to be established. This cannot be said about the

vertical system mentioned earlier which rather tends to invite pelvic tilt and malalignment of the pelvic portion created by forces of the support brackets.

(5) Time consuming fitting procedures are not always the result of fab rication processes, but may be due to a relatively congruent agreement about older functional and fitting prfinciples of an orthosis by physician and technician.

(6) Of course, I do agree with Engineer Scallas that we have to make use of more rational methods of fabrication.

I have pointed out the deviation of opinions with the interest of our subject, the patient, in mind, and shall now discuss technical details of the various manufacturing techniques.

A. Fabrication of orthoses with the aid of plaster-of-Paris molds.

B. Fabrication of orthoses making use of a mounting jig as used in the Pope-Klenzak or the Scallas/Passerini system.

C. The Uhlig Modular system of constructive orthotic fabrication.

ORTHOTIC FABRICATION METHODS UTILIZING A PLASTER-OF-PARIS MOLD

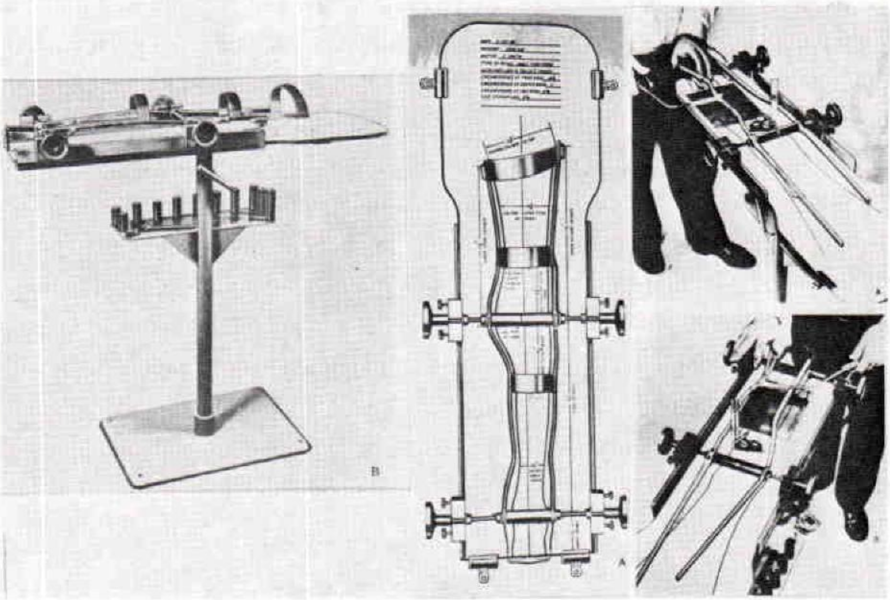
This technique is based on a plaster-of-Paris negative of the impaired extremity and the positive to be evaluated later on. Construction is based on body landmarks to be checked on the plaster positive. Difficult cases with pathological components are left up to the subjective judgment of the orthotist. It is his evaluation and ability to modify the positive which determines correct alignment or malalignment of the orthosis. Dependence on the experience of the individual handling the case is obvious.

In view of the principles involved, it is frequently necessary to cut the cast into individual segments which need to be modified and reassembled in a corrected position. Any malalignment needs to be corrected prior to actual fabrication and fitting of the orthosis. This type of fabrication process is primarily necessary for ischial weight-bearing components and lacers made of plastic or molded leather.

FABRICATION OF ORTHOSIS WITH THE AID OF MECHANICAL JIGS

Such a method is used after evaluation of the impaired limb and projection of a horizontal, traced outline.

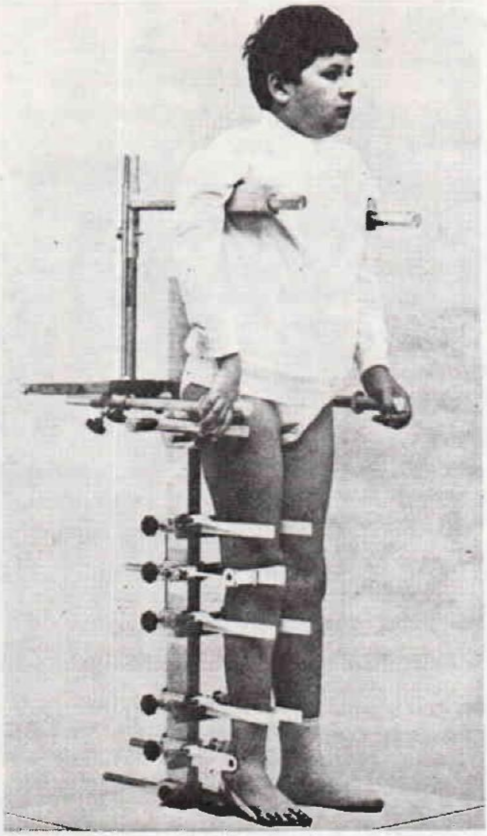
KLENZAK SYSTEM



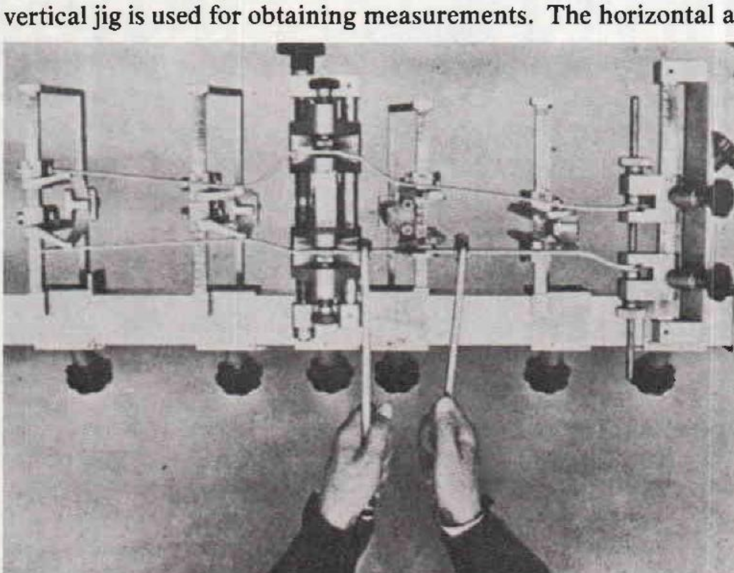
We learned about this technique in Europe in 1952 after publication of Volume I of the Orthopedic Appliance Atlas. This excellent book illustrates an American method of the Pope Foundation system, Klenzak, on Pages 406-414. A frontal tracing of a lower limb is placed on a working table, that can be adjusted in the frontal and horizontal planes. The parallel sides of the steel work table are attached solidly and function as a base for adjustable knee and ankle joint brackets. Fixation of knee and ankle joints make contouring of tubular bar stock possible by simply using an oxy-acetylene torch and bending irons. This method was used for central fabrication type of production according to measurements and corrected tracings taken at a clinic or office.

METHOD OF SCALLAS AND PASSERINI

Another method based on vertical projection utilizing a measuring and horizontal work jig which can be pivoted was developed by Scallas and Passerini in 1968. This Italian system has been published repeatedly.



The vertical jig is used for obtaining measurements. The horizontal assemb-

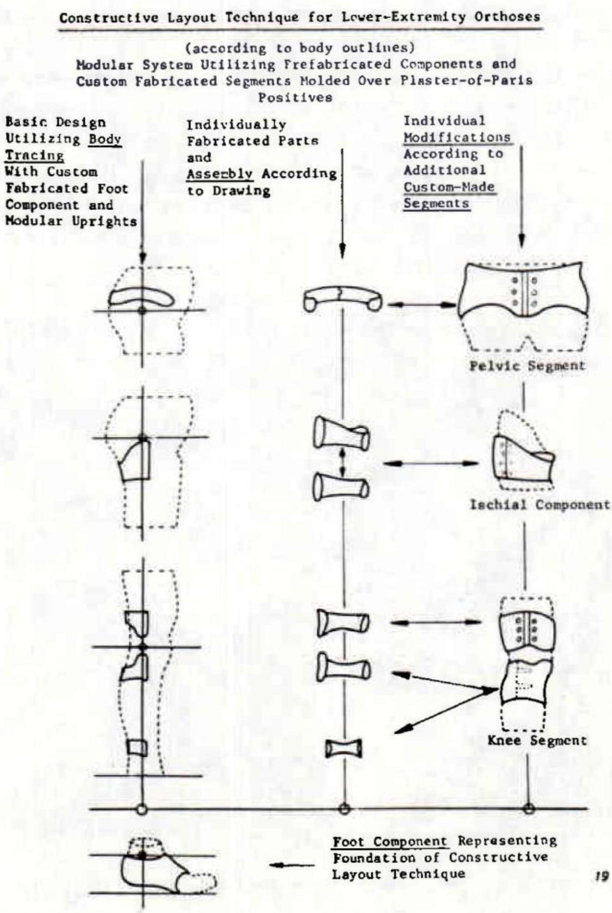


ly jig is provided with a turning fixture. The measuring device permits recording of longitudinal measurements such as the level of the ischium and ankle. The exact placement of foot control and the various bands can also be registered. Each measurement is recorded on a special chart.

Longitudinal and M-L measurements are fundamental data required for the alignment of the orthosis, and are transferred to the assembly jig. This assembly unit consists of a rectangular frame with adjustable brackets for fixation of the AK and BK uprights was well as depth and width indicators for correct location of the bands. Bending irons are used to make bars and bands conform to the established measurements. After completion of alignment, the bands and bars are welded while in the jig.

THE CONSTRUCTIVE ORTHOTIC FABRICATION TECHNIQUE

This method was developed by me in 1952 and 1953, and is based on earlier experience established in Germany. Constructive orthotic fabrication is based on technical drawings, evaluations of x-rays, bony landmarks, contours, and "body measurement tables" of the proportional sciences.



Plaster-of-Paris molds are utilized in conjunction with the before-mentioned information obtained. However, it is only necessary to case "extremity sections" that require special attention.

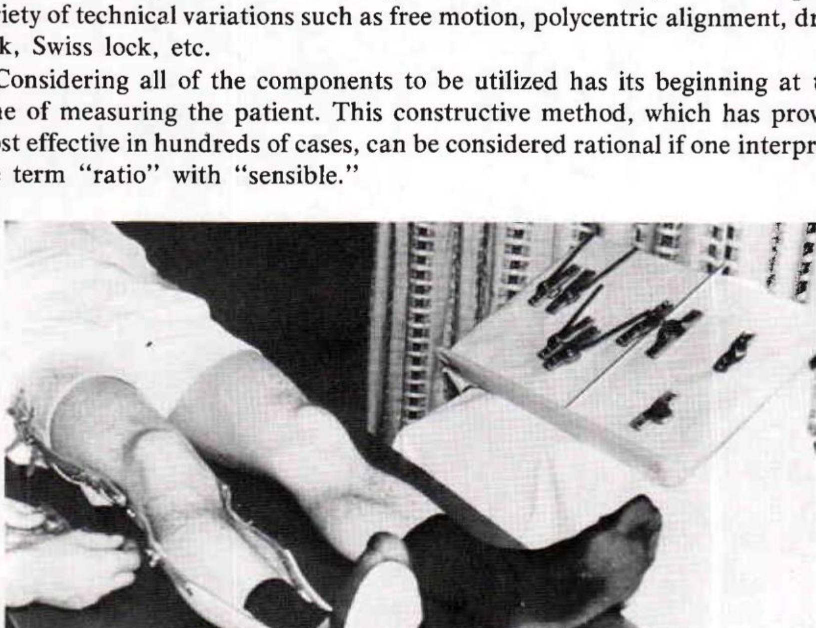
Why such segmentation? Malignment or malfit always results in malfunction. Therefore, prior to reaching a conclusion, it should be mandatory to first evaluate the overall condition, then to examine carefully each body segment individually.

The "constructive" lay up and fabrication method for lower-limb orthoses is a method utilizing the modular system, with application of prefabricated components such as uprights and only some segments which need custom fabrication.

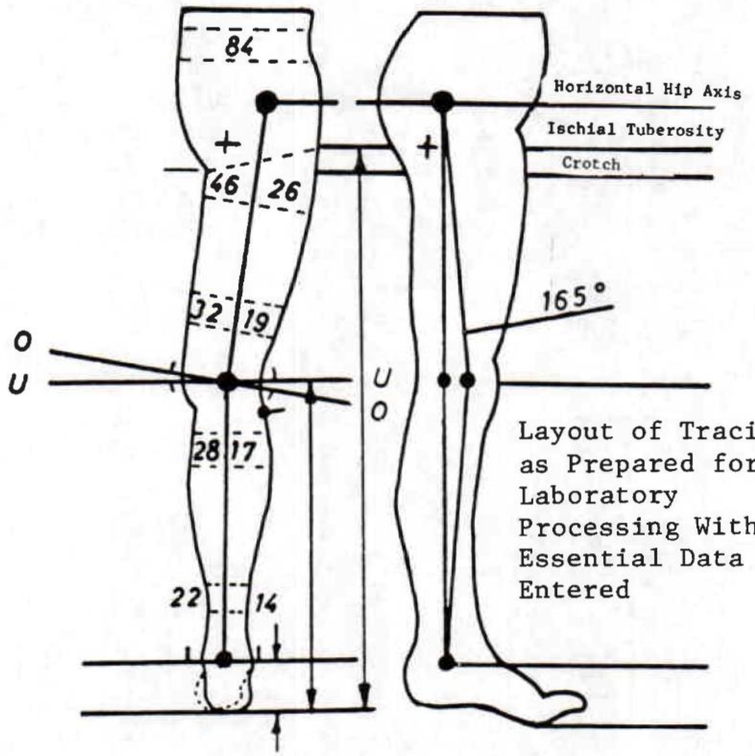
The need to obtain a plaster mold for the entire extremity, which at times is most difficult, is no longer required in most cases. All that is needed usually are tracings projecting frontal, sagittal, and horizontal views. Foundation of the constructive orthotic lay up technique is the foot control component which needs to be fashioned over a plaster mold in every case. Additional plaster molds are required if corrections are desired, or anatomical pathologic circumstances need to be met.

An additional advantage for my system came about with introduction of interchangeable joints, such as the one developed by Mr. John in Hanover and manufactured by Otto Bock. These joints are standardized, and offer great variety of technical variations such as free motion, polycentric alignment, drop lock, Swiss lock, etc.

Considering all of the components to be utilized has its beginning at the time of measuring the patient. This constructive method, which has proved most effective in hundreds of cases, can be considered rational if one interprets the term "ratio" with "sensible."

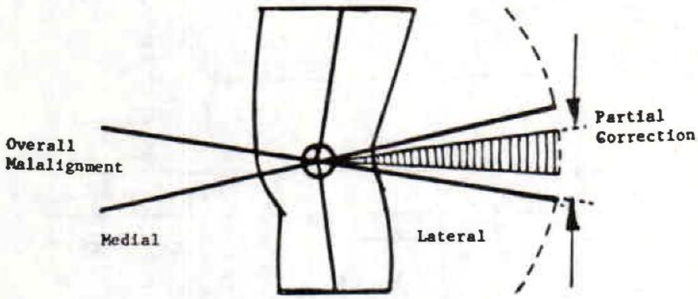


A horizontal examining table is used in drawing frontal sagittal, and horizontal view of the extremity. Accuracy in the vertical projection is assured by using a scriber holding the pencil. Anatomical landmarks and individual measurements such as circumferences and positional angles are entered on the drawing. Special attention is given to heel height and the forefoot section.

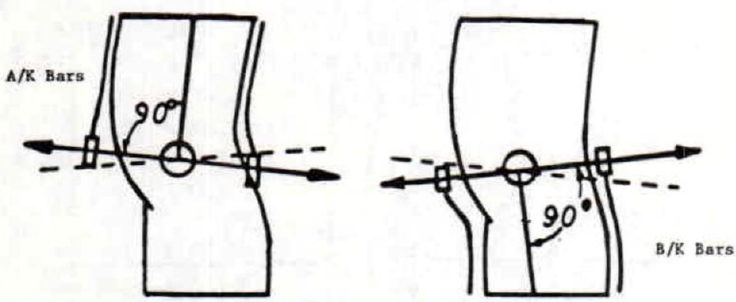


Layout of Tracing as Prepared for Laboratory Processing With Essential Data Entered

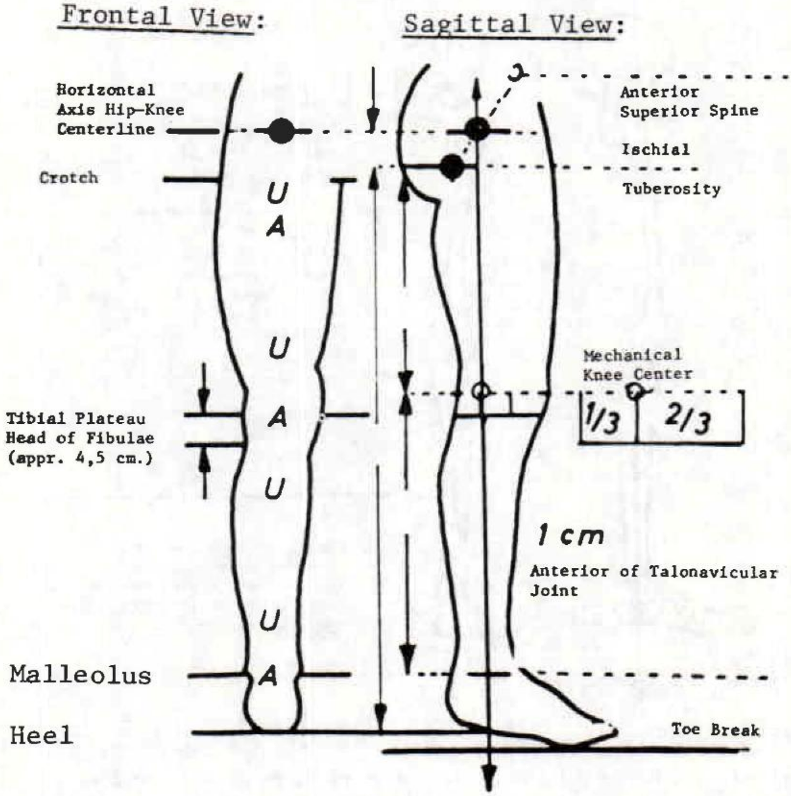
The body outline will next be transformed into a technical drawing. The skeletal alignment, or better, the pathological deviations, can be corrected or improved through therapeutic and precise mechanical exercises providing that no secondary findings such as contractures or other complications are present.



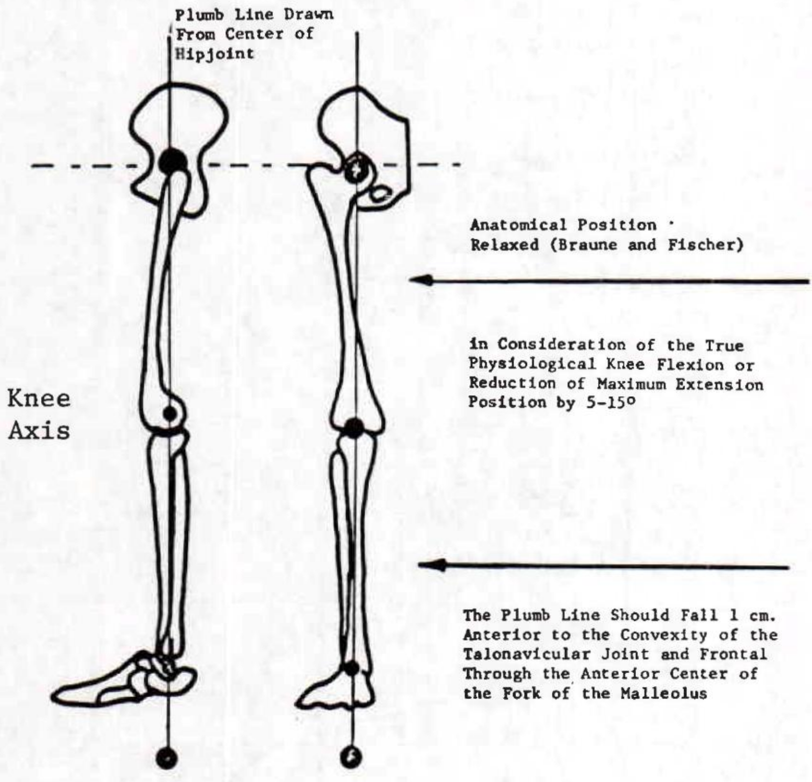
Example: Knock-Knee Angle



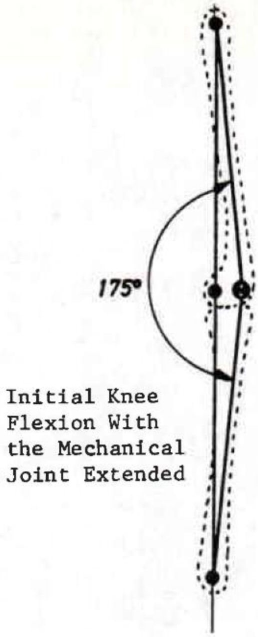
Most orthotists do not have radiological equipment at their disposal and are forced to depend on clinical examination in an attempt to reconstruct normal anatomical conditions. For that reason, it is that only exact technical drawings along with plaster molds, selected joints, and uprights will be processed in the laboratory. All of this information is controlled by a technical evaluation.

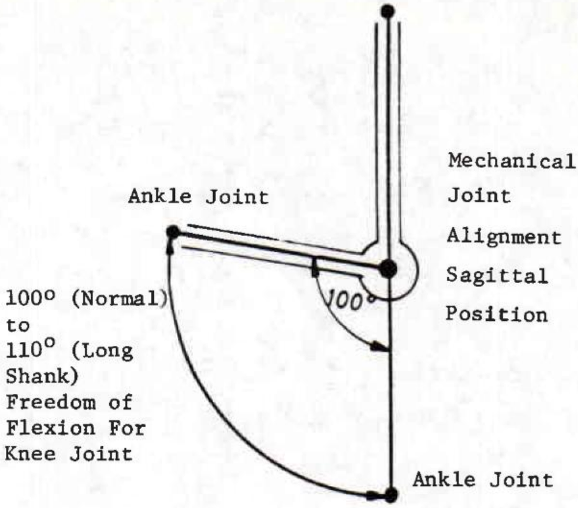


Anatomical reference points of importance are the horizontal hip axis, exact location of the ischial tuberosity, the knee and ankle joint, and location of the fibula. Additional points of reference are circumferences, longitudinal measurements, and M-L dimensions.

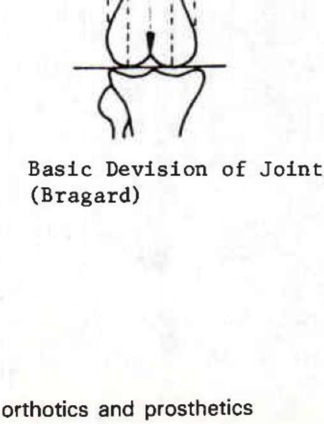


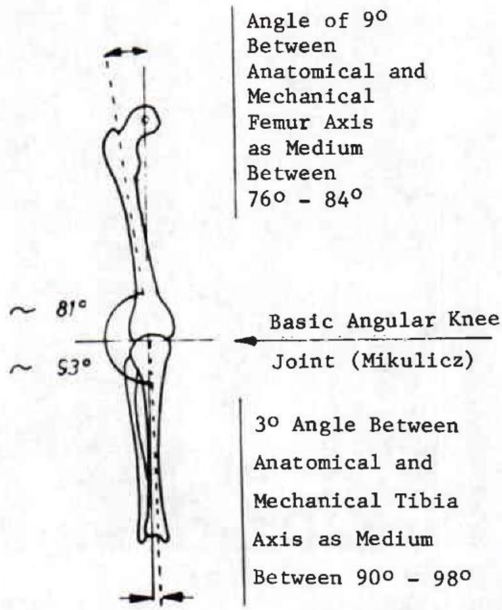
The orientation line in the sagittal view for a +/- deviation is projected from anterior to the femoral head to the mechanical point of knee rotation and a position 1 cm anterior to the convexity of the talonavicular joint. Anteriorly this line extends through the knee joint to the center of the malleolal fork. This is accompolished under consideration of the true physiological knee flexion. (Reducing 15° from complete knee extension under tension to a relaxed anatomical position according to "Braune and Fisher."(This individual physiological knee flexion also provides a comparison to the assumed skeletal position when a tracing is being projected.

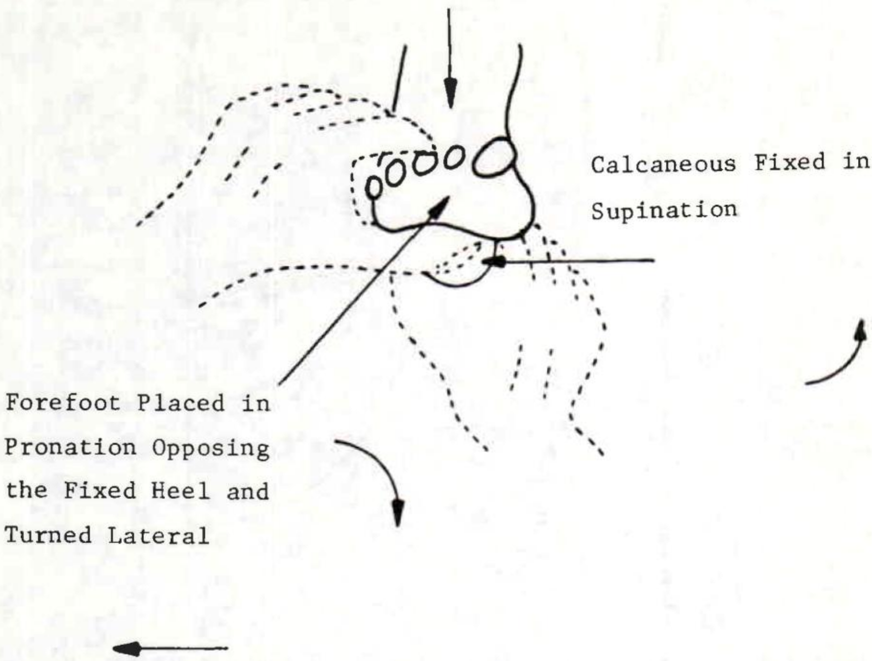




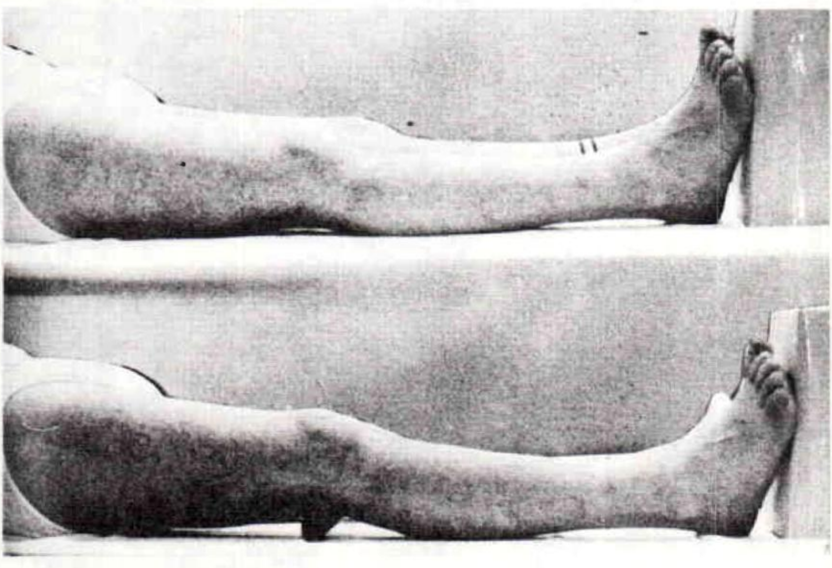
Founded on this physiological knee flexion, one can observe that the flexion angle of the orthosis consisting of 165° will actually result in an extended position. In addition, the orthosis will provide for a range of flexion and extension of 100°-110° accommodating the need for sitting comfort (average BK legth). Determination of the knee axis horizontally is based on the tibial plateau as well as the anatomical and mechanical function of the knee joint.



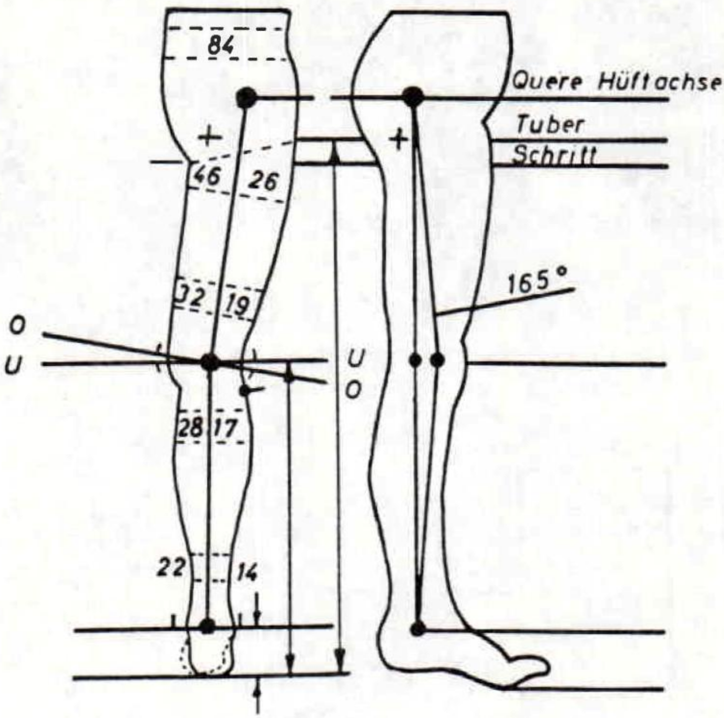




Thorough examination of the foot is required in order to achieve a functional and, if desired, correcting position. One must check the range of motion (pronation, supination, abduction, adduction, and rotation) prior to taking a mold or tracing of the foot portion. Deviations of importance need to be recorded. A foot support for the side not involved should be considered as essential if no leg length discrepancy is present.



Particular attention should be given to atrophied soft portions of the extremity while taking the tracing. Soft tissue displacement can easily cover recurvatum of flexion contractures present. Considerable experience and knowledge is required in order to recognize and correct such problems.



Essential information which should be listed on the tracing:

(1) Extremity outline for contouring of upright.

(2) Tibial plateau (exact position).

(3) Head of Fibula (center of head).

(4) Location of knee axis (compromising location).

(5) Distance of floor to knee axis (inclusive heel).

(6) Angular evaluation of Genu Varum, valgum, flexion angle, etc., as projected in anterior and lateral views.

(7) Intended corrections according to radiographic studies.

(8) Distance from floor to crotch.

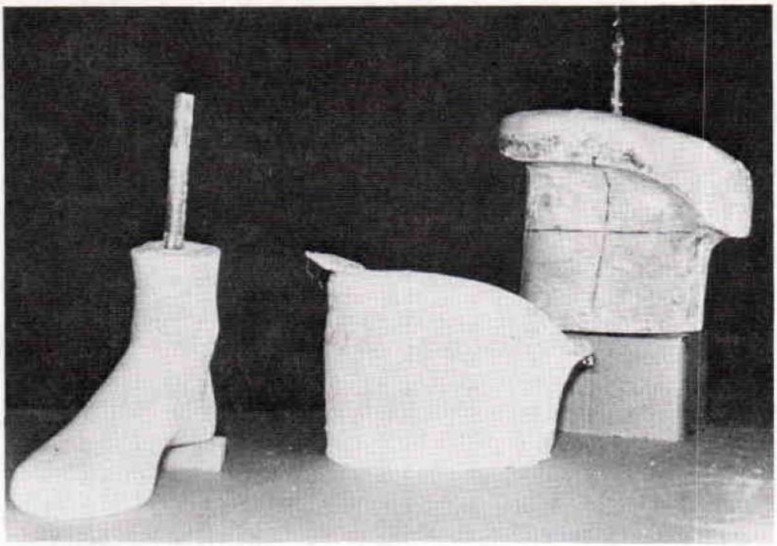
(9) Distance from floor to ischial tuberosity.

(10) Position of ischial tuberosity (sagittal and frontal).

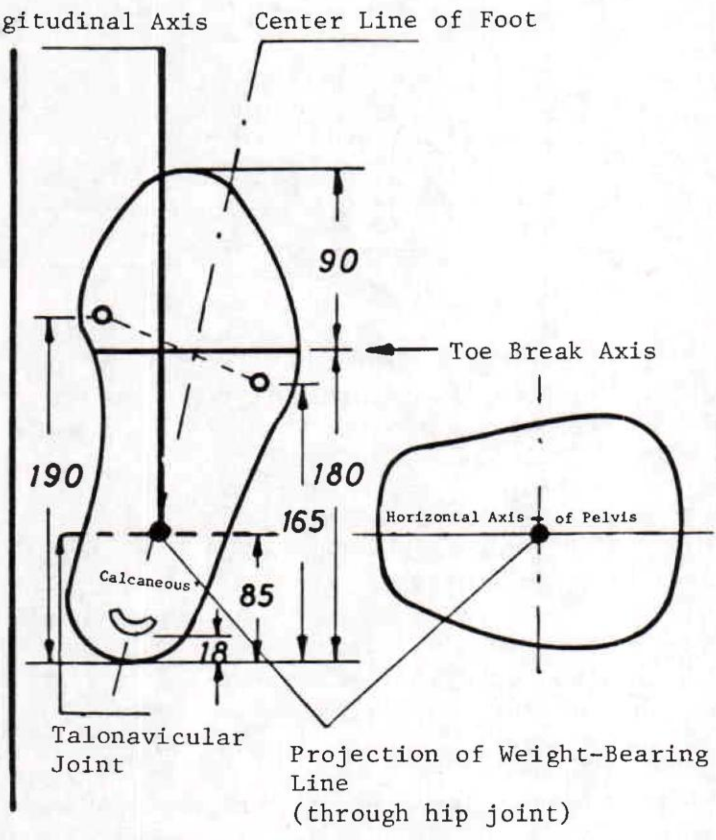
(11) Circumferences.

(12) M-L dimensions.

(13) Other information as obtained from body proportion analysis charts.



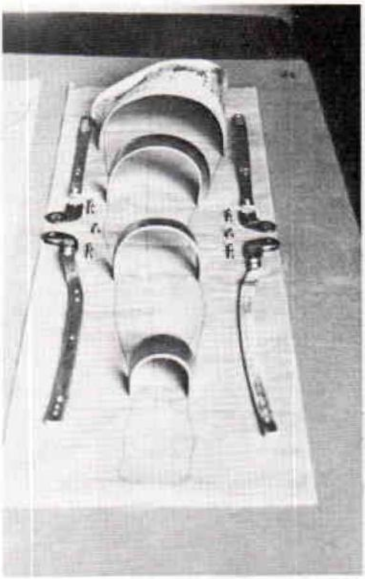
Plaster-of-Paris molds are utilized only when custom contouring is essential.

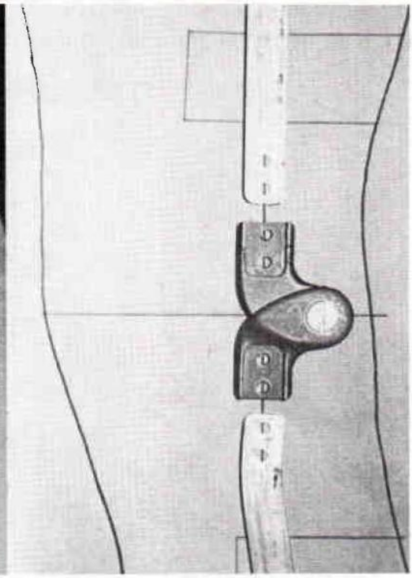


Of greatest importance is the position of the foot which requires correction in most cases.

Birds' eye view are used for projection of the foot component which will also aid in identifying the congruity of axial mechanic joint alignment.

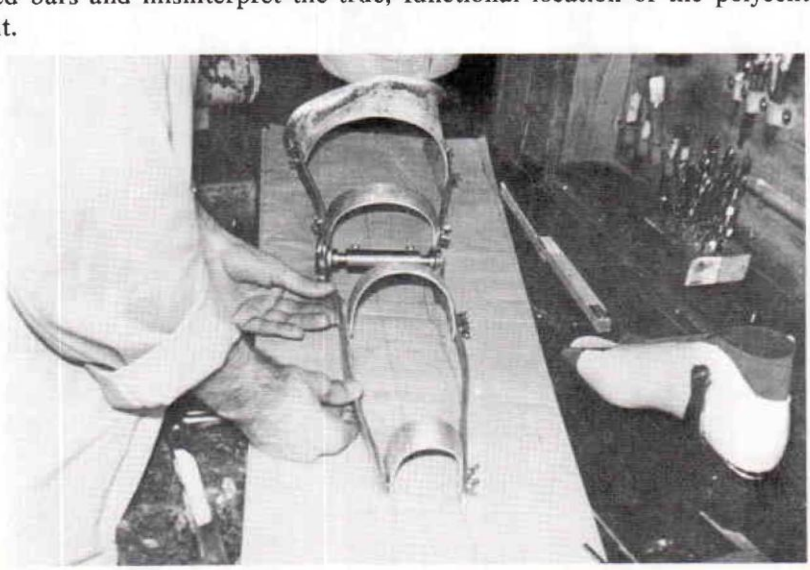
The longitudinal axis of the foot control component should always remain parallel to the mid-sagittal line and the mechanical toe break line which is located in an angle of 90° to this reference line.



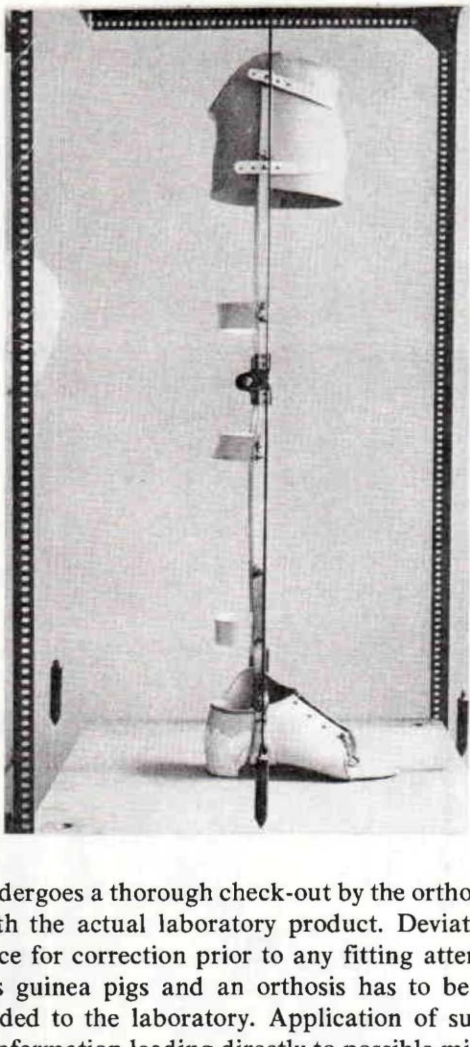


The orthotist can now select the mechanical components for fabrication of the orthosis.

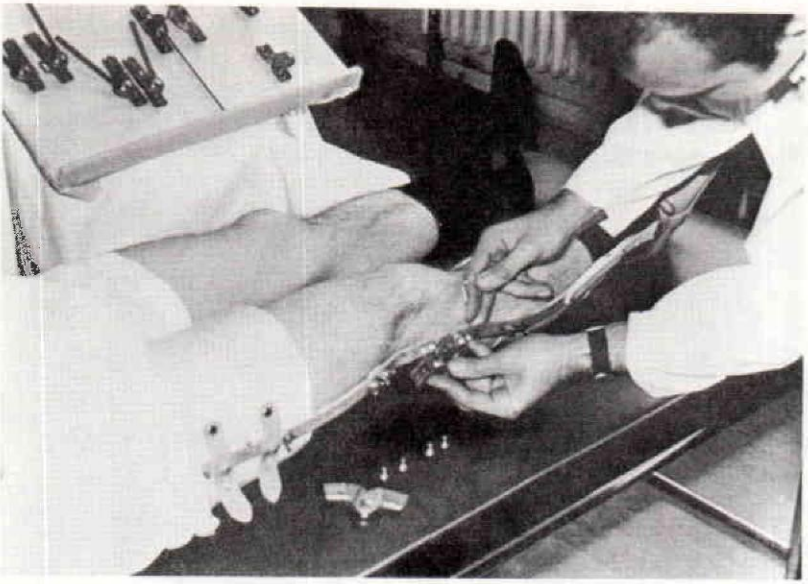
Particular attention should once again be given to the mechanical joint alignment since it is easy to be misled by the cosmetic contouring of prefabricated bars and misinterpret the true, functional location of the polycentric joint.



Assembly of the component is done with the aid of spacers at the knee and ankle joint. The bars are contoured with bending irons. All parts are temporarily fastened with wing-nut screws permitting easy adjustment at the time of fitting. Permanent fastening and finishing are carried out later.



The orthosis undergoes a thorough check-out by the orthotist comparing the technical data with the actual laboratory product. Deviations will result in return of the device for correction prior to any fitting attempts. Patients are not to be used as guinea pigs and an orthosis has to be as precise as the information provided to the laboratory. Application of such a rigid system provides us with information leading directly to possible mistakes making the constructive layout procedure a most precise time-saving and, with it, rational approach.



Fitting of the orthosis to the patient should in essence consist of no more than minor alignment adjustments and possibly the exchange of joint segments. Functional fittings with weight-bearing should never be performed without having the exact heel height established.

The contour and position of the foot component are greatest in importance since an ignoring of this principle results in considerable changes at higher locations. Attempts to correct those problems above the foot component are utopian experiments. It would also have no meaning to speak about millimeter precision of polycentric joint alignment at the knee or the individual influence on joint function at ankle or hip joint. Finally, one should postpone subjective thoughts and concentrate on technical principles easily recognized. Sufficient time is always left to meet individual requirements.

CONCLUSION

Taking into consideration all of the currently known orthotic systems and their easily identified pro's and con's—if one bothers to make a scientific evaluation—speaking for myself, I must state that one should rather utilize a system as discussed and not a "measuring machine." Utilization of tracings, technical and anatomical evaluations, plus selected bony impressions for preparation of the layout make it possible to engage shop supportive personnel of various qualifications for any given detail to be performed.

The final outcome of an orthosis will no longer be influenced by the work force available. Function of an orthosis (fixation, correction, and support) is depending on its exact alignment. The design must guarantee individual influences on skeletal conditions (the bony structure) as well as muscular and ligamental functions. The use of proper incorporation of mechanical joints is in relation to anatomical function of greatest importance. Alignment and joint evaluation should not be guided by the empiric feeling of a patient but based on accurate preliminary planning.

It is for this reason that I am speaking of a "constructive design" technique. After all, I think it to be better to use one of the four techniques mentioned or at least a system rather than to be an individualist without any formal approach. We, as orthotists, are also human and should attempt to eliminate outdated guess work through technical perfection.