Total Contact Restoration Prosthesis For Partial Foot Amputations

By SHERWIN E. LEVY, D.S.C.
Los Angeles, Calif.

In medical literature there are numerous references to substitution parts for amputated portions of the body. Throughout these publications there are only a few references to partial foot amputations, such as the statement by Daniel.[1] "After long experience and extensive investigation, it is seldom found that an artificial substitute can be worn after these partial foot amputations with any degree of comfort or satisfaction. Furthermore, the records of these cases show that over fifty per cent, sooner or later, submit to reamputation. Often it is after losing several years of time, with the attendant financial expense of securing one foot after another, and after much suffering and many disappointments, that reamputation is found necessary."

Since World War II much medical research has been directed toward the development of functional and cosmetic substitution parts for amputated portions of the body. During this extensive development program, no improved method over what was available before World War II has been made for the substitution of a partially amputated foot, although every other type of prosthetic has been improved upon.

The situation regarding prostheses for partial foot amputations can best be summed up in the statement by one prosthetic authority, Thomas,[2] who wrote, "The strain on any artificial appliance for partial foot or ankle joint amputation is severe and presents a formidable problem to the prosthesis maker. It is very difficult to make an appliance that is strong enough to withstand the strain to which it is subjected without making it so bulky as to be prohibitive from an aesthetic standpoint. Amputees, as a result, expect a great deal more from these foot appliances than it is possible for the limb maker to give them, therefore they are rarely satisfied with them. As a result, some of the most prominent limb makers in this country, rather than have dissatisfied customers, refuse to make these foot appliances at all."

Low level amputations of the extremities have become more common due to the use of antibiotics, recent research in vascular surgery and improved surgical techniques. The incidence of high level amputations has been greatly reduced, resulting in many cases of amputations of the most distal portion of the affected extremity. With the increase of partial amputations of the foot, the need for rehabilitating these patients with an adequate functional prosthesis has become increasingly imperative. This study was instituted to develop a functional and restorative prosthesis for the partially amputated foot, regardless of the shape or level of the stump.

The most common substitution for partial amputations of the foot in use today is a filler in the shoe. The filler in no way restores the amputated portion of the foot, since it merely fills the shoe and assumes the function of the shoe. The shoe and the filler then act as one unit and rub on the end of the stump, causing pressure and sometimes ulceration on the distal end of the stump. Eventually the toe of the shoe points upward and becomes distorted and makes the amputee and the people with whom he associates aware of his deformity.

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In some instances, a technique is utilized where a steel arch support with a toe extension, and a high laced anklet is laced around the stump and attached to the heel of the arch support. This is an improved method over that of the filler since it is somewhat attached to the extremity and to a limited degree, functions as part of the extremity. There are many disadvantages to this method. It is bulky and heavy, because of the materials used. It has poor conformity to the stump, and because of its weight, it is constantly pulling away at the heel. Its bulkiness necessitates a special shoe to be constructed. Constant repair is needed because it is essentially a rigid support and weight is being transferred from the heel to its forepart which concentrates pressure on the fulcrum of the appliance. This concentration causes a cracking or bending of steel which necessitates frequent replacement. The patient is never completely satisfied with this prosthesis. The most that can be hoped to be accomplished is that the patient will learn to live with it. Consequently, fifty per cent of these amputees submit to a higher level amputation and have a prosthesis with a full foot constructed.

Purpose

This study was designed to create a prosthesis which more adequately restores the amputated portion of the foot and returns the greater part of the foot's functional ability. The purpose of the prosthesis is to establish a weight-bearing area similar to that of the normal foot, so that the trauma of weight bearing will not be concentrated on just the resultant stump. It is important the amputee be able to utilize the restoration in the dynamic phases of gait, as well as in the static position of standing.

Materials and Methods

The materials and techniques that were utilized to construct this foot restoration prosthesis necessitated a complete departure from any previously employed method of constructing partial foot prostheses. This produced a flexible, light weight, total contact restoration prosthesis that accurately conformed to the remaining portion of the foot and the inside dimensions of the shoe.

Examination

The stump is carefully examined for areas of scarring, since allowances will have to be made for these areas in the construction of the prosthesis. Areas of excessive weight bearing are also noted. In a Lisfranc's amputation, the patient usually develops excessive callous formation under the cuboid. In patients where prostheses were not fitted early, there is plantar flexion of the stump with a contraction of the tendo-achilles, resulting in a postural shortage of the unamputated extremity. Some type of accommodation is necessary for these inequalities in leg length.

The patient's gait is closely examined since the old amputee will abduct the amputated foot while walking to create a wider weight-bearing surface. Allowances will have to be made for this abduction of the remaining portion of the foot.

It is important that the appearance of the shoe be acceptable to the patient. The psychological rehabilitation is as important as his physical rehabilitation. The patient is advised to purchase a shoe which fits well on his unamputated foot, has a leather sole, rubber heel and a high vamp. This eliminates a loafer and a low boy shoe, but the patient will usually be able to wear an oxford. The shoe should have at least five eyelets and have fairly good conformity around the heel. If the partial foot amputation is

bilateral, the patient should select a shoe the size he previously wore. In most instances, the shoe salesman will tend to fit the bilateral amputee short, if the previous size is not known. In children with bilateral amputations, an estimation of their shoe size from their height and weight will have to be made, and cannot be accurately determined by fitting the stump alone. The patient is advised to purchase an established brand of shoes in a popular last, that has a wide pattern of shoes so that the prosthesis will fit various styles of shoes made over the same last. In women, a Miller shoe with a walker last seems satisfactory. This study, to date, has not included total contact restoration prostheses for high styled women's shoes.

Shoe Modifications

Shoe modifications are necessary for a Lisfranc's amputation or higher. If this type of prosthesis is to be constructed, the shoe modifications must be completed first, since the modifications place pleats in the shoe in a slightly different position than they would be normally. To add the necessary rigidity to the shoe, a steel spring, approximately one and one-half inches in width, is placed between the insole and the outsole of the shoe, from approximately the medial anterior border to the lateral posterior border of the shoe. The exact position is determined by the abducted gait of the patient. The steel spring can be placed in the shoe by merely opening a small section of the shoe at its medial anterior aspect and slipping the spring back between the insole and the outsole. The reason for the spring being in this position in the shoe is so that it will be in relation to the amputee's gait and his weight force will roll over the spring from lateral to medial during ambulation, and thus he will learn to use the steel spring in the take-off phase of gait. There is no outward appearance of the steel spring and it is in no way touching the patient's foot. The spring is very light and the additional weight is not apparent to the patient, as would be a full steel plate.

The shank will have to be reinforced since in a Lisfranc's and Chopart's amputation or higher, the patient's weight is concentrated on the shank of the shoe. A level bar, one and one-half inches in width, is placed longitudinally between the heel and the sole. This bar does not extend below the level of the heel or the sole, and creates a narrow wedge which reinforces the shank. The wedge is made of leather with a strip of rubber soling to prevent slipping. The shank reinforcement prevents deformity of the shoe and the forcing of the steel spring, by the stump, through the bottom of the shoe.

Impression and Model

The areas of scarring and callous formation are marked on the stump with gentian violet. The level of the amputation determines the height of the impression over the stump. If the amputation is at the metatarsal phalangeal joints, it is extended to just below the ankle. If the amputation is transmetatarsal or higher, the impression includes the ankle. The extent of the prosthesis in its total contact attachment to the stump is dependent on height of the impression. The higher the prosthesis grips the stump, the less slippage there is at the heel. A plaster impression of the stump is made with the use of six inch lengths of plaster of Paris, rather than using the entire lengths. Better conformity of the plaster to the stump is accomplished with short plaster splints. After the plaster of Paris splints have been applied to the stump, the plaster is split over the extensor surface of the stump and molded smooth. The stump is inserted into a plastic bag, and the shoe is

then slipped onto the stump. The patient is instructed to take a few steps, and then stand in place on both feet, until the plaster of Paris sets. When the plaster sets, the impression is removed. Upon removal, the split portion is quickly remolded to the exact shape of the stump.

When the impression has completely dried, it is ready for the pouring of the plaster positive, the model. Dental stone is preferred to plaster of Paris, because plaster shrinks in proportion to the amount of water added. Dental stone, when mixed in a fairly hard consistency, has an expansion of one-tenth of one per cent and this compensates for the shrinkage of the latex. When the dental stone is ready to set, a steel rod is inserted, which aids in handling the positive during prosthetic construction.

Impression of the Void Area of the Shoe

The inside of the shoe is lined with saran wrap. Dental stone is mixed to a fairly thick consistency. The dental stone is then poured into the shoe. While it is still wet, the model of the stump is placed inside the shoe, to obtain the exact relationship between the model of the stump and the void space of the shoe.

Construction of the Mold

To accurately duplicate the void space of the shoe, a three-part mold will have to be constructed from the impression of the void area of the shoe. This is constructed in three steps so that the dental stone accurately encompasses the positive impression.

Dental stone is mixed in a firm consistency and poured into a puddle. The impression of the void of the inside shoe is pressed into the puddle and the dental stone is allowed to harden. Another small batch of dental stone is mixed and placed against the proximal portion of the impression and allowed to dry. A third batch of dental stone is mixed and poured over the remaining portion of the impression of the inside of the shoe and allowed to dry. After removal of the impression, a three-part mold is completed.

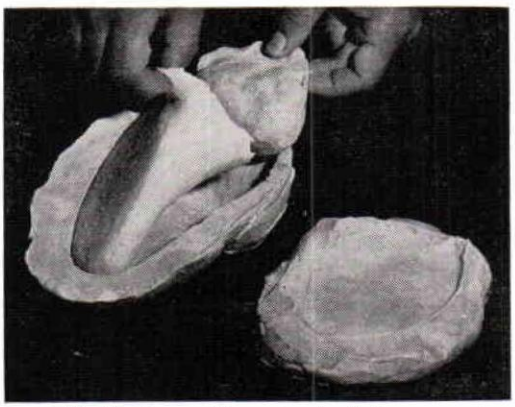

Fig. 1—Foam rubber extension being removed from three-part mold.

Construction of the Forefoot Extension

The three-part mold is now ready to receive the liquid foam for the construction of the forefront extension. The liquid foam is made by mixing seven ingredients, as outlined by the manufacturer.[3] The manufacturer does

not reveal the nature of the ingredients, but gives code numbers to the ingredients. The foam rubber can be made in different degrees of hardness or softness, by following the manufacturer's instructions. When the ingredients have been thoroughly mixed, they are poured into the three-part mold and placed in an oven at two hundred degrees for three hours. The rubber hardens to the degree desired. The foam rubber extension of the prosthesis is now completed (Fig. 1).

Preparation of the Stump Attachment

If desired, chamois can be placed over the model of the stump. This is not always necessary since some patients prefer to use a light stump sock. Zippers are placed on the model, behind the medial malleolus for a Lisfranc's amputation prosthesis or higher. The zipper can be sewn into either the chamois or the nylon that is used to reinforce the latex (Fig. 2). Tape is placed over the teeth of the zipper to protect it from the latex. The positive impression of the stump is dipped in latex approximately five times, allowing it to dry after each dipping.

Aligning the Forefoot Extension With the Stump

The foam rubber extension and the latex-covered model of the stump are placed in the shoe. When proper alignment in the shoe is obtained, two lines

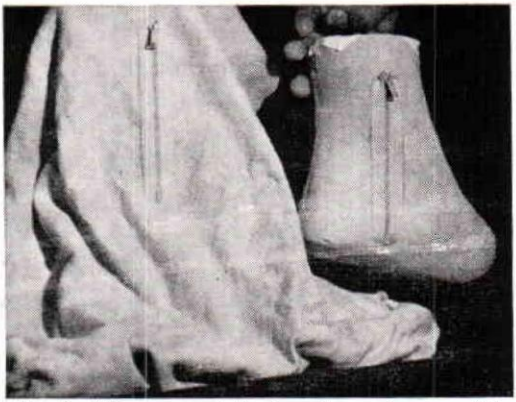

Fig. 2—Zipper sewn into chamois on stump model.

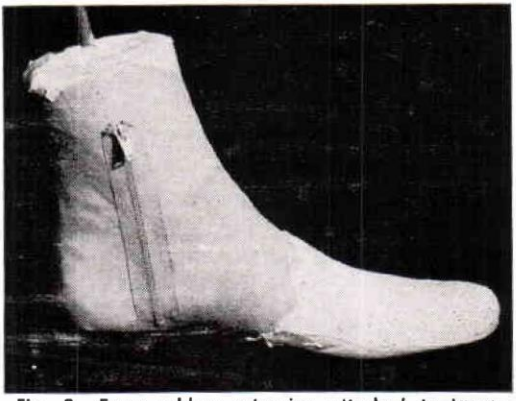

Fig. 3—Foam rubber extension attached to latex-covered model of stump.

are drawn from the foam rubber extension onto the stump to record the alignment. The foam rubber extension and the latex-covered models are removed from the shoe. If there are areas of scarring on the distal end of the stump, the proximal portion of the foam rubber is hollowed out in these areas to prevent trauma to these scars. Rubber cement is placed on the distal end of the latex-covered stump and the proximal portion of the foam rubber extension. The two pieces are placed together in proper alignment by matching the previously drawn lines (Fig. 3).

Completion of the Prosthesis

With the forefoot extension fixed to the cured latex surrounding the stump, the entire prosthesis is dipped into liquid latex approximaely five times. Nylon reinforcement is placed over the entire prosthesis for durability, during the dippings in liquid latex. If there are areas of excessive weight bearing on the plantar of the stump, sponge rubber paddings are placed between the layers of latex for protection.

After the latex is cured, the completed prosthesis is removed by trimming the excess latex liquid from the proximal portion of the stump. If a zipper is incorporated into the prosthesis, the latex is cut in this area and the protective tape is removed (Fig. 4). The prosthesis is fitted to the patient and usually no adjustments will be necessary due to the exactness of the casting technique employed. The patient is instructed to wash the prosthesis only in mild soap, such as ivory or woolyn, never in a strong detergent, and never allowed to soak. The prosthesis should be washed, rinsed, dried and allowed immediately to air dry.

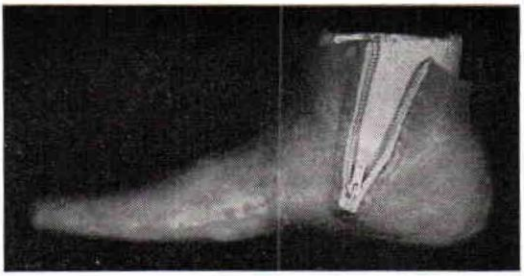

Fig. 4—The completed prosthesis.

Discussion

This study has developed a total contact restoration prosthesis which fits firmly and exactly around the remaining portion of the foot and provides an extension of the stump. This extension becomes a restoration and replacement of the amputated portion of the foot and assumes the greater portion of its function during weight bearing.

The materials used in this prosthesis are soft, resilient and light weight and do not place excessive pressure on the unamputated portion of the foot. The patient wears this prosthesis directly over his entire stump. A standard sock is then slipped on over the prosthesis and the stump. When the patient has his shoe off, it is not apparent that an amputation exists and consequently a good cosmetic result accompanies a good functional result. The patient can slip off his shoes, wear flexible footgear, such as slippers, and have some of the function that a normal foot might have, and the general appearance of a normal foot.

The construction of this prosthesis is such that it fits very accurately into the void space of the shoe and eliminates unsightly creases and wrinkles across the vamp of the shoe. These and other distortions of the shoe have in the past brought about a poor cosmetic result for those patients fitted with partial foot prostheses. The lightness and freedom of action of the total contact restoration prosthesis enables the patient to learn to use it during ambulation with a high degree of stability. In many instances, the amputee functions so well with the prosthesis that many gait problems are eliminated.

The materials used in the construction of the total contact restoration prosthesis are primarily latex and foam rubber which are relatively inexpensive. Once the initial prosthesis is constructed it is very simply and inexpensively replaced, by utilizing the original plaster models and molds.

Many patients with low level amputations seem to manage well at first with no prosthesis whatsoever. As the patient's gait accommodates to the missing portion of the foot, gait variations develop, which lead to severe muscular strain. These usually resolve themselves in some type of postural imbalance. The amputee should be fitted as soon as the stump is ready to receive the prosthesis.

Case No. 1

This 59-year-old white male, with a diagnosis of diabetes mellitus, dating back to 1937, was admitted to Wadsworth General Hospital on November 29, 1956, with cellulitis of the left foot and gangrene of the second and third toes. Radiographic examination revealed no bone involvement.

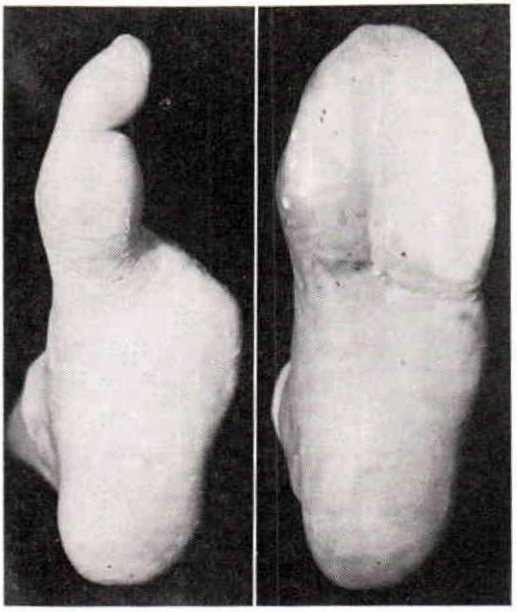

Fig. 5—Case No. 1.

The patient was seen by the orthopedic service on December 5, 1956, and it was their opinion that below-knee amputation probably would be required. The patient was treated with saline soaks and antibiotics, and on February 28, 1957, the left second and third toes were amputated. The wound healed

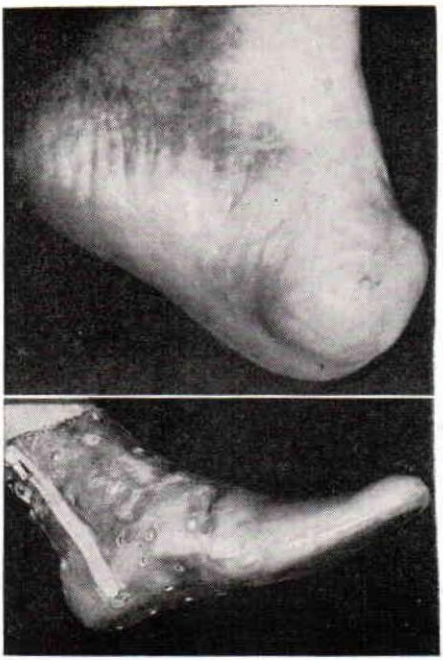

Fig. 6—Case No. 2.

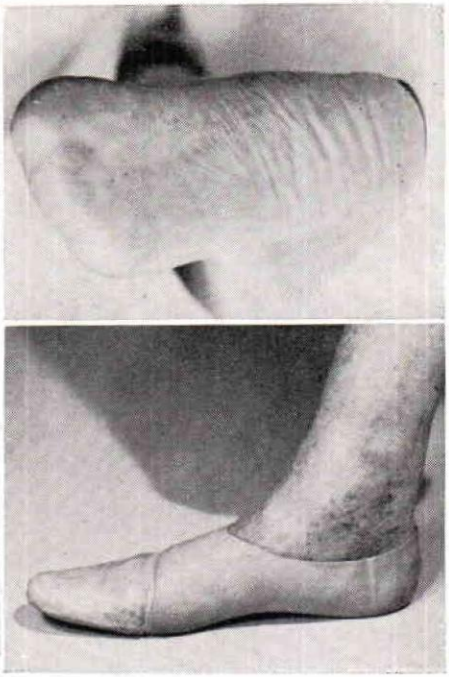

Fig. 7—Case No. 3.

well. Subsequently, the patient developed gangrene of the fourth and fifth toes. On March 26, 1957, these two toes were amputated along with a portion of each of the lesser metatarsals. The patient was discharged to the domiciliary on May 14, 1957. On July 15, 1957, a total contact restoration prosthesis was dispensed. The patient was immediately able to perform all ambulatory functions comfortably in a standard stock shoe with no apparent gait changes or outward visual evidence of the patient's deformity.

Comment: The ability of this restoration to conform to an irregular stump provided the patient's foot with a means to return to almost normal function and appearance and the prevention of a subsequent amputation at a higher level.

Case No. 2

This 66-year-old white male was first seen on August 3, 1959, at which time he presented a history of an industrial accident in 1936, which resulted in crushing of the forepart of his left foot and also a head injury, for which he was hospitalized for six months. The patient stated that the foot "spit out" small pieces of bone for a long time. Four years following the accident a Choparts' amputation was done. Following the amputation a steel plate was placed on the entire outsole of the patient's shoe and was covered by an additional outsole and a felt filler was placed inside the shoe. At the time the patient was seen, he complained of foot and leg fatigue and pain in his hips, especially the left hip, after short periods of ambulation. During ambulation there was a noticeable dip to the left side. On October 19, 1959, a total contact restoration prosthesis was dispensed.

The patient was re-examined on November 4, 1959, at which time his limp was practically undetectable. The hip pain had subsided and he was

able to ambulate for long periods without fatigue. The patient was seen on January 20, 1960, at which time he complained of moisture around the stump. Ventilation holes were placed in the prosthesis. On January 28, 1960, the patient's stump was re-examined. Ventilation appeared adequate and there was no evidence of maceration of the stump.

Comment: The patient's gait was markedly improved with the disappearance of the associated pain and fatigue by removing the filler and the heavy steel plate and adequately restoring the foot.

Case No. 3

This 56-year-old white male was involved in a train accident in 1941, resulting in an amputation of all five toes of the right foot at the metatarsal phalangeal articulations. The patient was hospitalized for six months and was walking within two months. Since the amputation the patient had been wearing canvas shoes. He had not been able to wear any stock leather shoes because the wrinkle in the upper would irritate the stump. The patient had been provided with three pairs of custom shoes by the orthopedic shoe shop. Of these, he was only able to wear one pair, which contained a steel plate inside the shoe plus a filler. The patient was seen on April 3, 1956, at which time he complained of recurrent callous formations on the stump which required debridement at three-week intervals. On April 17, 1956, the patient was fitted with a total contact restoration

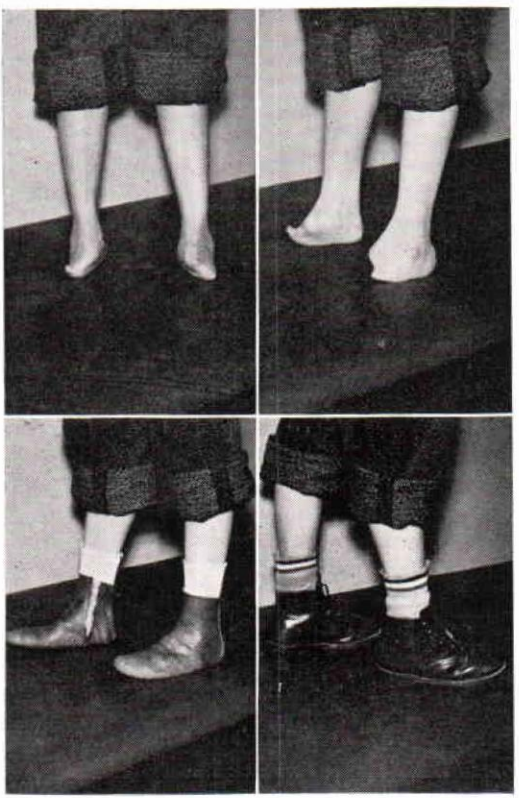

Fig. 8—Case No. 8.

prosthesis in a standard stock leather shoe. No shoe modifications were necessary.

The patient has been followed for the past four years and requires debridement of the callosities at five-month intervals and replacement of the prosthesis approximately every year.

Comment: Stabilizing the foot in the shoe with an adequate restoration retarded the callous formation and allowed the patient to wear any standard stock leather shoe. This is the lowest level of amputation for which a total contact functional restoration prosthesis has been constructed.

Case No. 4

This 6-year-old white male was first seen on April 5, 1957. Congenital absence of both forefeet with accompanying minor oral and ocular deformities were present. The parents gave a history of the child being examined at the Mayo Clinic at the age of 5 months, and no definitive treatment was undertaken. The patient started walking at the age of 18 months with hard sole surgical shoes. At the age of 3 years, a filler was placed in the shoe. Six months later this was discontinued, since the doctor whose care the child was under felt that it was unnecessary. The patient apparently ambulated well with a surgical shoe until the age of five and one-half. From this time on the patient would severely run over new shoes within two weeks. It was then that the parents began to seek further advice.

On examination, it was noted that the patient was wearing shoes which are approximately four sizes shorter in length than he should be wearing in comparison to his physical development. The parent stated that the child was frequently asked questions about his feet by his playmates, such as "Why are your shoes so small?"

Plaster impression casts of both stumps were taken on April 24, 1957. The prostheses were dispensed on May 20, 1957. No shoe modifications were necessary. The patient immediately accepted the prostheses. The gait improved to a point where there was no noticeable limp and the wear pattern of the shoes became normal. A clavus present on the distal end of the right stump completely disappeared within four weeks after wearing the prostheses. The parents observed a personality improvement in the child and there was no longer an apparent psychological problem in regard to his foot deformities.

The patient was seen at intervals of four months, at which time adjustments were made in the prosthesis for growth. Three subsequent prostheses were made at intervals of approximately every nine months with re-casting and construction of molds necessary for each prosthesis. Re-casting will be necessary for each prosthesis until the patient reaches maturity, at which time the prostheses can be constructed on an adult basis.[4]

Comment: The psychological rehabilitation of this patient was accomplished largely through the replacement of the missing body parts which enabled the patient to ambulate normally.

Case No. 5

This 51-year-old white male was involved in a hunting accident in 1952, at which time a shotgun was discharged into his right foot. The patient was hospitalized for six weeks. During this time the greater portion of his foot was amputated, leaving only a portion of the calcaneus and talus, so that the leg appeared similar to a "peg leg," with an end weight-bearing stump. Following the amputation, the patient was fitted with a Syme's type amputation prosthesis that enveloped the small remaining portion of the foot

and the lower leg to just below the knee. The prosthesis was heavy and bulky, being constructed primarily from molded leather and stainless steel.

The patient was first seen on October 2, 1959, at which time he complained of the uncomfortable prosthesis and the shoe deformity. He stated that the weight of the prosthesis tired him out, to a point where he ambulated frequently at home without the prosthesis. On October 23, 1959, the patient was fitted with a total contact restoration prosthesis. The steel spring was inserted into the shoe in a direct anterior posterior manner, since there was no forefoot and there did not appear to be external rotation of the extremity. A one-fourth inch lateral wedge was necessary on the shoe to prevent inversion of the prosthesis. The patient was immediately ambulatory and felt a greater freedom of movement and lightness.

On November 20, 1959, the patient was re-examined and it was noticed that there was no distortion of the shoe. The patient was not as conscious of his deformity and he was able to ambulate for longer periods.[5]

Comment: With very little of the patient's foot remaining, a prosthesis was constructed that restored most of the funcion of the foot and prevented any shoe distortion that would bring attention to the patient's disability. The difference in weight between the two prostheses was eighteen pounds. This is the highest level of partial foot amputation for which total contact restoration prosthesis has been constructed.

Summary

1. The literature was reviewed regarding methods of restoring lost portions of the foot.

2. The foot appliances in general use for partial amputations of the foot and the advantages of the prosthesis developed by this study are discussed.

3. An inexpensive method for construction of total contact restoration prosthesis for partially amputated feet is described in detail.

4. A total of fifteen patients have been treated. The average follow-up is four years, during which time the gait has been satisfactory and no further complications have developed.

5. Five case histories are reported to illustrate some of the various types of partial amputations of the foot.

6. The prosthesis described more adequately restores the lost portion of the foot and returns most of the foot's functional ability so that below-knee amputations will not be necessary in cases where only the disabled portion of the foot need be amputated.

Veterans Administration Center
Wadsworth Hospital

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