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A FUNCTIONALLY ACTIVE ECONOMICAL FLEXIBLE FINGER PROSTHESIS –A PROTOTYPE

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Abstract:

Amputation is the complete removal of an injured or deformed body part. It usually occurs during a traumatic injury or due to surgical amputation. The rehabilitation of amputed finger depends on the amount of injury, amount of tissue and bone involved, location of residual finger and the esthetic and functional needs of the patient.Most of the finger prosthesis are designed for an esthetic purpose which help the patient to pass unnoticed. A good prosthesis should provide life like appearance to duplicate the missing structures which should meet esthetic and functional requirement of the patient. This article describes the steps in rehabilitation of an amputed finger and working principles and design of the flexible finger prototype.

Key words: amputation, finger prosthesis, functional finger prototype

Introduction

Finger amputations can occur due to various reasons such as accidents or explosions, severe infections like untreatable vascular diseases or malignant tumors. Amputations can occur directly at the time of injury itself or as a result of surgical amputation when the surgical reconstruction of the finger fails like in extensive damage cases where finger cannot be restored. Amputations can cause a great physcological and emotional trauma to the patients, as it causes impairment of their skilled and daily life activity. There are different types of amputations which are self amputation, congenital amputation, and traumatic amputation. [1, 2, 3] The prognosis of treatment for the rehabilitation of the amputed finger or phalanx depends on the following factors like amount of tissue and bone involved, angles and levels of amputation and involvement with other fingers. [4]

An accurately fitting prosthesis should restore normal length, protect the stump, maintain sensitivity, transmits pressure and position sense for doing various activities. Prior to the treatment a proper evaluation of patient's needs and expectations, occupation, advantages and limitations of final prosthesis has to be discussed and taken into consideration. Different methods of fabrication of esthetic finger prosthesis were done in patients all these years. Most of them had esthetics but lacked the functional ability of the finger[5-8].

Aim and Objective

The aim of the article is to introduce a new prototype of functionally active economical flexible finger prosthesis which could meet both esthetics and functional requirement of the individual. This article describes the steps in rehabilitation of an amputed finger and working principles and design of the flexible finger prototype.

Materials and Methods

Alginate Zhermack Tropicalgin, Hydrorise addition silicone impression material putty consistency for making impression, Hindustan modelling wax No:2 for making wax pattern, Stone gyprock dental stone class III and Dental Plaster for making models. DPI Heat cure Denture base material, DPI RR cold cure acrylic for acrylisation, MP Sai enterprises silicone for prosthesis and Acrylic paints for esthetic designing, Wax knife, wax carver, rubber bowl, camel haired brush for manipulation of materials.

A patient of age 50yrs who was already rehabilitated with esthetic finger prosthesis before 5yrs has reported back demanding for a flexible functionally active finger prosthesis to meet his occupational requirement. The steps in fabrication of his previous prosthesis followed conventional method which permitted minimal movements along with his adjacent fingers connected by double ring. (Figure 1a, Figure 1b)

A new prototype was planned for making a prosthetic finger with interphalangial movement simulating flexion and extension like a normal finger.

A proper case history and measurements were taken which included the patient's personal details, dentist details, occupation of patient, reason for amputation. A detailed case history mentioning about the movement of amputed stump, width of the bone end, pain and sensation of the area were recorded. Affected fingers were correctly marked, and measurement of corresponding finger in the sound hand were taken, which included measurement of distal, intermediate and proximal phalanx. (Figure: 2a), total length of the nail of corresponding finger on the sound hand was measured (Figure: 2b), and following photographs were taken for proper esthetic fabrication of the prototype.

Palm and fingers on sound hand, Close up photograph of fingers on sound hand, Dorsum and fingers on sound hand, Close up of finger nails

Alginate impressions of the amputed hand and donor finger were made for making a mould. Instructions were given to patient during impression making like, hand should not touch the bottom or walls of the tray during impression making,

Figure 1a: Amputed left little finger

Figure 1b: Esthetic finger prosthesis

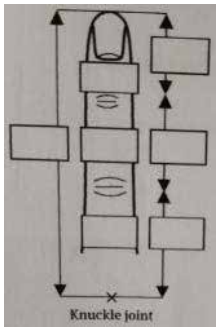

Figure: 2a Mesurement of sound finger

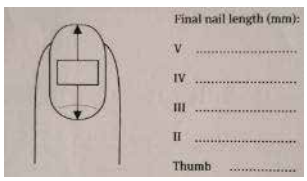

Figure: 2b Nail measurements

hand should be in functional position and finger space is to be maintained. After obtaining the cast proximal edge trim lines were marked on the mould. Knuckle positions were marked on cast. (Figure:2a, Figure:2b)

Fabrication of hollow wax pattern

Molten wax was poured into the impression of the donor finger. A hollow wax pattern was fabricated by placing a pencil in the centre of the mould by applying petroleum jelly on it for easy retrieval from the wax pattern. Pencil was held, above two third the height of the distal phalanx in-order to get the perfect morphology of distal phalanx. The wax pattern of the donor finger was adjusted and carved accordingly for the left little finger. A wax trial of the prosthetic finger was done on the stump of the amputed finger. The Measurements of the wax pattern was reconfirmed again with the measurements of sound finger during trial, and photograph was taken. (Figure. 4a)

Shade selection of the following areas of the finger was done during the trial. Dorsal base colour, dorsal joint colour, palmar base colour, palmar joint colour of the finger were taken. (Figure:5a). Number of layer of joint colour of dorsal side and number of layers of joint and tip colour on the base skin of the finger were taken. Nail colour was taken in following area. Tip of the nail colour, the middle of the nail colour, whether moon present or not, number of layer of nail root skin colour were noted (Figure:5b).

After the necessary corrections were done on the wax pattern, the interphalangial joints were cut and made into three pieces, then two new hinges in wax were attached in the interphalangial joint regions. A wax pattern of retentive ring was

Figure:3a Impression making of amputed hand

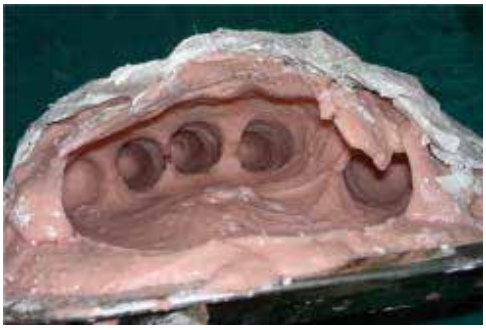

Figure:3b Impression of donor finger

Figure. 4a Fabrication of hollow wax pattern

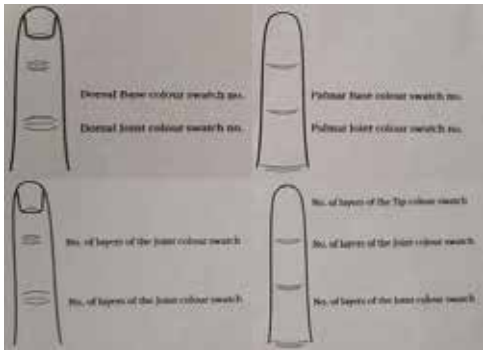

Figure:5a shade selection of the finger

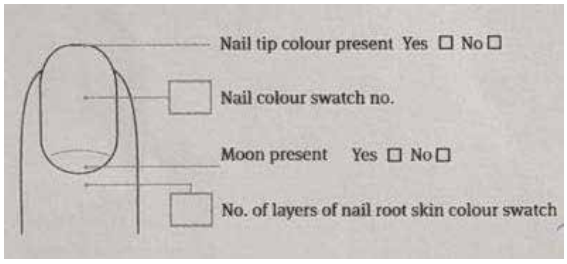

Figure:5b shade selection of nail

Figure. 6 Acrylised finger prosthesis

made on the model, which was extended into the proximal phalangial area and metacarpal region. The entire prosthesis was acrylised. Each of the phalangial halves were joined together with orthodontic wires for flexibility and movements were checked. (Figure. 6)

Trimming and polishing was done in necessary areas for the smooth functioning of the prototype, which was cut in the interphalangial joint area, and was made into 3 pieces. Then acrylic hinges were given in the innersurface of the hollow finger at each interphalangial joint area. A retentive ring was fabricated on the cast which encircles the bottom portion of the amputed stump. Tightness of retentive ring was adjusted with an orthodontic wire which was around the amputed stump. A nail head was fabricated with cast metal alloy with a hook positioned towards the interphalangial area. The size of the casted nail head was reduced and adjusted so that it correctly fits inside the acrylic outer part of distal phalanx. (Figure. 7)

A sleeve for elastic band was attached to the middle phalanx lengthwise. The elastic band was inserted with the help of elastic band puller through the sleeve. Then the finger was assembled to one piece by connecting all the hinges in position using 19-Guage orthodontic wire. The anterior end of the elastic band was stretched and pulled inside the hollow space of the middle phalange. The other end was attached to the hook in the nail head inside the distal phalanx with the help of customized band puller which was. Hence the functional finger prototype was fabricated. (Figure. 8)

Figure. 7 Casted metal nail head with hook

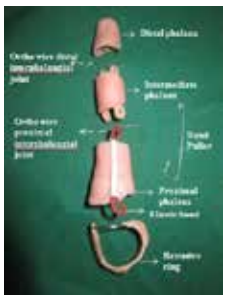

Figure. 8 Parts of functional finger prototype

Principle of functional finger

The prototype is capable of flexing like a normal finger by using the principle of gravity and elasticity. When there is flexion or positional change of the proximal phalanx, the casted metal-nail head inside the distal phalanx will make the elastic band which is embedded along the intermediate phalanx of the prosthesis, stretch due to weight of nail head and gravitational pull. This continuous downward pull induces loss of elasticity of the band and leads to the bending of the prosthesis. On extension of the stump of the proximal phalanx the elastic band gains its elasticity after a certain positional change of the proximal phalanx. It pulls back the casted metal nail head in the distal phalanx making it straighten like a normal finger

Designing of outer covering of prosthesis

Designing can be done in two ways. 1) By gloving the acrylic finger 2) By fabricating a silicone outer covering for the prosthesis.

Gloving Method

In-order to reduce the cost factor, finger glove was inserted over the acrylised prototype, and artificial nail was made using self-cure acrylic resin and fixed, glove was then painted using fabric paint and was attached to the very minute hooks on the retentive ring. This is a cost effective and less technique sensitive method, but the colour stability and durability of the prosthesis is less compared to silicone outer covering. (Figure 9a)

Procedure for fabricating silicone prosthesis

Two impressions of the wax pattern of the finger prosthesis were made and one was poured in dental stone and other was poured again in wax. The waxed model was used to create a mold space

of the finger by lost wax technique. The stone model was then reduced in size by trimming 2mm all around for creating space for the passive vacuum fit slicone cover. A putty is packed to lift the stone model by 2mm in the anterior nail head region, for the easy flow and packing of the silicone material when placed inside the dental flask. (Figure. 9b). The dorsal surface is in the lower part and palmar surface is in the upper part of the flask. (Figure. 9c)

MP Sai enterprises room temperature vulcanizing silicone is mixed and made to different shades needed for making dorsal, palmar, knuckle joint areas of the finger prosthesis and filled to space inside the flask, which is then closed and allowed to set for 24hrs. After complete curing it is then trimmed and finished. Final color correction is done by extrinsic painting in required areas. Artificial nail is then made using self cure acrylic resin by mixing with pink color acrylic to get appropriate shade of the nail and which is then polished and fixed to silicone prosthesis using cyanoacrylate glue. (Figure. 10a), (Figure. 10b)

Discussion

An ideal prosthesis should meetsss both esthetic and functional requirement of the patient without being too expensive, so that he can do his daily activities. Several prosthesis available for finger rehabilitation include esthetic acrylic finger which is retained by structures like ring, Functional fingers with interphalalgial movements, adhesive silicone fingers, osseointegrated implant retained fingers, Didricks X finger, Knicks prosthetic finger, Motorised finger with biomedical neurosensors, M Fingers, Pro Digit system, Vincent fingers etc. Custom made acrylic finger prosthesis is a esthetic, cost effective and less technique sensitive treatment. Patients are initially satisfied but later find difficult as it lack interpahalangial movements of normal finger. Functional finger can be made by incorporating small attachments inside the prosthesis in the joint area.[9-10] When the length of the residual finger is very less only option which can provide retention is the osseointegrated implants.

Figure. 9a Gloving of acrylic finger

Figure. 9b Mold space

Figure. 9c Putty packing for 2mm Space

Figure. 10a Functional silicone prosthesis Figure

10b Silicone Prosthesis

A study which compared esthetic and functional outcome of adhesive and implant retained finger found that esthetics, function and comfort is more with implant retained prosthesis, but it is not affordable for all patients because of higher cost and surgical intervention required. Adhesive retained is less expensive but has common prosthetic complications like mild discolorations and tear at the margin of the prosthesis[11]. The term osseoperception described by Lundborget al described the vibration and position sensations acquired withosseointegration of implants.[12] Rydevik et al proposed that implant retained finger prosthesis allowed partial recovery of tactile sensation by transfer of tactile stimulus to inter-osseous nerves, because of direct pressure of implant on bone.[13] Popkong et al compared one stage and two stage implant placement in finger prosthesis and found that number of stage depends on the primary stability of implant during placement and condition of surrounding sift tissue. Two stage has advantage of low risk of infection and better soft tissue management, but one stage has more patient acceptance because of earlier prosthesis delivery and less surgical procedures.[14] Marcello et al used used O-ring retention system with modified hexagon shaped capsule adapted to the acrylic resin to attach the prosthesis to the implant.[15]

Didricks X- fingers are stainless steel the mechanical fingers which are controlled by spring action. They replace missing phalanges that are controlled by the movement of the remaining portion of a finger when available or by the movement of the hand when no finger is available. They were usually used to rehabilitate wounded US and British soldiers.

M fingers were introduced in 2009 by liberating technologies for patients missing the entire finger. Fingers are available as a kit, which was to be assembled to address the index through small fingers. Thumb is passive with a hinge that allows it to be manually prepositioned. Extension and flexion of the wrist activate the device and pull the cables attached to it and control the opening and closing movement of the finger respectively. Each finger has independent action when the individual finger meets resistance it stops and others continue which gives M finger a conforming grip around an object. The strength generated by the user at the wrist determine the force of the grip. Both X finger and M finger are the body powered options

Knicks prosthetic finger are also foldable 3D printed partial finger replacement device where the movements are controlled by longer elastic band attacing to the wrist area with an wrist band. It is unaesthetic with less of patient satisfaction.[16]

Motorized fingers with biomedical neurosensors are also available which can incorporate hand motor function and feedback application. Array sensors are incorporated to finger tips and palm area to understand the amount and direction of applied force, to know the point of application of force on contact surface, to know the texture of the object, to detect slipping for improving grasping stability. Microfabricated tactile sensors are developed to mimic one or all of the properties human tactile system by simulating machanoreceptors for pressure and vibration, thermal receptors for temperature, nociceptors for pain or damage.[17-18]

Prodigits (prosthetic digits) designed and distributed by touch bionics are the first commercially available powered finger with a conforming grip. Fingers can be configured to address any or all five missing digits. This device is controlled by myoelectronic control and touch pads. Myoelectronic control is by small amount of electricity taken from remaining muscles in the hand and forearm. Touch pad or force sensitive receptors work on the pressure applied to a thin pad by a portion of the remaining hand. It has two input, one for opening and one for closing the

fingers. This allows the user to have a conforming grip around an object.

Vincent Finger system is designed by Dr Stephan schulz, is currently undergoing clinical trials. It is similar to Prodigits that each finger has independent action and is powered by its own motor is made from high strength, light weight metal alloy. They are also developing Vincent hand which is having a metal alloy chasis for mounting five Vincent fingers and a sixth motor to control thumb position. Both Prodigits and Vincent finger system are externally powered options.[19-21]

Conclusion

This article describes the prototype of functional finger prosthesis which is affordable for patients of low economic status who have lost their middle and proximal phalanx in accidents like crushing away while using heavy machineries. The distal phalanx has to be intact and in a movable condition. Advantages include finger is functional and esthetic with the matching skin color, the cost of the finger can even be reduced if ordinary glove is used instead of silicone. This finger can be repaired and serviced by any dentist. Elastics used are easily available and can be replaced by himself or by a doctor. Prosthesis is light weight and comfortable to the patient compared to commercially available other functional prosthesis.

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