Transtibial Prosthetics: A Review

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ABSTRACT

The review paper briefs about different types of sockets used in below the knee or transtibial amputation. Patellar tendon bearing, total surface bearing and joint corsets have been compared and reviewed. Their advantages and disadvantages in below knee amputation have been stated. Patellar tendon bearing is compared with joint corset prosthesis and is found to be better than the joint corset prosthesis in most cases, with a few exceptions. Further, total surface bearing is compared with the patellar tendon bearing, total surface bearing overcomes the disadvantages of patellar tendon bearings.

Keywords*: Prostheses, Socket, Knee Joint, patellar tendon bearings,total surface bearing,transtibial prosthesis*

Introduction

Joint corset prosthesis were one of the earliest inventions, they caused extreme discomfort and agony amongst patients. They consisted of straps and wooden blocks that held the leg in place. In 1957, University of California, Berkley invented the patellar tendon bearing socket for below the knee amputees.[1] The PTB were a good fit for transtibial amputees but they had their own set of disadvantages. Patients complaining of excessive pressure in patellar tendon area had the disadvantages of knee flexion, abrasion, skin bruises or dermatitis. To solve these problems, a total surface bearing (TSB) prosthetic socket a type of suction socket was invented. Suction suspension transtibial prosthetic sockets were tested in the early 1950s, and their advantages led to further development and research.The specimens included-thirty-two subjects who could walk with the TSB prosthesis and had already used the patellar-tendon bearing,seventy-five percent of the specimens were satisfied with the newly found TSB socket. The added advantages included comfort, ease to swing, reduced pain, piston movement , appearance, and durability were regarded as good by more than 75% of the patients. Donning, perspiration, odour, tightness, and staining were regarded as disadvantages by the specimens. Items tagged satisfactory with the TSB socket were comfort, ease to swing, and piston movement, while donning was a disadvantage.

1.Patellar Tendon bearings Prosthesis

Patellar Tendon bearing or PTB is a type of a socket. The residual limb has low weight bearing capacity. The patellar-tendon-bearing (PTB) socket, which originated in the late 1950s, used the design criterion that pressure should vary according to the pain threshold of different tissues in theresidual limb.Specific pressure-tolerant and -intolerant areas of the residual limb were identified, and socket biomechanics for different periods of gait cycle were defined. Further it was noted that since soft tissues was displaced during loading, a socket that made equal contact with the surface area of the residual limb might cause more pressure over bony anatomy and less pressure over soft tissues, These area over the bones may not be able to tolerate high stresses [2,3].

There were inconsistencies in the PTB socket due to lack of training in the PTB technique.The main problem included prosthesists wrapping plater bandages around the residual limb inconsistently which led to linear tension lines.Therefore, Murdoch introduced a pressure-casting (PCast) concept, where uniform pressure was applied around the residual limb using fluid. It was named as the Dundee socket, and was developed to remove some factors related to human error during the casting process. A small addition of plaster was added at the end of the tibia. In 1968, Gardner introduced a pneumatic pressure sleeve that wrapped the entire residual limb during casting [4,5].

Kristinsson used the PCast concept by using air as a medium in the Icelandic Roll On Silicone Socket (ICEROSS) system [6]. The socket shape was defined by casting plaster wrap over the residual limb wearing the ICEROSS silicone liner with the use of an air pressure chamber in a seated non-weight-bearing state. He corrected the design by adding pads over bony areas of the residual limb during casting .Kristinsson argued that a transtibial socket, designed to transfer loads primarily to limited areas of the limb such as the PT and the medial flare, was in most cases both ineffective and uncomfortable. The most effective socket, in hisview, was one that relied on the hydrostatic principle for load transfer [6].

Hydrostatic principle for load transfer meant that the volume of tissue in residual limb can be occupied in the same volume of socket so that no fluid is lost or tissue gets displaced.A completely packed system is achieved

Another theory based on the PCast concept is Pascal's principle of fluid mechanics. This principle states that a pressure change occurring anywhere in a confined incompressible fluid is transmitted throughout the fluid such that the same change occurs everywhere.

However, most of these theories have limitations in being applied to hydrostatic weight-bearing in sockets. Firstly, they assume that gravitational forces are negligible. Also, achieving a closed system is difficult when the residual limb is not a closed fluid system. It should be noted that Pascal's principle assumes a fluid at rest. Fluid in the residual limb is not at rest and therefore shear stresses cannot be zero.[5]

Sockets produced using these theories are known as hydrostatic sockets. They usually include small errors on the anterior distal tibia, fibula head, and the tibia crest. The sockets produced are significantly different in shape than the traditional PTB socket. One difference is that, the hydrostatic socket was not indented proximally in the PT region and in the hollow at the back of the knee region of the socket. Another difference was that while the PTB socket biomechanics were developed with respect to each of the progressive phases of gait motion, the hydrostatic socket simply assumed that pressure at one point would be transferred by the fluid principle to another point which accommodates soft tissues [7,8].

1.1 Errors in PTB fitting

The most common error made with a PTB socket is an excessively tight fit in the hollow at the back of the knee region of the stump. Too large a bulge in the popliteal area was constrictive, affected circulation, caused edema, and in turn led to deterioration of the stump end. In order increase the area for pressure against the popliteal surface of the stump , many prosthetists have extended the rear of the socket up to the space between the hamstring tendons, cutting grooves to relieve the tendons during knee flexion. This design contributed to constriction of circulation in the popliteal area when the amputee stood or sat.Edema was also caused by constriction at the mid-stump level, and such constriction would result from the combined effects of modifying the plaster stump model. The least desirable modification was that made in the lateral fibula area. This modification was meant to help stabilize the stump mediolaterally in the socket, but the fibula was a structure which lacked the strength to stabilise.Although breakdown at the end of the stump was sometimes attributed to pressure on the end, a more likely cause was constriction at the mid-stump level. Tightness around the middle of the stump gave the amputees the feeling that the end was in contact with the bottom of the socket or that the tissues were being pulled up against the end of the bone. There were, however, circumstances in which end pressure was damaging and painful.

2. Joint Corset Prosthesis

The number of amputees using a joint corset prosthesis was noticed to be less than 10%. The PTB over comes the disadvantages of joint corset prosthesis.A person prone to heavy duty work usually used a joint corset prosthesis. The joint-corset system was especially effective when the knee was slightly flexed so that forces were beared by the back of the thigh and were further transmitted to the shank through the side joints. When the thrust on the prosthesis was along its axis, the amputee could prepare for it by temporarily tightening their thigh corset. Many amputees kneel, climb ladders, or climb stairs frequently. Such activities may be especially difficult or troublesome to the bilateral amputee because of rotation of the PTB prosthesis on the stump.Only if the amputee bore heavy load on the corset or has an extremely atrophied thigh , he needed a joint corset prosthetic. Also amputees who could not bear weight effectively either on stump or femur were rare. Sometimes an amputee is mentally retarded or senile. In such an event, especially if there were no qualified helpers to ensure that the prosthesis is donned correctly, the joint-corset system would be used. A problem often faced by the prosthetist fitting a PTB prosthesis to an experienced wearer of a joint-corset prosthesis was that the amputee was not prepared to make the change, either because they had doubts whether they can do so successfully or easily, or because they had a definite bias toward the joint-corset prosthesis.[4-7]

3.Total Surface Bearing Prosthesis

The PTB were a good fit for transtibial amputees but they had their own set of disadvantages. Patients complaining of excessive pressure in patellar tendon area had the disadvantages of knee flexion, abrasion, skin bruises or dermatitis. These problems resulted from the socket design; because the socket did not suspend the prosthesis from the stump, it needed auxiliary suspension, and it could not prevent unwanted piston motion and sliding off from the skin. The Kondylen-BettnngMtinster (KBM) socket is a supracondylar PTB modification in which the medial and lateral walls are high enough to enclose the femoral condyles and suspended the socket from the stump without auxiliary suspension. The KBM, sometimes prescribed for short specimen with

transtibial amputations, had the same problems as the PTB.To solve these problems, a total surface bearing (TSB) prosthetic socket, a type of suction socket, was applied. Suction suspension transtibial prosthetic sockets were tested in the early 1950s, and their advantages led to further development and research.Several studies of rigid suction sockets and semirigid insert suction sockets for transtibial amputee persons were completed, and a total-contact silicone gel-lined socket was developed, that improved the pressure seal during sitting, bending down, and athletic activities and natural gait.After a survey of amputees with different suction socket was conducted, a high degree of acceptance and satisfaction by users along with decreased piston motion, better skin condition, and increased activity levels were observed. Some problems concerning materials, casting, and fitting had to be solved.In general, the socket was reviewed as favourable. Because weight bearing was spread more evenly over the entire surface of the stump, subjects were comfortable wearing the socket and felt no excessive pressure against the patellar tendon area. They reported less piston movement during walking, less edema of the skin of the residual limb, and less interference with knee flexion than experienced with the PTB socket.

There were, however, several problems with the socket. Patients with visual and sensory disturbances or hemiparesis may have had difficulty donning and doffing it; the PTB socketwas more appropriate for these patients because it was easily donned and doffed. Another problem was perspiration on the stump, which caused unpleasant odour and greasy staining of the socket

The TSB socket seemed to be sensitive to change in stump circumference. The circumference of an immature stump decreased with time, while it fluctuates in a patient undergoing hemodialysis. Subjects with such stumps benefited from modification that emphasized patellar-tendon weight bearing (modified TSB), and were taught to adjust for changes in stump circumference by wearing a sock between the silicone inner socket and rigid outer socket. For patients undergoing hemodialysis, the model would be cast when the stump is largest, usually before hemodialysis. The durability of the TSB socket remained unquestioned. Whereas a prefabricated silicone inner socket may show an incidental fissure, in this study the laminated silicone inner socket showed neither fissure nor breakage, except for fraying at the proximal end.[8-16]

Conclusion

The article compares patellar tendon bearing , joint corsets and total surface bearings, their advantages and disadvantages have been discussed and total surface bearings has been found to be most feasible amongst the three.

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