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CLINICAL EXPERIENCE AND FUNCTIONAL CONSIDERATIONS OF AXIAL ROTATORS FOR THE AMPUTEE

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Throughout the growth of the prosthetics profession numerous components that have appeared promising for the amputee have been developed. However, after clinical evaluation the component was often shelved because of poor function, high costs, lack of reliability, excess weight, and poor cosmesis.

The objective of this paper is to examine the clinical use and acceptance of the axial rotation component of an artificial leg. We define a rotation unit as that device which allows external and internal rotation to occur when a transverse rotational force is applied at the prosthesis-floor interface, and permits the foot to return to its aligned position when the force is removed.

During normal walking transverse rotations in the lower limb occur with relation to the pelvis, the hip joint, the femur, and the tibia. These rotational forces are somewhat absorbed at the joints of the lower limb and finally resolved at the torso of the body.

In the below-knee and above-knee amputee, these rotational forces are absorbed at the interface between the socket and the residual limb creating shear forces on tissue. Also, instability can occur (especially in bilateral lower-limb amputees) as a result of the rotational forces causing a transverse rotation between the foot and the ground.

Three axial rotation devices are presently commercially available (Table 1); the Weber-Watkins design, the STAR (Shank, Torque Ankle Rotator), and the Hosmer Modulorotator. All three devices perform the same function in that they allow axial rotation to occur along the longitudinal axis of the prosthesis and each returns the prosthetic foot to the aligned position once the axial torque is removed.

EVALUATION OF AXIAL ROTATORS

In order to draw any conclusions as to the indications for use and acceptance of a component, it is first necessary to define its need and function. Then one can compare the definition with actual clinical use, receiving feedback from both prosthetist and patient.

Generally, rotators are designed to provide a substitute for the lost axial rotation and to provide axial rotation when necessary prosthetic components (i.e. BK side joints and thigh lacer or hip joint and pelvic belt) restrict motion of the residual limb.

Normal gait requires a total of approximately 23 deg. (*2*) of axial rotation between the foot, the tibia, the femur, and the pelvis. Because the below-knee amputee retains natural knee rotation (except when side joints and thigh lacer are used), the above-knee amputee will receive greater rotational benefits from an axial rotator unit, especially when an external hip joint and metal pelvic band are used.

Can an axial rotator device reduce the shear force on the tissues of the residual limb? Lamoreux and Radcliffe (*3*) (Fig. 1) compared the axial torques occurring in an above-knee prosthesis with and without an axial rotator unit operating. An approximate 60 percent reduction in external torque on the shank of the prosthesis was found in mid-stance phase, and an approximate 76 percent reduction of internal torque

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TABLE 1
DESCRIPTION OF COMMERCIALLY AVAILABLE AXIAL ROTATOR UNITS

WEBER-WATKINS:

1. First commercially available unit, in late 1971.
2. Weight is approximately 700 gms, but now is available in a lighter endoskeletal model.
3. Problems have included weight, cosmesis, special installation, and reliability.

STAR:

1. Developed at Rancho approximately mid 1974 in conjunction with United States Manufacturing Co. of Glendale, California.
2. Weight of crustacean type is approximately 450 gms.
3. Problems have included breakage and slow return of foot to aligned position. Both initial problems appear to have been resolved.

HOSMER MODULOROTATOR:

1. Developed in mid 1974 from experience gained by U. C. Berkeley with their axial rotator.
2. Lightest of available units, approximately 300 gms.
3. Most cosmetic — in crustacean type of prosthesis it is located at the junction of the foot and ankle.
4. Problems have included breakage and noise. Both these initial problems appear to have been resolved.

upon the prosthetic shank was found in late-stance phase on the amputated side.

We consider the amount of time lapsed between the maximum external torque without torque absorber in mid-stance phase and the maximum internal torque in late-stance to be as significant as the magnitudes of the torques (Fig. 1) in causing injury to the soft tissues of the residual limb. The amount of time elapsed was approximately two-tenths of a second when the amputee was walking at a cadence of 85 steps per minute (*1*). We consider that the addition of a torque absorbing device besides reducing the magnitude of shear forces on the residual limb also reduces the abruptness of the forces, thus providing a smoother transition of forces to the residual limb during the application of external and internal torques to the prosthesis during walking.

Lamoreux and Radcliffe (*2*) found that the relative internal-external rotation between pelvis and AK socket increased during stance phase with an axial rotation unit operating (Fig. 2). They attribute this increased rotation to the effects of muscle action within the AK socket acting about the long axis of the prosthesis. As a result, incorporation of an axial rotation device in a prosthesis allows the socket to move freely to relieve the pressures and torques caused by cyclic action of the musculature.

Without a rotator, the amputee during stance phase attempts to maintain a level pelvis by action of the hip abductors. Also, the amount of external rotation between the socket and pelvis is less compared to the same patient using a rotator. This produces a total restriction of hip joint motion as the amputee moves his body through space during mid-stance. With a

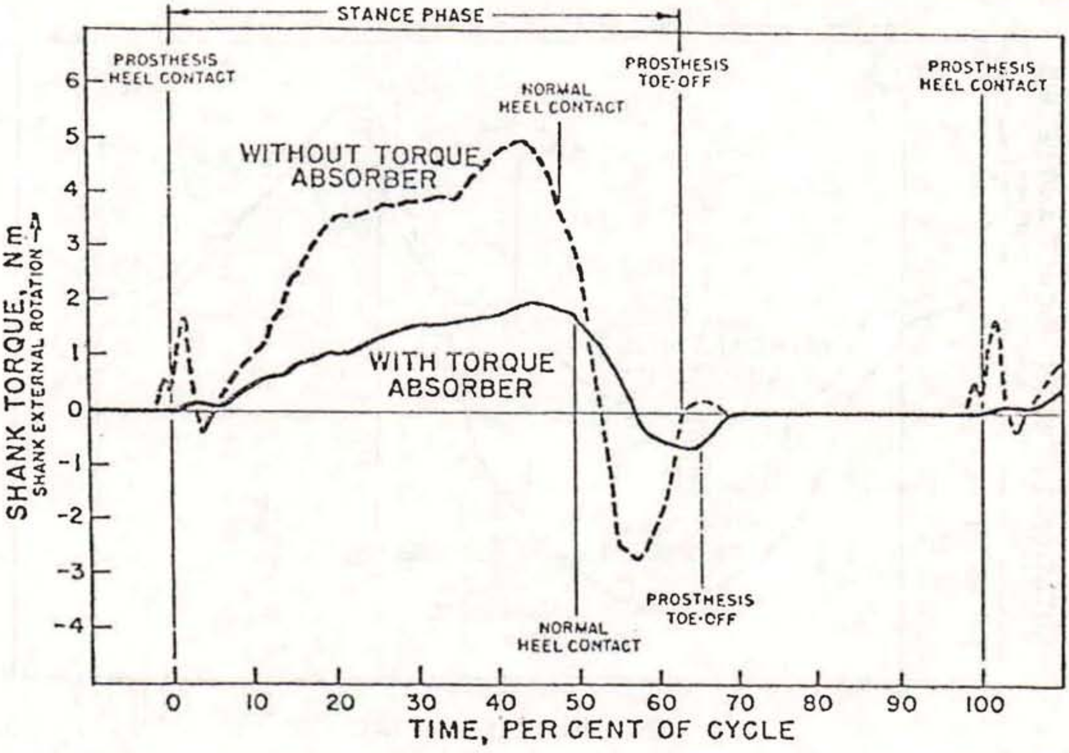

Fig. 1. A comparison of axial torques occurring in an above-knee prosthesis with and without the Axial Rotation Unit operating. (From Lamoreux and Radcliffe, 1974).

rotator, the amputee is able to rotate his pelvis in relation to the prosthesis allowing a smoother shift of his center of gravity over the prosthesis during mid-stance, and thus improving the appearance of the gait.

The biomechanical advantage mentioned above allows the active amputee to perform a full range of transverse rotation movements for such activities as golf and dancing. Also, kneeling is easier as the foot will rotate in relation to the floor when the rotator is placed below the knee joint.

CLINICAL EXPERIENCE

To determine the use and acceptance of rotators, ten prosthetic facilities in California were questioned. A total of 130 units were used over an 18-month period. Patient distribution was as follows: 60 on above-knee amputees, 65 on below-knee, and the remainder on knee- and hip-disarticulation cases. The units used were: 38 Weber-Watkins, 61 STAR, and 31 Hosmer Modulorotators. All types of artificial feet were used including the SACH, single-axis, and the Greissinger Five-Way foot. In most cases the SACH foot was indicated because it is lightest and has the lowest maintenance requirements. Many of the younger BK patients with long residual limbs and well suspended prostheses were very enthusiastic about the freedom and the added movement they had with the combined use of the rotator and Greissinger foot.

We draw to the readers attention that gait training periods have been necessary to gain maximum effects of the rotator unit, especially for amputees who were converted to an above-

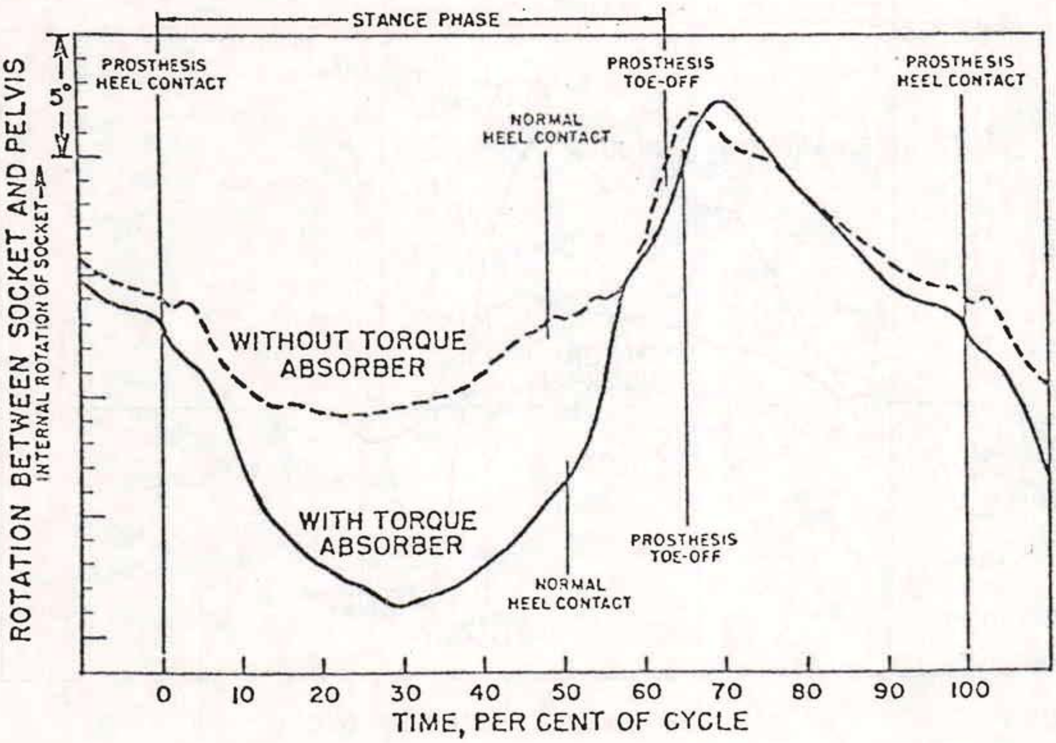

Fig. 2. A comparison of relative axial rotation between the pelvis and the socket of an above-knee prosthesis, with and without the Axial Rotation Unit operating. (From Lamoreux and Radcliffe, 1974).

knee prosthesis with a rotator installed after years of previous ambulation without a rotator. The patients had to learn to eliminate previous gait compensation patterns such as avoiding weight on the prosthetic foot while changing directions. Although most previous wearers initially commented they felt "unstable" or "off balance", after approximately one-half hour of training they quickly adapted and appreciated the increased freedom of motion.

BELOW-KNEE PATIENTS

The PTS design was used in the majority of below-knee patients in which the rotator devices were installed. PTB cuff suspension was also used but allowed too much movement to occur between the residual limb and the socket as compared to the prosthesis incorporating supra-condylar brim suspension.

Many of the 65 BK amputees using rotators were fitted with side joints and thigh lacers. Patients reported that the rotator allowed them to carry or lift loads with less residual limb stress and generally were more comfortable during a long active work day.

Acceptance of the rotator devices has been favorable by the below-knee amputee group. Good suspension was a "must" to combat the added weight.

All the BK amputees reported feeling less shear on the residual limbs and less restriction of motion in performing their varied activities of daily living.

Prosthetists reported a reduction of previous problem areas seen on the residual limb of the patients.

The Modulorotator was the most effective in below-knee prostheses because it is suitable for all lengths of residual limbs, lightest in weight, and the most cosmetic for the crustacean type of prosthesis. The STAR was used in several patients where length of residual limb allowed room for the unit. Weight of the Weber-Watkins was a contra-indication for its use in BK prostheses.

ABOVE-KNEE PATIENTS

The patient wearing an above-knee prosthesis appears to receive the most benefit from incorporation of a rotation device in the prosthesis. Most of the AK patients were suction socket wearers who experienced relief from discomfort in the proximal socket brim area (both medial and posterior) previously experienced before the rotator was installed in the prosthesis. Many patients reported that troublesome skin abrasions in the ischial tuberosity and ischio-pubic ramus regions cleared up and generally they experienced less residual limb soreness. Patients wearing pelvic joints, belt, and prosthetic sock commented on a much "freer", less restricted feeling while turning, sitting, getting in and out of cars, and many other twisting type of activities. They also concurred with the suction socket wearers in feeling less socket discomfort.

SUMMARY AND CONCLUSIONS

Axial rotators have been accepted by our patient group for the following reasons:

1. Greater socket comfort
2. Improved gait symmetry
3. Reduction in the frequency of occurrence of skin trauma in the residual limb.
4. Improved freedom of movement when changing direction of motion, working at a bench or counter, and in sports activities.

We conclude from our findings that axial rotator components offer functional advantages to the amputee and should be considered routinely during prosthetic prescription.

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