

Contoured Adducted Trochanteric-Controlled Alignment Method (CAT-CAM): Introduction and Basic Principles

by John Sabolich, C.P.O.

Since 1969, it has become increasingly evident that quadrilateral sockets have serious bio-mechanical problems. Even my old-timer above-knee prosthetic patients seem to be more comfortable in their ancient plug sockets, although transverse rotational stability was not as good. Fundamental to these objections is the lack of adequate stabilization in the frontal plane, which results in the gluteus medius gait most AK amputees demonstrate.

In order to stabilize the upper trunk and pelvis in normal gait, the gluteus medius and abductors on the stance side must fire vigorously when the contralateral side is in swing phase. However, we are dealing with a pathomechanical situation when we consider the case of the above-knee amputee. No longer are bones and ligaments positively connecting the hip to the floor. There is an intervening pseudo-joint, "the patient socket interface." We now have part of the femur inside a gelatinous semi-fluid mass, the human thigh.

When the abductors fire, what is most likely to occur in a rectangular socket with a wide M-L dimension and no bony areas for the socket to lock against medially? The answer we have discovered, is that the femur tends to abduct. In quadrilateral sockets, the ischial tuberosity is sitting on top of the ischial seat and is free to shift about (Figure 1). As the gluteus medius pulls the femur into abduction, the pelvis slides medially on the ischial seat and makes the abduction worse. The unsupported femur has little choice than to drift into an abducted attitude within the wide M-L quadrilateral container.

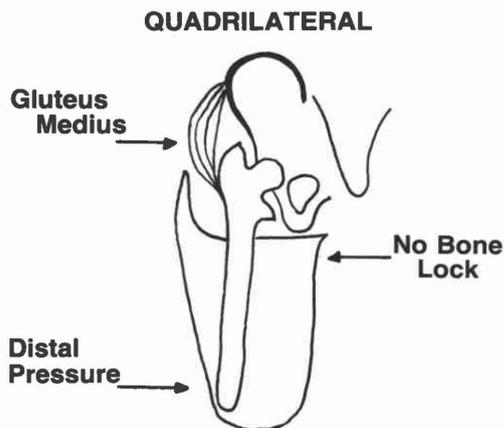


Figure 1. No bone block and no real force system to prevent femoral or ischial drift. Ischial tuberosity acts as a fulcrum. Pelvis can rotate as well as the femur abduct.

Pain at the distal femur and at the proximal medial area is due to this abducted position and excessive soft tissue pressure medially.

We now have a perfect set-up for the classical above-knee "lateral trunk leaning" gait familiar to prosthetists. The patient has to lean to the side to position his upper torso over the base of support (the abducted distal femur) during stance phase, since the prosthesis is falsely placed under him (Figure 2). The patient executes this maneuver to prevent excessive pressure on the lateral distal femur and the medial proximal soft tissue. In essence, the patient must walk in a fashion similar to a person who has two sound legs with one leg out to the side in abduction.

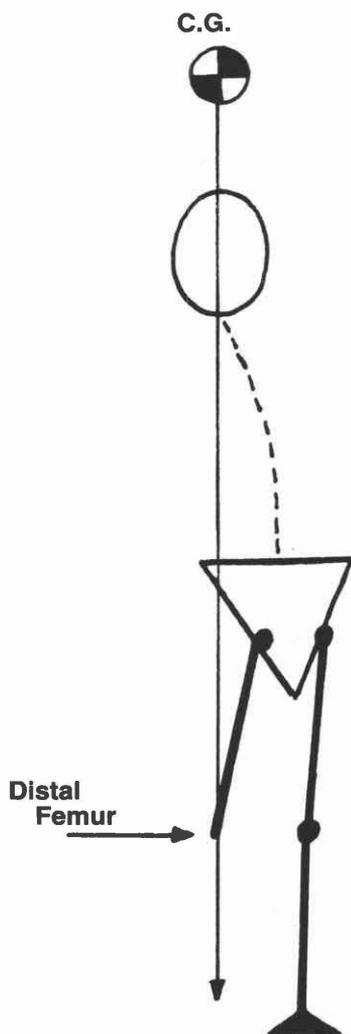


Figure 2. Patient must lean lateral over distal abducted femur, use inertia, or muscular tightening to prevent pain on lateral distal femur.

To the best of my recollection, I began questioning the validity of the quadrilateral socket theory in 1969 when I was a student at New York University. Dr. H. Richard Lehneis, C.P.O., of that institution taught that it is not necessary to put most of the patient's weight on the ischial tuberosity and, if the truth were known, most of the weight is probably borne by the peripheral tissue and gluteal musculature. Moreover, at heel strike, when the largest inertial forces are placed on the above-knee re-

sidual limb, the ischial tuberosity is not on the ischial seat due to the flexed hip.[†]

This concept was reinforced in my mind by the idea that if the majority of the amputee's weight was borne by the ischial tuberosity on the quadrilateral socket's flat ischial seat, one would only be able to obtain a tangential force at best, which would bring to bear tremendous force on a very small part of that bony prominence, and consequently cause great discomfort. Placing extra force in the neurovascular bundle anteriorly, Scarpa's triangle, with the purpose of pushing the ischial tuberosity up onto the ischial seat, has never made much sense to me. This seems to be the worst place to apply pressure and can not have a positive effect on circulation. These thoughts confirmed my concern that the quad socket theory had serious biomechanical problems and spurred my subsequent efforts.

We began to close the M-L dimension of the socket by adding material to the lateral and medial sides to try to force the femur into adduction. We also began opening up the A-P dimension, not only to reduce the pressure on the neurovascular structures of the Scarpa's triangle, but also to compensate for the reduced diameter in the M-L dimension, and thus to maintain the original circumference. (Prosthetists naturally tend to be fearful of such modifications since they have been taught to tighten the A-P to keep the ischial tuberosity on the ischial seat.) In addition, I began to slant the ischial seat in the frontal plane upward laterally at about a 30° angle, rather than leaving it horizontal, so as to increase the weight bearing of the gluteal muscles, and thus rely less on the ischial tuberosity. These are some examples of early attempts to change the quadrilateral design and may be considered as our first generation efforts.

In early 1981, the Sabolich Prosthetics Center sponsored a seminar to investigate non-quadrilateral alternatives for A.K. management. Participating in this seminar, among others, was Ivan Long, C.P., developer of the concept of Long's Line and an associated socket design.¹ The information learned from Mr. Long was of the greatest benefit in advancing our efforts. However, for reasons that

[†] Dr. Lehneis states that the first person to indicate that the ischial tuberosity was more efficient biomechanically if it was in the socket proper was a German man by the name of Schnur in the early 1950's.

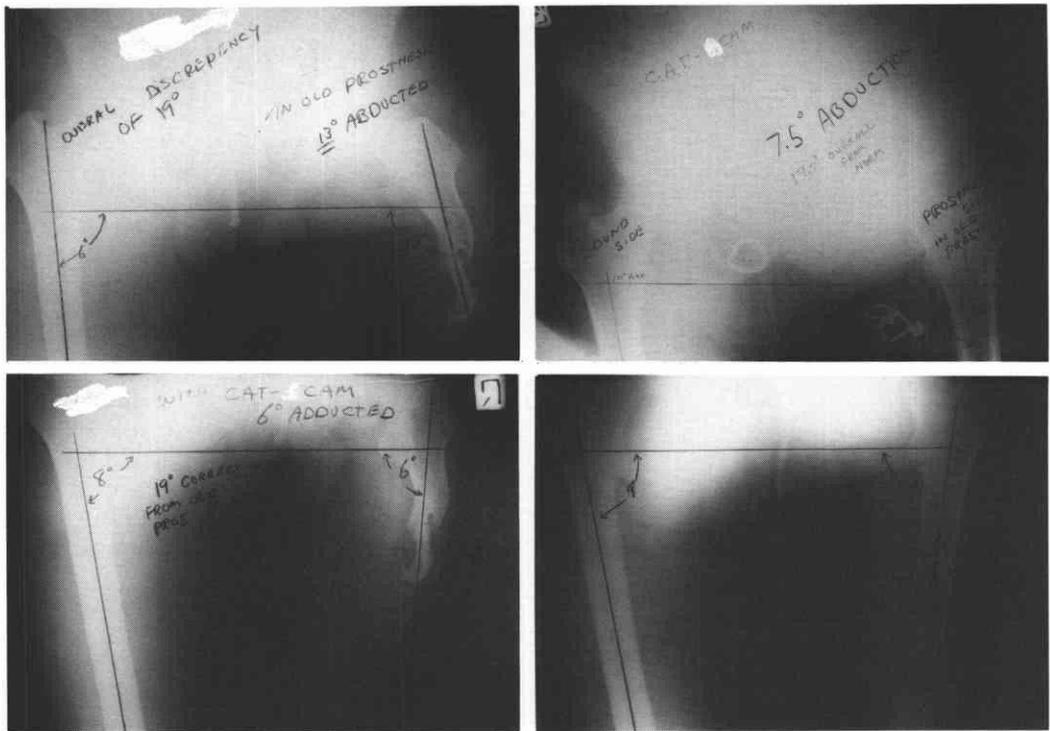


Figure 3. Weight bearing x-rays comparing CAT-CAM and quadrilateral sockets.

will become apparent in this article, we found it essential to proceed on a different track that experience has shown was necessary to make this program work for us. After this seminar, the Sabolich Center continued research study of non-quadrilateral above-knee designs.

Over 900 non-quadrilateral sockets have been fit on a documented basis in Oklahoma City to patients ranging from six months to 103 years of age. X-rays (Figure 3) and Xerography have been impressive, showing the femur to be in a much improved adduction attitude. We have made major changes in shape and contour, especially in the last three years. We have coined the acronym CAT-CAM, which stands for Contoured Adducted Trochanteric-Controlled Alignment Method, to describe the second generation design which is covered in the remainder of this article.

This design includes undercutting of the trochanter and a special fossa in which the ischial tuberosity and descending ramus can rest, giving this bony prominence three-dimensional support within the socket. No more consideration is given to the transverse angle of the posterior wall relative to the medial wall (Figure 4). The Scarpa's triangle is virtually eliminated,

CAT-CAM vs QUAD

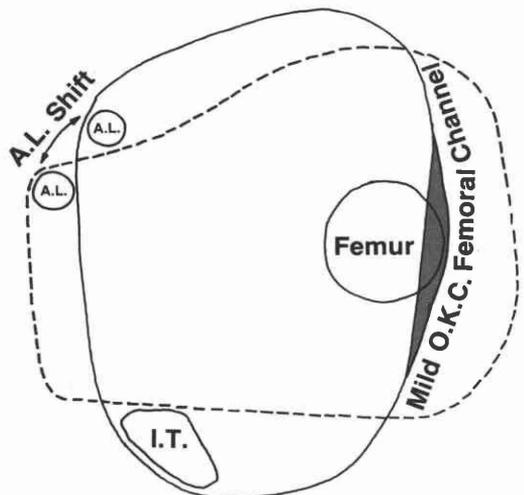


Figure 4. Comparison of CAT-CAM and quadrilateral sockets in a transverse view. Since the femur and ischial tuberosity are fixed in position, the adductor longus tendon has to shift a small amount. Note mild O.K.C. (Oklahoma City) channel about the femur.

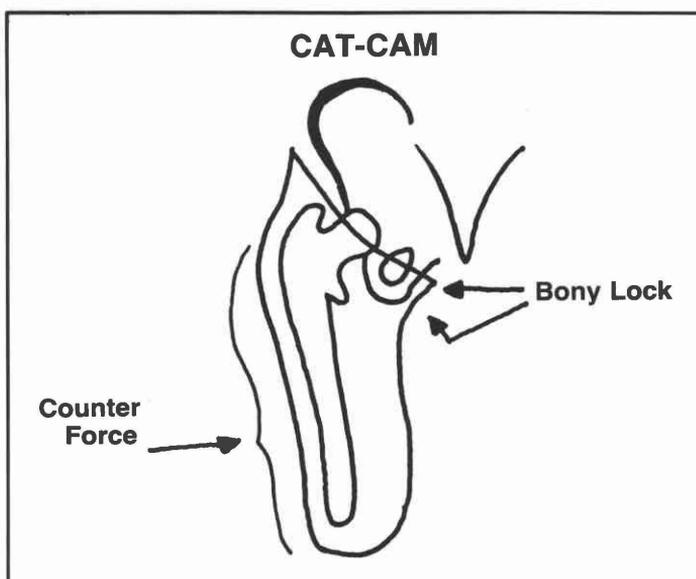


Figure 5. Ischial tuberosity is locked in the socket to provide a counter force against femoral shift.

as are the adductor longus and rectus channels, and the ischial seat. The ischial tuberosity still bears some measure of vertical loading since it rests on an angled surface. The old principles of the quadrilateral design simply do not function, since we are dealing with a completely different design in shape, contour, and biomechanical principles. The socket is so different that it looks somewhat like a quadrilateral socket turned sideways with a large A-P and narrowed M-L.

A number of prosthetists have come to our facility to learn these techniques on a one-on-one basis. We have gained much information and feedback from the other prosthetists who have participated in these informal educational efforts. However, this process is not altogether appropriate and has come to be tremendously time consuming. We feel that in the future, education should be administered to several prosthetists at once in an organized and structured course by one or another of the schools. In March, 1985, a preliminary course was taught at UCLA after two years preparation and the writing of a manual. This effort confirmed, in the minds of those involved, the necessity of such a course, and also the necessity of further efforts upon the part of the teaching staff involved to perfect techniques and teaching material. Moreover, it should be borne in mind that the acronym CAT-CAM embraces a number of varying concepts advanced by a number of prosthetists working in common directions and these differences must be recon-

ciled into one technique to be taught. In the strongest possible terms, and in view of the problems some prosthetists have had, we can not recommend using the CAT-CAM method without a hands-on instructional course.

CAT-CAM THEORY

The CAT-CAM holds the femur in adduction primarily by two means. First, the ischial tuberosity and part of the inferior ramus of the ischium rest inside the socket proper, and bear laterally directed forces which work in conjunction with medially directed forces borne by the femur (Figure 5). Medially directed forces bearing on the proximal portion of the femur in the trochanteric and sub-trochanteric region act to hold the ischial tuberosity on an inclined medial-posterior surface within the socket, while forces on the mid and distal portion of the femur act to maintain the proper adduction angle. Actually, it could be described as a wedging or "locking effect." (Imagine yourself holding the ischial tuberosity of a skeleton in the cupped palm of your hand and pushing the femur into adduction with your opposing hand; thus, the "locking effect.") The lateral surface of the socket proximal to the greater trochanter is contoured intimately into the soft tissue distal of the iliac crest. It is hypothesized that medially directed forces in this area, working in conjunction with the medially directed forces on the lateral surface of the femur and laterally directed forces borne by the ischial tuberosity,

create a three-point pressure system to lock the femur into adduction and reduce motion that can occur when the ischium is free to shift about.

Second, the narrow socket means that the pressure bearing areas of the socket bear directly against the skeletal elements, thus reducing motion lost through intervening soft tissues. A wide socket M-L cannot provide this locking phenomenon since the femur can fall away from the supporting surfaces.

In the transverse plane, the medially directed force of the ischial tuberosity is posterior to the laterally directed force of the trochanter and femoral shaft. One might assume, therefore, that the socket would twist or whip about its long axis. This does not happen, and apparently the adductor longus tendon and other medial proximal tissues anteriorly generate enough counter force to resist this tendency. Also, the ischial tuberosity creates a posteriorly directed force (since it is nestled in the posterior medial corner of the socket), resisting this tendency. Last, this tendency is checked by a new medial trimline (described later) which captures the medial portions, or the inferior ramus of the ischium, which are almost exactly opposite the trochanter.

The exact weight bearing mechanism of the CAT-CAM socket with its wide A-P diameter and decreased emphasis on ischial tuberosity weight bearing is unclear. However, it is assumed that the femur is capable of bearing some measure of the patient's weight due to the increased adduction angle. It is also assumed that hydrostatic weight bearing plays an important role and that the ischial tuberosity still bears a measure of weight.

In general, we have discovered that the prosthetic foot should be placed considerably lateral of a plumb line through the ischial tuberosity, but not always under the center of the hip joint or distal femur as with "Long's Line." This line changes position with how well the ischial tuberosity is locked in the socket and how narrow the mid and distal M-L dimensions can be molded. This alignment line also changes from patient to patient and depends on gluteal muscle strength, ischial ramus shape, femoral length, and subcutaneous tissue thickness. The prosthetist is now able to align the prosthesis in a normal physiological and anatomical fashion because the femur is no longer in abduction.

The Berkeley Adjustable Shank is very useful in determining this critical relationship. By outsetting the foot more than with quadri-

lateral designs, the patient must adduct his femur to get his feet close together again. With the femur in abduction, as in the quadrilateral socket, a patient would be standing with his prosthesis scissored over his sound leg if he tried to stand with his femur in normal adduction angle. One cannot use a standard unchangeable line and always obtain the same adduction angle as with the contra-lateral femur, since the shorter the femur, the greater the adduction angle must be in order to place the distal femur under the center of the hip joint resulting in hyper-adduction. This was the reason I abandoned this line in favor of an adjustable line utilizing the Berkeley Adjustable Shank. This has resulted in much better alignment.

One may ask, "If everything is stabilized in the M-L direction, then what about in the A-P plane?" After all, this is of the utmost importance at heel strike in order to stabilize the prosthetic knee and to help propel the patient over the foot. Our experience has not shown this to be a problem. In fact, if anything, an increase in A-P stability has been noted. We hypothesize two ways by which this might be explained.

First, the majority of the muscle activity about the hip is in the A-P direction. The flexors and extensors are allowed to expand naturally, filling the socket quickly, and thus firmly stabilizing it (Figure 6). Also, this change in contour allows the A-P muscles to function naturally, increasing their size and strength. We have noted many cases of hypertrophy of the A-P muscle groups rather than atrophy. No longer are these muscles being squeezed, stifling their motion and effectiveness. Even suction sockets seem to hold on better since the tissues are not being deformed in an unnatural fashion, causing air pockets and channels to form. Second, the ischial bone is inside the socket, creating a solid posterior stop as opposed to simple soft tissue pressure, aiding A-P control at heel strike (Figure 7). Distally, CAT-CAM's become more round, again aiding A-P control.

We have noted several interesting phenomena during this research effort. The first I have dubbed the "lateral pylon lean syndrome." Sometimes during dynamic alignment on the adjustable shank, the pylon has to lean laterally in order for the patient to be comfortable. The pylon can be brought vertical by increasing the socket adduction. This turns out to be a temporary solution and does not solve the real problem. This eventually results in pain in

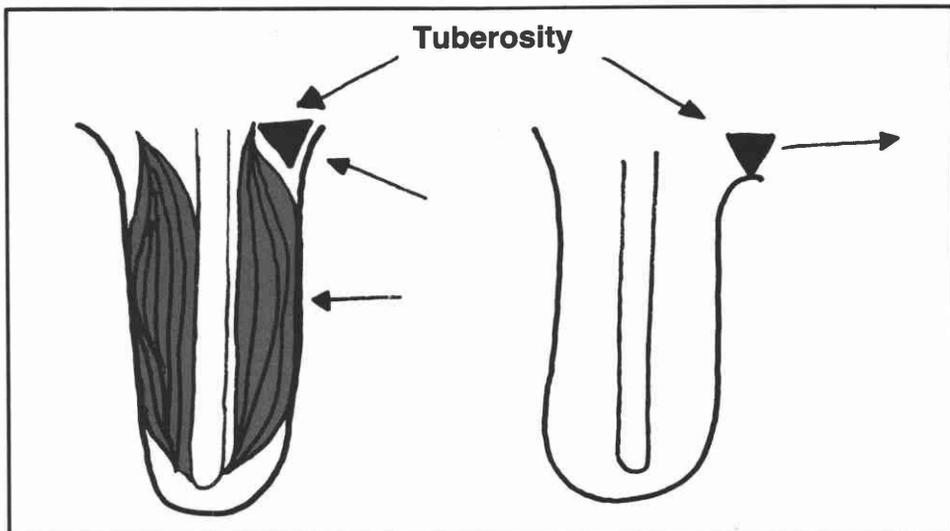


Figure 6. Most muscles function in the A-P plane. The CAT-CAM socket gives these muscles room for their normal dynamics.

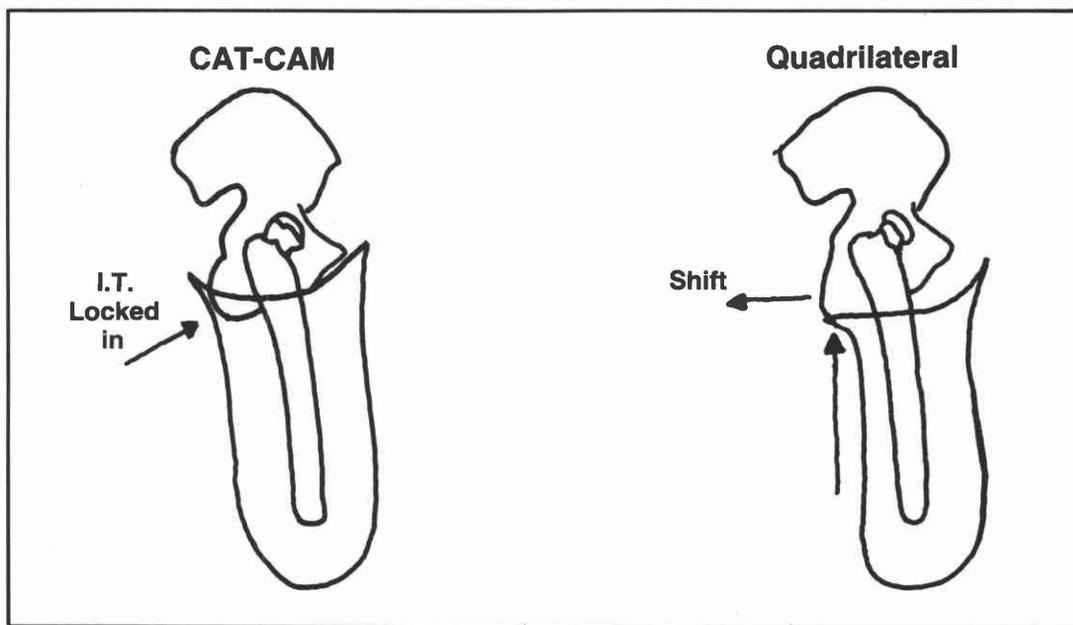


Figure 7. The ischial tuberosity is free to shift about in the A-P plane as well as the M-L plane when sitting on top of the ischial seat.

the perineum. What is actually happening is that the ischial tuberosity is slipping out of the socket proper and migrating medially on the proximal brim. As a result, the femur falls into abduction, or more realistically, the superior lateral portion of the socket drifts laterally on the patient, the medial superior brim digs in, the pylon leans laterally, and the proximal lateral brim gaps. The problem is not one of alignment at all, but of ischial containment (Figure

8). This happens when the socket is too tight in the M-L plane. This happened with sockets fitted after the 1981 seminar when circumference charts were used to determine socket M-L. These resulted in the ischial tuberosity being on top of the medial brim and that is why the brims of such sockets were so wide and thick. The intention was to get the ischium in the socket, but in actual practice it invariably ended up on top. This is no longer necessary due to

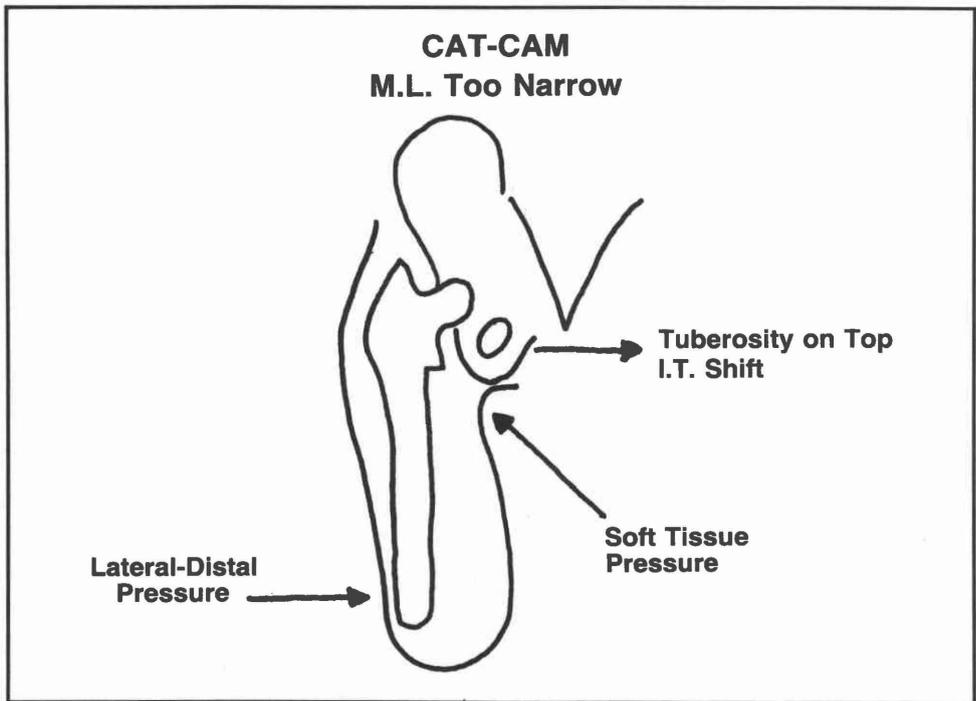


Figure 8. When the CAT-CAM socket is too tight, the ischial tuberosity shifts medially, the femur abducts and the lateral superior brim gaps.

improved measurement techniques used to determine true M-L.

Secondly, it seems that the shorter the femur and the greater the volume of the residual leg, the more noticeable is the "CAT-CAM effect." This is due to the favorable comparison of the CAT-CAM sockets versus quadrilateral sockets. The shorter the femur and the greater the relative amount of soft tissue in which it can move, the more obvious the problems of the quadrilateral socket become. However, even with long and lean residual legs, patients still notice the difference in comfort and adduction associated with the CAT-CAM method. A common statement is "it feels more solid," "it feels like its under me again," or "my leg goes where I want it to go." Also, the short residual limbs simply have much more peripheral tissue containment in which to bear vertical and horizontal loading, since the CAT-CAM extends much higher and contains more tissue, especially gluteal.

Third, we have virtually eliminated use of hip joints even on very short sub-trochanteric above-knee patients. The adducted femur and the high lateral wall, snugly pressing into the

intraillio-trochanteric region, help stabilize the M-L and tend to reduce the need for external support.

Fourth, to the question of sitting: will there be a lot of gapping anteriorly? Not if the socket is dimensionally correct. Bending forward at the hip is actually enhanced due to increased room anteriorly, and with the new flexible brim described next, the problem is completely eliminated.

Fifth, both the modified version of the Swedish Flexible design, with medial and lateral framing, and the new Total Flexible Brim (T.F.B.) mesh with CAT-CAM principles perfectly as both allow increased function of the A-P muscle groups (Figure 9). The CAT-CAM with T.F.B. is preferred because of its superior sitting comfort, adaptability, and dynamic comfort without sacrifice of A-P muscle freedom. The T.F.B., which allows the entire upper three-fourths of the posterior wall and the entire proximal portion of the socket to be flexible and allows a flexible anterior window, is actually opposite of the Swedish Flexible design, which has its greatest measure of flexibility concentrated in the mid-thigh. The T.F.B. is possible

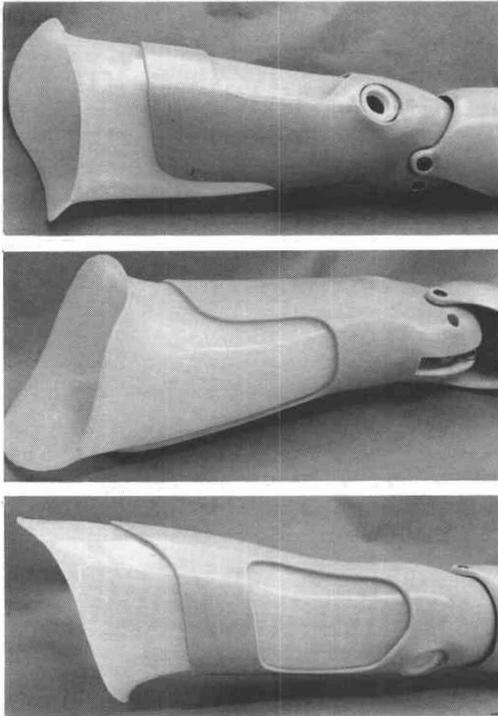


Figure 9. Three views of the Total Flexible Brim (T.F.B.) CAT-CAM.

because the ischial bone is no longer on top of the posterior or medial seat, but down in the socket, so it does not tend to collapse or push the flexible seat distally. Instead, the tuberosity forces out against the side of the socket as does the trochanter, adductor longus tendon, and peripheral tissues. This can be thought of as one trying to hold his body in place in a V-shaped vertical tunnel or shaft by pushing out on the walls of the tunnel with one's hands and feet. The residual leg pushes out in all directions at once, thus there is no collapse of the flexible posterior brim. For the first time in prosthetics, the proximal thigh is actually allowed to deform naturally during sitting and to change contour dynamically while ambulating. I feel this is important since a great deal of pain complaints are related to the proximal areas. This flexible brim has also allowed us to become much more aggressive and make a major change by extending the posterior and posterior-medial brims higher to capture the ramus and ischial tuberosity more effectively. It has also allowed us to actually slant the medial brim superiorly to better capture the ischium and ramus while relieving the pubis.

Sixth, bilateral above-knee patients gain additional benefit from the CAT-CAM design. Our bilateral patients who rejected their quadrilateral socket accept the CAT-CAM enthusiastically. They benefit from the extra space provided in the perineal area by the narrowed M-L (especially with male patients). Even the old round plug sockets gave more room in the perineal area (Figure 10). The shaded area in Figure 10 demonstrates the extra area available for the genitalia from plug sockets over the quadrilateral socket represented by the rectangles. The CAT-CAM, of course, allows even more room in this area due to its opposite shape and contour.

Seventh, the CAT-CAM has great advantages for the geriatric patient for several reasons. We have had our worst difficulties with quadrilateral socket on people with poor muscle tone. The shortcomings of the quadrilateral design become more obvious in the older population. The sharp angles of the adductor longus channel, the posterior medial corner, the medial brim, and the Scarpa's triangle of the quadrilateral socket were almost never really comfortable. With the CAT-CAM, these patients seem to have improved vascular flow; their residual limbs feel warmer after removing the prosthesis. This seems reasonable since the neurovascular bundle is not being choked off with a large bulge in the Scarpa's triangle. The

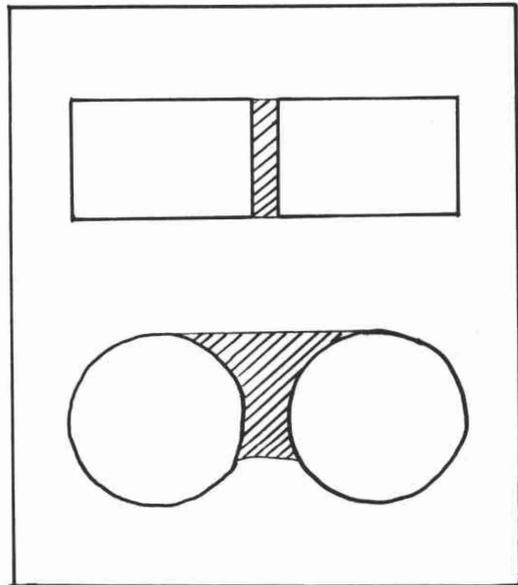


Figure 10. Graphical representation of the amount of room afforded in the perineum by a non-quadrilateral socket.

A-P is not being choked but opened up. We hope to conduct comparative temperature and later Doppler blood flow analysis of this phenomenon. For the extremely large geriatric patient population, this alone might be one of the single greatest benefits of research with CAT-CAM design. When the Total Flexible Brim is added, we have not only greater comfort, but further increase in circulation.

Eighth, we have noted that a large percentage of patients who were switched to CAT-CAM comment about energy savings. They do not seem nearly as tired after walking the same distance in the CAT-CAM as with their old prosthesis. This is probably first due to less lateral displacement of the center gravity. Second, patients do not have to fight to keep the femur from hitting painfully against the socket distally by tightening their musculature. Third, with more boney contact inside the socket and thus a more solid purchase, the prosthesis moves quickly without delay from false motion.

Ninth, we have found that by undercutting the greater trochanter, a much better purchase and counter force to the ramus and tuberosity can be generated with less M-L play and, I suspect, some vertical component of weight can be borne on the flare of the trochanter much like that of the medial tibial shelf in the below knee. Also, now that the femur is actually adducted, we are now probably picking up a vertical component of force on the lateral shaft of the femur.

Tenth and most important, after the 1981 seminar, we used a chart that related circumference of soft peripheral tissue to the desired medial lateral dimension of the socket. We found many fallacies with this method. The reason for this is that one cannot rely on circumference measurements to indicate the proper diameters between the ischial tuberosity and sub-trochanter, or the ramus and sub-trochanter. In our work, we found that it was ab-

solutely necessary to obtain both of these measurements to obtain consistent results. A patient may be very fleshy and obese, but that in no way changes the anatomical dimension of the bony structures. The reverse is true with a thin patient. This was one of the most difficult stumbling blocks to obtaining truly good results. It seemed that when using this chart, the tuberosity was usually up on top of the medial superior shelf, which acted as an ischial seat, and this explained why the medial brims at the 1981 seminar were flat and 1 1/2" to 2" wide. In effect, the medial brim became an ischial seat. The sockets fabricated at the 1981 seminar still had the ischial tuberosity out of the socket proper and superior medial lateral diameters that were too narrow, resulting in M-L socket shift. True, the ischial tuberosity was no longer on the posterior shelf, but we had simply moved the tuberosity to the top of the medial shelf. The narrow M-L did provide better adduction of the femur, but not as good as when the ischial tuberosity and ramus are totally locked in the socket, providing a medial stop.

The reason for this was discovered with more research. Namely, that it is incorrect to rely on what a patient measures in circumference at the perineal or ischial level, and to expect to extrapolate the medial-lateral dimension of the socket. I had two years of severe problems in this area until we dropped the circumference chart and adopted methods to determine exact measurements through xerography, x-rays, and anatomical measurements. Only then was I able to obtain consistent results, symmetrical adduction of the femur, and stabilization of the proximal socket to prevent lateral socket shift.

Eleventh, through the course of our research, we have defined three ischial tuberosity-ramus types. We call these different configurations: alpha, beta, and gamma types (Figure 11). These classifications are valuable since they can

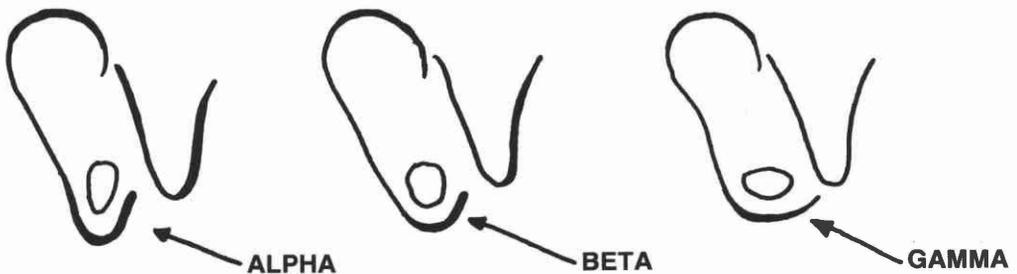


Figure 11. The well defined high slope of the alpha type usually results in improved femoral adduction and M-L control. At the other extreme is the gamma type which is more difficult to grasp properly with the socket.

be used to predict to what extent we will be able to control femoral adduction comfortably. The more purchase one can obtain by locking against the medial border of the ischial-ramus, the less the pressure that comes to bear on the soft medial proximal tissues, and the less the M-L shift of the socket.

The alpha type is the most desirable, since it has a medial side which slants up at a sharp angle, making it more appropriate for good M-L purchase, and also making it easier to slip into the socket. The beta type has more sloping sides, making purchase somewhat more difficult.

The gamma is the poorest type for purchase. We tend to have some pressure problems in the medial proximal area with the gamma types due to M-L socket shift. It is difficult to get this wide bone inside the socket proper. This necessitates widening the medial lateral dimensions of the socket so the wide gamma tuberosity will slip into the socket. With the gamma types, we usually have to settle for a less adducted femur than the patient exhibits on the contralateral side.

Another very important point that finally emerged as research continued was that, not only ischial tuberosity, but medial inferior ramus containment was very important to stabilize the socket from lateral shift. The reason for this is that, while the ischial tuberosity is more posterior, and thus helps prevent anterior shift of the socket at heel strike, the ramus is a greater asset when it comes to prevention of M-L shift of the socket and is in a much better anatomical and mechanical position to provide a true medially directed force to the socket, since it is more diametrically opposite the trochanter and sub-trochanteric regions than is the ischial tuberosity.

We have had some problems in the beginning with CAT-CAM due to inexperience. However, these have fallen below the one percent range. I find this one percent figure extremely interesting since most patients, especially older people, tend to reject new designs. We found almost none of this phenomenon, however, in switching from quadrilateral to CAT-CAM. We did experience problems due to low back pain in two very old patients. This problem is probably due to the fact that the quadrilateral sockets worn for years and associated with an abducted femur, allowed the lumbar spines to drift to one side. Apparently, fitting the CAT-CAM sockets suddenly pulled the lumbar spines in the opposite directions, inducing low back pain.

During the early years, we sometimes had to fit many transparent check sockets to the same patient before we had successful outcomes. With increased experience and the formulation of rational guidelines and more exacting anatomical measurements, this necessity has been greatly reduced. However, one should expect to spend a great deal more time fitting CAT-CAM design sockets due to the intimate bony contouring.

A comprehensive CAT-CAM program should include use of comparative x-rays, which aid in modification and establishment of the angle of correction, as well as transparent diagnostic sockets, video gait analysis, and bio-feedback as described in the next paragraph. We also recommend that previous quadrilateral patients undergo an intensive program of abductor strengthening with a prosthetically knowledgeable physical therapist, who will also later teach them not to laterally trunk bend from habit. The full benefit of the CAT-CAM socket is not achieved if the patient has been using a quadrilateral socket long enough to weaken his gluteus medius and abductor mechanism. If the femur tends to be in abduction (Figure 12), the gluteus medius is slack and not under normal tension, causing it to have a poor mechanical advantage and makes this muscle effectively weak.

We have developed a CAT-CAM program to strengthen the gluteus medius muscle through the use of myoelectric biofeedback during gait training. Pressure sensitive electrodes are mounted to the patient over the gluteus medius, and the biofeedback unit emits an audible signal proportional to the electrical activity generated by the muscle when it fires. Using this method, the patient can actually listen to the muscles fire and begin to force himself to use

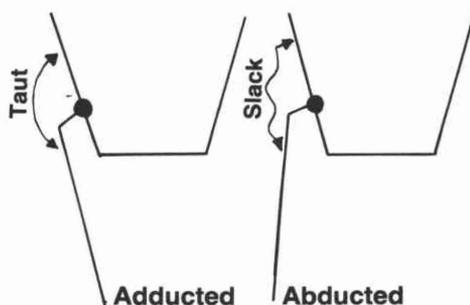


Figure 12. The gluteus medius is not effective when the femur is in abduction.

the abductors more. The stronger this abductor mechanism becomes and the more training the patient receives, the less the classical A.K. "lateral trunk lean" during stance phase is observed. This is an important phase of the program and a very effective way to not only strengthen the gluteus medius, but to do so dynamically while the patient is ambulating. We also explain to the patients the reason why they must trunk lean laterally in a quadrilateral socket and use a video system to provide visual feedback to enable them to see themselves walk. This works very well since people seem to react better to watching themselves walk incorrectly and correcting it voluntarily, than to have a practitioner telling them what they are doing wrong. With former quadrilateral patients, do not expect this lean to go away completely because the habit is so well entrenched; however, it can be greatly reduced if not eliminated.

FUTURE PLANS

In late 1985 or early 1986, we will introduce the SCAT-CAM, or Skeletal CAT-CAM, which is a highly bone and muscle contoured design. We have been working on this design for three years and it looks considerably different than CAT-CAM (Figure 13). We feel this approach is the next logical step with the evolution of CAT-CAM and are very pleased with the results. SCAT-CAM is actually a third generation CAT-CAM exhibiting, among other refinements, a highly relieved lateral wall with Oklahoma City channel (O.K.C.), which is actually a trough for the entire femoral shaft along with full length of the lateral wall (Figure 14).

I feel this is a major advance, since it attempts to capture the femur in the A-P direction and to prevent A-P and transverse pseudo movement.

The O.K.C. fossa is provided in a SCAT-CAM to place the ischial tuberosity in a hollowed out relief as opposed to the angular shelf of the second generation CAT-CAM. This fossa enhances the locking effect A-P and M-L. A transparent diagnostic socket is very helpful to properly locate this fossa placement. Also, the medial superior wall has undergone drastic changes to allow relief for the pubis, but still quickly slant superiorly posterior of the pubis to trap even more of the inferior ramus of the ischium and tuberosity. This gives a much improved medial superior locking counter force than a horizontal medial brim. It takes on the shape of a letter "V." With the SCAT-CAM, the pubis can be relieved in the vortex of the "V," while the medial border of all but the inferior apex of the ramus and all of the ischial tuberosity are caught in the arms of the "V."

The use of direct anatomical measurements instead of the circumference chart has resulted in a drastic change in general contour where the superior medial-lateral dimension is wider to catch the bony areas, then quickly reduces in M-L dimension and becomes very narrow distal to the sub-trochanteric area, resulting in superior adduction control of the femur. Another important change was with the radius of the superior medial brim. We have changed from a 90° to a gentle upward sloping brim, which prevents the ramus and tuberosity from sliding or shifting out of the socket. With the SCAT-CAM, even more vertical loads are possible on the ischium than with quads sockets since the

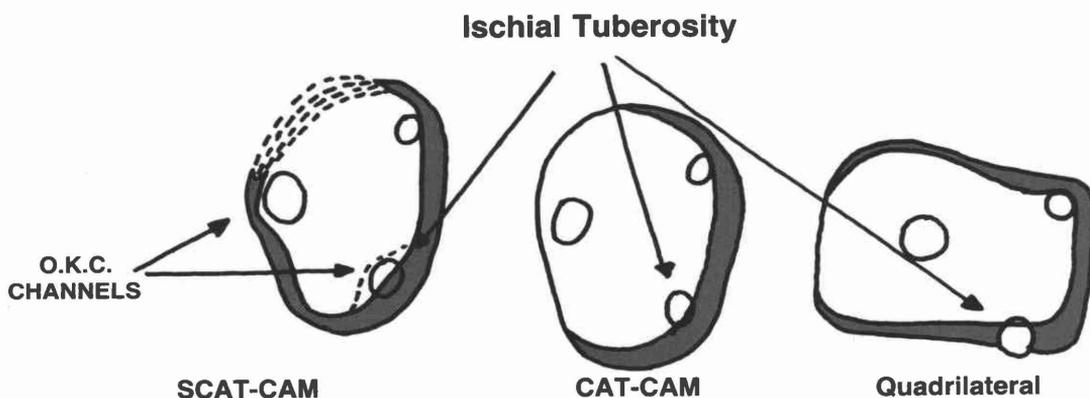


Figure 13. Evolution in shape from the quadrilateral socket (right) to the SCAT-CAM socket (left).

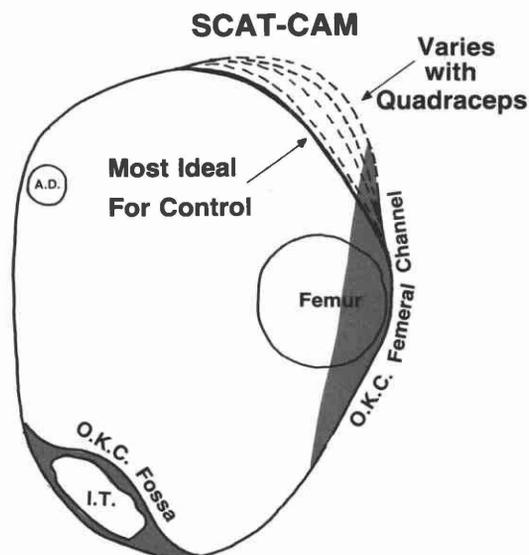


Figure 14. Cross-sectional view of the SCAT-CAM socket.

forces can be wrapped around this complex and curved ischial-ramus bone, which in essence can now be used for vertical posterior and medial loading.

We are planning a research program which we hope will contain the following studies:

Quantitative

1. X-ray with comparative study of femur adduction-abduction angles.
2. Digitally timed video comparison of gait A-P and lateral analysis.
3. Myoelectric measurements of major muscle groups, especially the abductors.
4. Dynamic oxygen consumption rates to monitor energy expenditure.
5. Relative Doppler blood flow in distal residual leg.
6. Temperature of skin in both sockets after controlled time factor.
7. Data on acceptance rates.
8. Atrophy data or hypertrophy comparisons.
9. Determination of the weight bearing mechanism.

Qualitative

1. Video comparisons.
2. Patient comments.

CONCLUSION

Even though the CAT-CAM and SCAT-CAM are diametrically opposite to the quadrilateral in design and precept, I believe these new principles will eventually be widely accepted and deeply penetrate the prosthetic field. I encourage practitioners to insist on weight bearing x-rays as part of a comprehensive prosthetic program, which lend credibility to our premise by exposing internal problems which result in external manifestations. My sincere hope is that the prosthetic community will not take this article to be controversial, but as a statement of what we have discovered and felt compelled to share.

BIBLIOGRAPHY

¹ Long, I., "Allowing Normal Adduction of Femur in Above-Knee Amputations," *Orthotics and Prosthetics*, Vol. 29, No. 4, pp. 53-54, December, 1975.

ACKNOWLEDGMENTS

The main source of strength in perpetuating my interest in CAT-CAM has come from the support of my father, Lester J. Sabolich, C.P.O., Thomas Guth, C.P., Mike Wilson, C.P.O., and Dr. Ernest Burgess. These people have supported this project from early on and deserve much credit.

I would also like to credit Ivan Long, C.P. who defined his alignment principles in 1975 and thus started us on the right track. Enough credit cannot be given this man!

Also I thank my wife Lee, who has not complained about many lonely evenings during this research project.

I thank the entire staff of Sabolich Prosthetics Orthotic Center. Without these people, none of this research could have been achieved. Only they understand the grit of many failures and garbled plastic in the trash.

I thank all of the prosthetists who have worked with us and tried this method. Their feedback has been invaluable.

Last, special credit goes to Chuck Childs, C.P.O., who could see the profound effect of this method and was in hot pursuit of it when he was taken from us.

AUTHOR

John Sabolich, C.P.O., is Vice-President of Sabolich, Inc., 1017 N.W. 10th Street, Oklahoma City, Oklahoma 73106.