# Observations on Failures of Back Checks on Artificial Legs


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### I. INTRODUCTION

About a year ago[1] we described an improved design for a back check on artificial legs. Subsequently, a number of persons brought to our attention the fact that no mention was made of the problem of impact on the back check. This occurs at the end of the swing phase during walking just prior to the time the patient's weight is put on the artificial leg. These prosthetists believed that the impact was severe, and if back check breakage occurred it was primarily due to the impact at the end of the swing phase.

The authors, and several bracemakers who wear above-knee artificial legs, believed, on the other hand, that the maximum load on the back check would occur at the step-off phase of walking. This would be especially large while walking up-hill or doing anything that puts the center of gravity of the patient forward of the knee-bolt. Accordingly, we decided to determine just what loads are imposed on a back check with the hope that this information might help not only in designing improved back checks, but with other parts of the artificial legs as well.

### II. Experimental Procedure

A type A-5 SR4 bonded wire strain gage was mounted on the back of an aluminum back check and used in conjunction with a Brush amplifier and oscillograph to measure the load. (See Figure 1). We used the usual precautions in employing shielded wire, grounding, and checking the instruments for each run. The entire setup can be thought of as a kind of complicated bath room scale used to measure the number of pounds acting on the back check while in use.

The system was calibrated statically using dead weights. The artificial leg was mounted in a horizontal position and lead weights suspended from the center of gravity of the shin. The shin weighed 4.82 pounds including the shoe and the center of gravity was located 12 inches below the knee bolt. The bumper was located two inches below the knee bolt. The system was calibrated to read directly the number of pounds force on the back check.

As a preliminary test the artificial leg was mounted in a vertical position fastened by the wooden socket in a sponge rubber lined vise. The shin was lifted to the 45 and 90 degree positions and allowed to drop. (See Figure 2).

Three different materials were tried for the bumper. The original leg had a bumper made of hard felt covered with leather. Bumpers made of plastisol with a Durometer A2 reading of 32, and bumpers made of rubber with a Durometer A2 reading of 52 were used.

Although there may be a significant fabricating difference in these three bumpers, it did not seem to influence the load on the back check to any great amount. The reason is that too much energy is absorbed elsewhere

[1] Smith, Francis L. and Young, J. L., *Orthopedic and Prosthetic Appliance Journal*, Pages 23-24, March, 1954 issue.

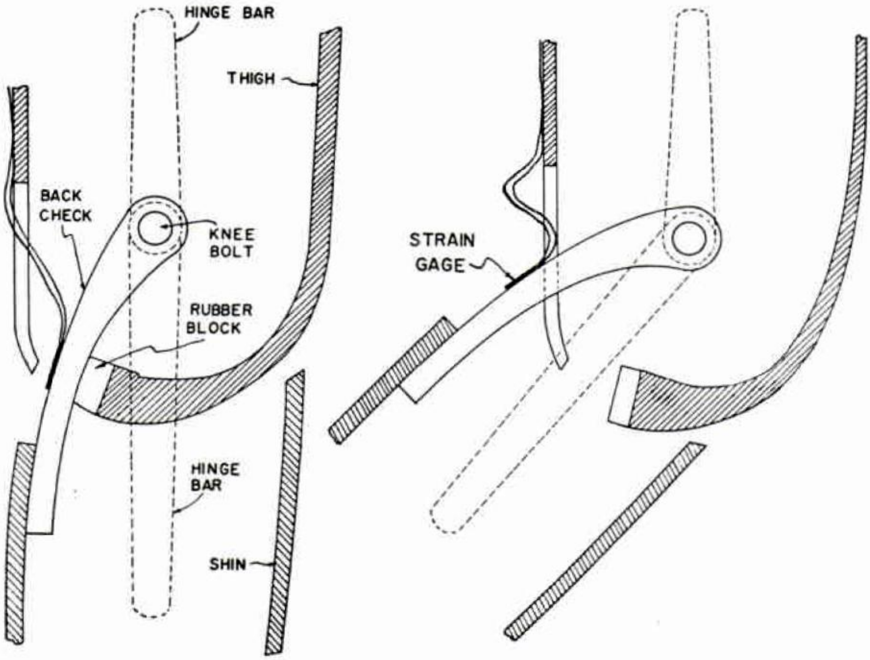


Fig. 1

in the leg, so the amount absorbed by the bumper is small in comparison.

The artificial leg we tested has a knee friction device that could be adjusted from no friction to enough friction to lock the knee.

With the friction device set for no friction, the average load on the back check was 127 pounds from the 45 degree position and 329 pounds from the 90 degree position.

With the friction device set in the normal position of a slight amount of friction, the average load was 61 pounds from the 45 degree position and 261 pounds from the 90 degree position. (See Table I).

The writer believes that the values obtained from the 45 degree position probably correspond to the values obtained during use of the leg, and expressed this opinion in a letter to at least one person who inquired about the impact load at the end of the swing phase.

The only sure proof of how much load is imposed on a back check is by actually testing a leg worn by a patient. This was done by installing the same back check in an above-knee artificial leg worn by Mr. B., an experienced bracemaker from Pittsburgh, who weighs 200 pounds. Mr. B. has been regularly wearing an artificial leg with one of our experimental aluminum back checks. He had broken several malleable cast iron back checks prior to wearing the aluminum model. His leg has a knee friction control built in and he uses this friction control.

Tests were conducted with the patient walking normally, walking very fast, walking up a 10 degree slope, and carrying a 75 pound weight in his arms.

Ordinary walking put a 37 pound load on the back check due to the impact at the end of the swing phase. The push-off phase gave 260 pounds for the first step and then settled down to 185 pounds after three or four steps.

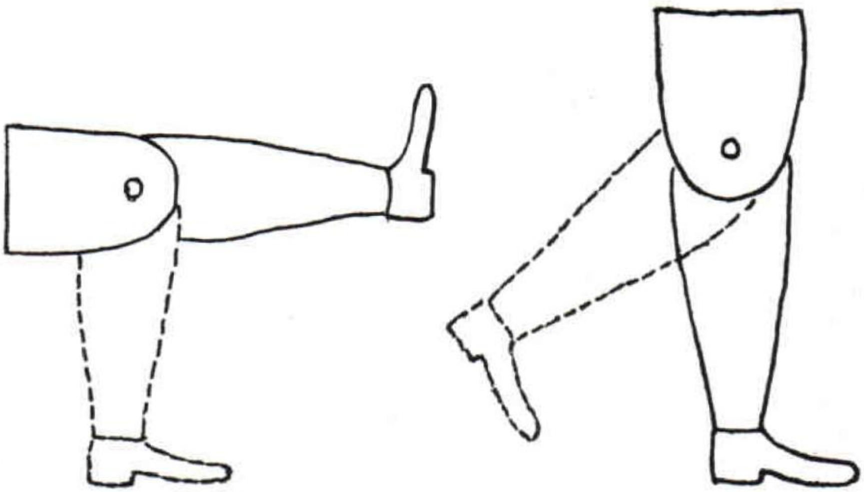

Fig. 2. Left: 90° Shin Drop. Right: 45° Shin Drop

Fast walking put a 74 pound load on the check due to the impact at the end of the swing phase and a 224 pound load due to the push-off phase after three or four steps. The initial step caused a 335 pound load due to the push-off phase.

Walking up a 10 degree slope caused a load of 444 pounds during the push-off phase. There was no load due to impact at the end of the swing phase.

Carrying a 75 pound weight cradled in the arms resulted in a 370 pound load on the push-off for the first step, reducing to 225 pounds after a few steps. The load due to impact at the end of the swing phase was 37 pounds.

During the test the patient walked about ten steps in one direction and then turned and walked the opposite direction. The process of turning around placed a load of 300 pounds on the back check.

While walking normally, the patient gave the shin an extra hard kick to see how much load would result at the end of the swing phase. The load was 112 pounds. The patient also stood on his good leg and deliberately whipped the artificial leg back and forth. This resulted in a 370 pound load. The noise from the impact was quite loud, and no leg would take much of this kind of mistreatment, although the back check itself could easily withstand much higher loads.

Normal walking was at an average rate of 80 steps per minute and fast walking at an average rate of 100 steps per minute.

## III. Conclusions

The results of the tests were as we had expected. The load caused by the impact at the end of the swing phase was low in comparison to the loads caused by the step-off phase.

The amount of energy involved in the swing phase of walking would probably be enough to eventually damage the back check by a combination of impact and fatigue if all of this energy were absorbed by the back check. Fortunately, so far as the back check is concerned, most of the energy is absorbed by other parts of the leg and by the stump of the person wearing the leg.

The amount of energy that a body absorbs depends upon its volume, its material and the amount it is stressed. The larger the volume the more energy a body can absorb. If the body is made of a material that is easily deflected, it will absorb more energy than one made of material harder to deflect. The wooden shin

## TABLE 1

| BUMPER MATERIAL | POSITION OF SHIN | KNEE FRICTION DEVICE | MEASURED LOAD (POUNDS) |
|---|---|---|---|
| FELT | 45° | FRICTION | 94 |
| FELT | 90° | FRICTION | 260 |
| FELT | 45° | NO FRICTION | 150 |
| FELT | 90° | NO FRICTION | 300 |
| PLASTISOL | 45° | FRICTION | 38 |
| PLASTISOL | 90° | FRICTION | 242 |
| PLASTISOL | 45° | NO FRICTION | 112 |
| PLASTISOL | 90° | NO FRICTION | 334 |
| RUBBER | 45° | FRICTION | 50 |
| RUBBER | 90° | FRICTION | 280 |
| RUBBER | 45° | NO FRICTION | 120 |
| RUBBER | 90° | NO FRICTION | 353 |

has a large volume in comparison to the back check and wood deflects easier than aluminum. Even if the shin were made of aluminum, its volume would be larger than the back check and its deflection would be larger than the comparitively short, stiff back check.

The standard Engineering Handbooks list different materials and how much energy a certain volume of each material can absorb. These tables show that a good grade of steel can absorb more energy than aluminum, and that aluminum absorbs more energy than wood. This is true because the allowable stress is higher for steel than for aluminum, and higher for aluminum than for wood. What must be realized is that these tables show *capabilities* of absorbing energy; no material absorbs energy unless it is stressed. The supports for the back check deflects enough that the back check is not stressed very much and so does not absorb much energy, even though it is capable of absorbing more than it does. Thus, if a bar of aluminum is supported at each end by blocks of steel, a weight dropped on the aluminum may break it. If the same bar of aluminum is supported at each end by large blocks of rubber, the same weight dropped on the aluminum will not break it. The rubber supports will absorb most of the energy.

This is quite similar to the soft tires, soft springs and soft seat cushions in a car absorbing energy so the passenger will not receive sharp jolts when a car hits a bump.

One other engineering fact keeps the impact load on the back check low, and that is the location of the center of percussion of the shin piece. This can be explained without defining the actual "center of percussion" by comparing the shin piece to a baseball bat. To be a good solid hit the ball must strike the bat at the center of percussion, located out on the thick part of the bat. If the ball hits the bat on the handle, a weak hit results and the hands sting. Similarly, the center of percussion of the shin piece is located down near the ankle. The back check and rubber bumper hit up near the knee bolt, resulting in a weak hit on the back check and a jolt on the knee bolt.

Because the distance from the knee bolt to the bumper was two inches and the maximum load measured on the back check was 444 pounds, the maximum moment at the knee was 888 inch-pounds while walking up a 10 degree ramp. Ordinary walking produces a 370 inch-pound moment at the knee. These tests give some indication of the loads on a back check and the moment at the knee. The loads vary with people, depending upon body weights and walk.