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# Clinical Experience with Epiphyseal Stapling

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## *ABSTRACT*

For the correction of leg length discrepancy in children, epiphyseal stapling was done for 41 epiphyses on 25 cases. The time of the stapling operation was chosen by using the chart of Green and Anderson, so that the leg length would be equal automatically at the end of epiphyseal bone growth. In this way an operation to remove the staples according to Blount's method was eliminated, an operation which usually injures the epiphyseal cartilage and often results in angular deformities. Also it eliminated the fear of retarding or stopping epiphyseal bone growth after holding the epiphyseal plate by staples for a long period.

All 3/64 inch and some of the 5/64 inch rod staples were broken, and the rest of the 5/64 inch rod staples were widely open. Therefore, in the later period of this experiment, the authors used three 7/64 inch rod staples as a unit. Because the staples are to resist continuously the tremendous growing power of the epiphysis, danger always exists until growth ceases. Therefore, selecting staples with adequate strength and conducting close follow-up studies at frequent intervals are very important in preventing complications.

In the average period of observation of 3 years and 2 months, the average discrepancy of leg length was decreased from 6.5 cm to 2.3 cm instead of the gradual increase that occurs in untreated cases.

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## *INTRODUCTION*

Correction of inequality of leg length has been one of the major problems for orthopedic surgeons for many years. Any discrepancy of an inch or more in leg length means disability. Prior to the use of anesthesia and modern surgical technique, we could compensate for the discrepancy by the use of an elevated shoe or some type of prosthetic device. Thereafter, either the shaft or the epiphysis became the site of approach for surgical correction of unequal leg length. Today four approaches are available for leg length equalization: shortening of the longer leg, lengthening of the shorter leg, inhibiting the epiphyseal growth of the longer leg, or stimulation of the epiphyseal growth of the shorter leg.

In 1845 Rizzoli obtained shortening of the leg by osteotomizing the shaft of the femur and overriding the fracture ends. Other surgeons followed with repeated successes in correcting inequality by this operation.

From the point of functional and cosmetic results, the lengthening of the shorter leg is more ideal than shortening of the good leg. Also it is disturbing to both the patient and surgeon to propose an operation on the good leg. Many surgeons attempted lengthening of the short leg rather than shortening of the long leg.

In 1905 Codivilla performed an osteotomy and obtained considerable lengthening of the affected leg by traction. However Codivilla and others pointed out that it is relatively easy to obtain as much as 4 cm. lengthening of the femur, but it is difficult to obtain as much lengthening of vessels and nerves as of the femur itself without untoward symptoms. Paralysis, deformities, infection and many other tragic complications followed attempts to do so. Consequently, for many years this lengthening method was almost completely abandoned. However, in 1936, Abbott and Saunders (1936) developed an extensive technique for leg lengthening. This was soon discarded however because of the danger of vascular and nerve complications, paralysis, nonunion, deformities, and even loss of the leg. Today most orthopedic surgeons believe that the shortening of the longer leg is a less extensive procedure, is less dangerous and more accurate.

When bone growth is complete, bone lengthening or shortening is done by operation directly on the shaft of the bones. However, if the patient is a growing child, we may control bone growth by operation on the epiphysis. The ideal treatment is the stimulation of the epiphysis of the short leg. No technique has been developed to the present time that will give consistently predictable results. Hutchinson (1954) observed that stasis of blood circulation resulted in stimulation of bone growth in animal experimentation. On the assumption that the increased blood supply would stimulate epiphyseal growth, Harris (1930) in 1930, performed lumbar sympathectomy on the side of the shortened leg. Shands, in discussing a paper of Pease (1952), pointed out that this might be practical if there is some clinical evidence of associated vasomotor disturbance like wet and cold skin. This procedure generally produced so little stimulation that it was soon abandoned. Further attempts were made to stimulate epiphyseal bone growth by periosteal stripping and fracture. But because of variable results, this approach was also discarded. Very recently, Pease (1952) and Wilson (1952) found that they could stimulate epiphyseal bone growth experimentally and clinically by inserting metal or ivory bolts or screws into the metaphysis near the epiphyseal plate. It is too early to come to a definite conclusion at the present time, but the results from this method are promising.

On the other hand, arrest of epiphyseal bone growth has been accomplished in many ways. In 1888 Ollier was the first to inhibit epiphyseal growth by destruction or excision of the epiphyseal cartilages in the correction of varus deformity of the ankle. In 1932 Phemister (1932) reported the method of arrest of longitudinal growth of bone by epiphyseometaphyseal fusion at an age which would result in an approximately equal leg length at the end of the growth period. This approach was the most scientific and the least hazardous of all attempts to date. This operation was of less magnitude than any other previously described procedure, and was carried out with relatively little risk of complications. Phemister at that time used as a guide for the time of surgical intervention a chart of expected growth of the good leg. Later, many orthopedic surgeons (1936, 1946, 1945) reported that the failure to stop the growth on one side of the bone caused angular deformity; and mistakes in estimating the future growth resulted in inadequate or excessive correction.

To arrest the epiphyseal longitudinal bone growth in the long or normal leg so as to have it the same length as the short leg when growth is complete, an accurate prediction of the future growth of the bones is required in order to determine the time for operation. Baldwin and Hatcher (as quoted in Campbell's Operative Orthopedics, 1954), Gill and Abbott (1942), Green and Anderson (1947), and Stinchfield et al. (1949), have contributed growth studies and have compiled growth tables and graphs. Determination of the patient's bone maturation age (1937) together with accurate measurement of leg lengths (1954, 1940) are required, and from these bone growth charts the prediction of future growth can be determined.

Another method was proposed to retard epiphyseal bone growth. This was by x-ray irradiation (1943). This was popular for a short period of time, but was soon discarded because the result was uncertain and because of fear of complications in the soft tissues in the growing child.

In 1945, Haas (1948) discovered the very important principle of temporary arrest of the epiphyseal plate first in laboratory animals and later in children, and proved that in both the longitudinal growth at an epiphysis could be mechanically stopped and that growth was resumed when a wire binding the metaphysis to the epiphysis was broken or removed. This opened a new field of endeavor.

Haas' study stimulated Blount to approach the problem of mechanical arrest of epiphyseal growth by placing stainless steel staples across the epiphyseal plate. Since the report of Blount (1949, 1952) describing this most valuable aid in the correction of leg length discrepancy, interest in the procedure has been widespread.

We became interested in the procedure at the Jersey City Medical Center after Blount and Clarke (1952) described it in 1949, and this report is concerned with experiences in epiphyseal stapling gained from July, 1951, to June, 1956.

## *FINDINGS*

**General Findings:**

At the Jersey City Medical Center, 43 epiphyseal arrests on 27 cases were done over a 5-year period. Of those 27 cases, there were 2 epiphyseodeses by Phemister's method in 2 cases, and 41 epiphyseal staplings in 15 cases. In 16 cases of tibial epiphyseal arrests, the fibular epiphysis was curetted in 14 cases, was stapled in 1 case, and in 1 case there is no record.

In general, the operative procedure described by Blount (1949) has been followed (Fig. 1). The procedure in each case was carried on under x-ray control. During the operation, correction or replacement of the position of the staples was repeated until the x-ray showed it to be satisfactory. There was no particular postoperative reaction except in cases where there was longstanding tenderness in the knee. These we will describe below.

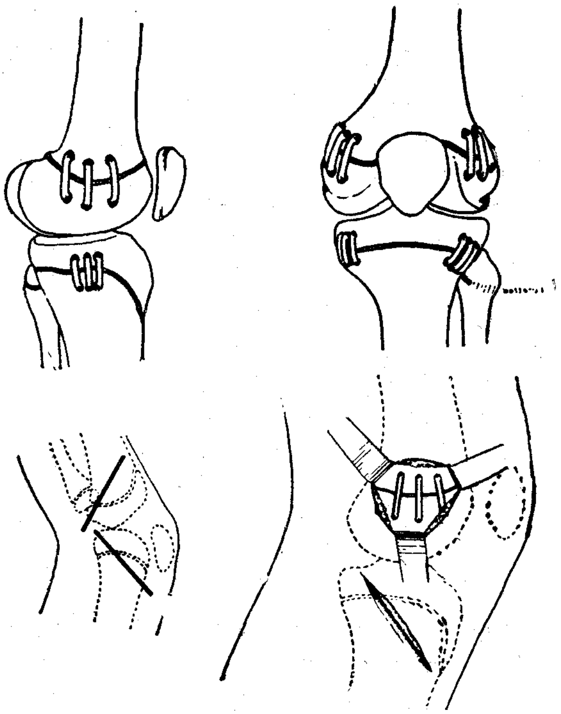

**Fig. 1.** Blount's Operative Procedure (from Blount W. P.: J. B. J. S., 31-A: 464)

In 25 cases, 41 epiphyses were stapled. There were stapling procedures done on both distal femoral and proximal tibial epiphyses at the same time: 8 on the distal femoral epiphyses only and 1 on the distal tibial epiphysis only.

**Table 1.** Sites of Stapling

| | |
|---|---|
| Both Distal Femoral and Proximal Tibial | 16 |
| Distal Femoral Only | 8 |
| Distal Tibial Only | 1 |

Fourteen patients were males and 11 were females. In 13 patients, the procedure was done on the right leg and in 12 patients, on the left.

**Table 2.** Incidence

| | | | |
|---|---|---|---|
| Males | 14 | Stapled on Right Leg | 13 |
| Females | 11 | Stapled on Left Leg | 12 |

Leg length discrepancy among 25 patients was due to poliomyelitis in 14, congenital shortening in 4, infectious process in 3 (tuberculosis 1, osteomyelitis 2), premature fusion in 2 (traumatic 1, cause not known 1), postdiphtheritic paralysis in 1, and osteochondroma in 1.

**Table 3.** Cause for Inequality

| | | | |
|---|---|---|---|
| Poliomyelitis | 14 | Premature Fusion | |
| Congenital Shortening | 4 | Traumatic | 1 |
| Infectious Process | | Cause Not Known | 1 |
| Tuberculosis | 1 | Postdiphtheritic | 1 |
| Osteomyelitis | 2 | Ostechondroma | 1 |

The average age of the 25 patients was 11 years and 9 months at the time of stapling; the male verage was 12 years old, and the female was 11 years and 7 months old. The average age at the time of last examination of the 25 patients was 15 years and 2 months; the male average was 15 and 1 month, and the female was 15 years and 3 months. The average period of observation after stapling was 3 years and 2 months. The longest period of observation was 5 years and 6 months, and the shortest period was 10 months.

**Table 4.** Average Age

| At Stapling | At Last Examination |
|---|---|
| Total.........11 9/12 years. | 15 2/12 years. |
| Male .........12 years. | 15 1/12 years. |
| Female......11 7/12 years. | 15 3/12 years. |
| Average Period of Observation......32/12 years. | |

Green and Anderson (1947) pointed out in their study that epiphyseal growth ceases at the age of 15 and 3/4 years in males and 13 and 3/4 years in females, on the average. The average age of the female at the time of last examination was past this period, and for the male was very close to it. This report therefore approximates an end-result study.

The oldest age at the time of stapling was, in the male, 14 years and 9 months, and in the female, 13 years and 7 months. Therefore, in these 2 patients, little was to be gained by stapling, because it was done so late. On the other hand, the youngest at the time of stapling was 5 years and 1 month in a male, and 5 years and 2 months in a female. These two are improving satisfactorily, and it is planned to remove the staples in these two cases when the lengths become equal.

If we exclude the two cases immediately above, the youngest at the time of stapling was 10 years and 3 months in the male and 10 years in the female. The oldest age at the time of last examination was 19 years in the male and 19 years and 1 month in the female. The youngest age at the last examination was 7 years and 2 months in the male, and 6 years and 10 months in the female. These last two patients are those same exceptions noted above.

If these two extreme cases are excluded, the youngest age at the last examination was 11 years and 9 months in the male and 13 years in the female.

According to Haas (1945) and Blount (1952), the stapling procedure should not be done before sufficient ossification of the epiphysis has taken place; i. e., after about 8 years of age. Two of this series were done before the age of 8 years; one is now 2 years and 1 month, and one is 1 year and 8 months after the stapling operation respectively. In both, the staples are in good position, and 1 inch in one, and 3/4 inch in the other, has been gained in correction.

According to the charts of Gill and Abbott (1942) and Green and Anderson (1947), the age between 9 to 11 years is the most active growing period. Some authors (1949, 1952, 1954) have suggested that stapling should be done while there is still sufficient growth potential remaining to permit correction of any inadvertent angular deformity resulting from improper placement or use of the staples. Furthermore, if stapling is done early, it eliminates the necessity of calculating future growth because we anticipate removing the staples when the leg lengths are equalized.

On the other hand, Phemister (1932) in his paper noted that there is a tendency to interfere with or even to stop permanently the epiphyseal growth if the epiphyseal plate has been held more than 2 years. In most of the cases in this series, the stapling time was determined from the chart (1942, 1947) of expected growth. The time was chosen so that at the end of growth of the epiphysis, the leg lengths would be equal. In consideration of Phemister's warning, there was some doubt as to what would happen to the growth of the extremity operated upon after the staples were removed. In addition to that there is the risk of injury to the epiphyseal plate at the time of removal of staples.

This doubt was likewise eliminated by timing the Procedure so that removal of staples would likely be unnecessary. There has not been any instance of removal of the staples in this series because of equalized leg length before the epiphyseal growth ceased.

**Specific Findings:**

Ten cases in a group in this series have not yet completed their growth. Fifteen cases in another group had completed their epiphyseal growth at the last examination. The first group had 1 inch of average discrepancy at the last examination, with the least, 1/2 inch, and the greatest, 2 inches. This group has a remaining period for growth arrest of 1 year and 11 months on the average, with the least, 9 months, and the greatest, 4 years (excluding the two patients of 6 and 7 years). The residual difference of the second group (excluding the 2 cases of overcorrection) averages 0.7 inch, with the least, 0, and the greatest, 2 3/4 inches. This residual discrepancy

**Table 5.** Results

| | |
|---|---|
| Ⅰ. Cases in which Epiphyseal Growth is Not Completed | 10 cases |
| 1. Average Discrepancy at the Last Examination | 1.0 inch |
| Greatest | 2.0 〃 |
| Least | 1/2 〃 |
| 2. Average Remaining Period for Growth Arrest (Including 2 patients noted above 6 and 7 years old) | 3 3/12 yrs. |
| Greatest | 7 7/12 〃 |
| Least | 9/12 〃 |
| 3. Average Remaining Period for Growth Arrest (Excluding 2 patients noted above 6 and 7 years old) | 1 11/12 yrs. |
| Greatest | 4 〃 |
| Least | 9/12 〃 |
| Ⅱ. Cases in which Epiphyseal Growth is Completed | 15 cases |
| Average Residual Discrepancy | 0.7 inch |
| Greatest | 2 3/4 〃 |
| Least | 0 〃 |
| Ⅲ. Average Leg Length Discrepancy of Total 25 Cases | |
| At Stapling | 1.9 inches |
| At Last Examination | 1.0 〃 |

indicates that the prediction of growth rate and the prediction of the time of cessation of growth was not accurate. This is one of the disadvantages of the prediction of these factors from statistical charts for the purpose of timing the staplings, though done in an effort to eliminate the necessity of having to remove them later.

In the cases reported, the average limb length discrepancy at the time of surgery was 1.9 inches, the greatest was 4 inches, and the least was 1 inch. At the time of the last examination the average limb length discrepancy was 1 inch, the greatest was 2 and 3/4 inches, the least was 0. This latter is in a male 15 years and 6 months old at the time of the last examination. There were 2 cases of overcorrection; one had a 1/2- inch, and the other had 3/4-inch of overcorrection at the time of completion of growth. One patient had not changed at all in leg length after the stapling procedure up to the last examination. This was in a female 13 years and 7 months old at the time of the stapling. The age in the female in which the epiphyseal growth ceases is considered to be 13 years and 9 months.

In this series, the average amount of correction of discrepancy of leg lengths was 0.9 inches; the most obtained was 2 and 1/8 inches; and the least obtained was 0. If the stapling operation had not been done, the limb length discrepancy during this observation period would have shown a gradual increase instead of a decrease of 0.9 inch.

To prevent overcorrection and also to prevent failure of epiphyseal arrest because of broken or open staples resulting from the epiphyseal growing power, frequent careful follow-up of the patients is very important. While other orthopedic procedures immobilize against muscle power, gravity and posture, the force in epiphyseal stapling is to counteract the continuous growing power at the epiphyseal line. This force continues until growth is complete and is very strong. Every stapled patient should be observed at least every 3 months until the epiphyseal growth has stopped, as shown by precise clinical examination and repeated roentgenological study. The prediction of the expected growth calculated from the charts is not an absolute value, but it is an approximation of the average. By close follow-up study at frequent intervals, the surgeon can calculate the individual epiphyseal growth rate and can determine beforehand the time at which the patient's leg lengths will be equalized.

No instance of postoperative specific reaction or any erosion of staples was noted, and there were four cases in which the x-ray pictures showed some increased density around the staples (Fig. 2).

There were 12 patietns who complained of pain in the stapled knee from the time of surgery to the

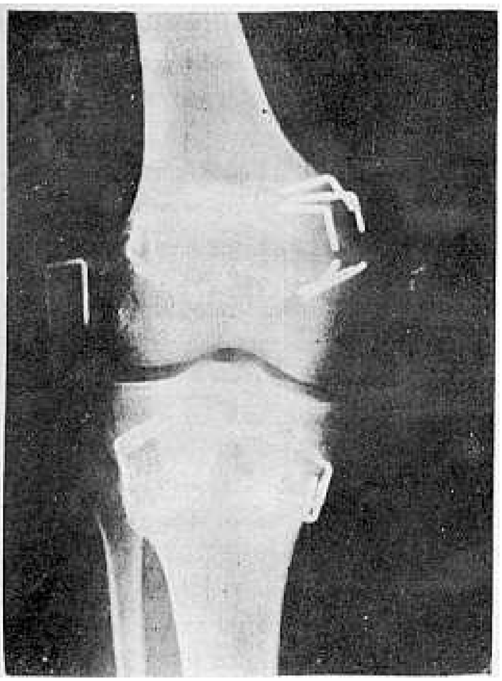

Fig. 2. Broken 5/64 Inch Rod Staples, Increased Density around the Staples, and Continuous Epiphyseal Growth after the Staples were Broken.

last examination. Following stapling the final complaint of pain in 6 cases was after one year, in 2 cases after 3 years, 3 cases after 4 years and 1 case 5 years after stapling. Thus there is a tendency for pain to subside spontaneously over a period of time. The pain was usually localized at the medial side of the stapled knee, particularly at the medial femoral epicondyle. This apparently was aggravated by full flexion and by exercise of the knee. One patient (Fig. 3) had stapling on February 28, 1950. Postoperative x-ray pictures showed some increased density around the staples, and about 1 and 1/2 years after the operation there appeared 2 small radiolucent areas, one in the medial femoral, and another one in the medial tibial condyle. The patient had been complaining of some discomfort at the medial femoral condyle since the operation, with 2 acute occurrences. Operation on October 27, 1955 revealed localized infection at one point of one staple in the medial femoral condyle and at one point of one staple in the medial side of the tibia. All 12

Fig. 3. Slightly Increased Density around Staples which are in Good Postion, with Two Small Radiolucent Areas Showing Abscesses in the Medial Femoral and Medial Tibial Condyles.

staples were removed. This exemplifies a localized bone infection from the staples. Blount (1949) mentioned that if movable fascial layers are impaled by the staples, there would be postoperative pain, swelling and limitation of motion; and warned that the soft parts should be divided down to the periosteum. If compression of undivided soft parts under the staples is the cause of pain, we would expect it to occur equally at each site of stapling. In view of the frequent occurrence over the medial condyle in this series, we suggest further study to determine the cause and to find means to avoid the longstanding postoperative pain in the medial side of the knee.

Four back-knees, three knock-knees, and three bowlegs have developed in this series. All those who had discrepancy in leg length at the time of the last examination had compensatory scoliosis with a tilted pelvis. The angular deformities of the stapled legs were caused by broken or spread staples. Blount (1952) and Brockway et al. (1954) pointed out the difficulty of inserting staples in the posterior knee as a cause of back-knee deformity. Three of the above mentioned 10 cases were so angulated that they had to be corrected by removal or replacement of staples before the epiphyseal line closed. The remaining 7 cases were not so seriously deformed, and they were all very close to or had passed, the

**Table 6.** Complications

| | |
|---|---|
| Postoperative Longstanding Pain | 12 |
| Angular Deformities | |
| Back-knee | 4 |
| Knock-knee | 3 |
| Bow-leg | 3 |

age of the epiphyseal closure, so that no further corrective surgery was necessary.

Blount (1949) suggested using 3 staples as a unit, and this was our procedure in 39 staplings. We used 2 staples as a unit in 2 cases. A total of 235 staples were used on 41 epiphyses in 25 cases. By roentgenological study at the time of the last examination, 50 (21.3%) of 235 staples were not holding the epiphyseal plate; 22 of these staples were widely open, and the remaining 28 staples were broken.

**Table 7.** Status of Staples

| | |
|---|---|
| Unit of 3 Staples Used | 39 |
| Unit of 2 Staples Used | 2 |
| At the Last Examination | |
| Intact | 185 |
| Widely Open | 22 |
| Open and Broken | 28 |
| 5/64 Inch Rod Staples Used...39, | Broken...5(of these 3 were replaced) |
| 3/64 Inch Rod Staples Used......2, | Broken...2(of these both were replaced) |

Two kinds of staples were used in this series, 5/64 inch rod staples in 39 epiphyseal arrests, and 3/64 inch rod staples in 2 cases. In the former group, there were 5 cases of broken staples, 3 of which were replaced (Fig. 4). Of the other 2 cases where 3/64 inch rod staples were used, one showed 10 of 12 staples broken (Fig. 2) and the other showed 1 of 12 staples broken (Fig. 5).

These had to be replaced. Of the 5 cases which had replacement of staples because of breaking, 3 developed significant deformities. The remaining 2 cases did not develop any deformity, but because of the probability that deformity would occur during the subsequent period of growth, the replacements were done. Such development of deformities because of broken or open staples indicates that the orthopedic surgeon needs to consider carefully the strength

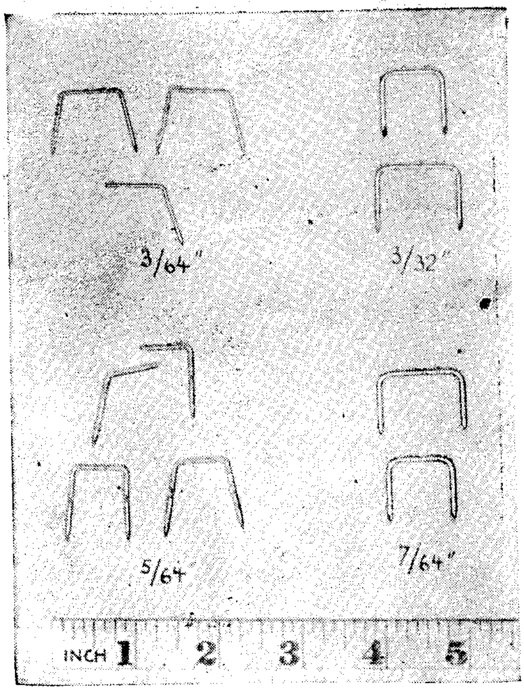


**Fig. 4.** Some of the Removed Staples. and 7/64 Inch Rod Staples for Our Present Use.

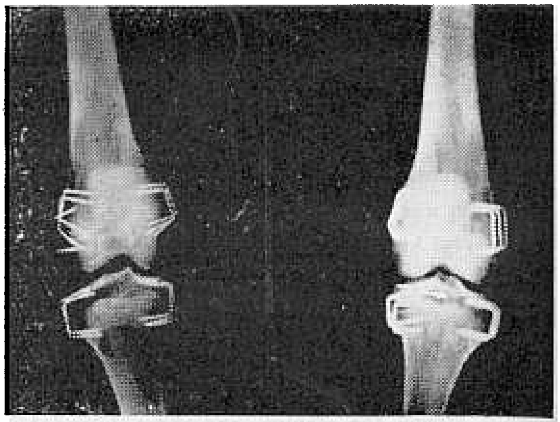

**Fig. 5.** A Case on Which 7/64 Inch Rod Staples were Replaced because the 3/64 Inch Rod Staples were Broken and Open, and Developing Bow-leg.

of the staples used. Since this series, we have used 7/64 inch rod staples, because of our experience with the 5/64 inch rod breaking.

Strobino et al. (1952) observed in their animal experiments that a force in excess of 120 pounds is required to stop the growth of an upper tibial epiphyses in a calf. They showed in their experiments that the epiphyseal growing power was in excess of the weight of the animal, which is more than 400 pounds. Haas (1945) in 1945 stated in his paper that the force exerted by the growth of the epiphyses in the lower extremities in the erect position is strong enough to raise the weight of the body, as well as to overcome muscle tension. Blount (1952) showed that if one staple was driven in a calf bone or in a 12-year old human bone, a distraction force of 80 pounds would cause the staple to tear out. To break a staple, 900 pounds of pull was required. A single staple was broken repeatedly in the growing child. Blount (1952) added that this amount of force develops as the result of the biologic factor of growth of the epiphysis. The force of the epiphysis which in growth pushes the epiphyseal cap away from the metaphysis is great, and the staples must be strong enough to counteract this strong force. Thus this growth force of the epiphysis must be understood by the surgeon when he chooses the staples to check epiphyseal growth.

## *CONCLUSIONS*

1) The literature regarding correction of inequality of leg length was reviewed.

2) A total of 41 epiphyseal staplings on 25 cases was done. In most of the cases in this series, the time of the stapling operation was chosen so that at the end of growth of the epiphysis, the leg lengths would be equal.

3) In the average period of observation of 3 years and 2 months, the average discrepancy of leg length was decreased from 1.9 inches to 1 inch.

4) To prevent angular deformity or overcorrection of the leg, close follow-up study at frequent intervals is necessary.

5) Many patients complained of pain in the medial side of the stapled knee following surgery. Further study is suggested to determine the cause of this.

6) The fact that the epiphyseal growing power is so great that it can break the staples must be understood by the surgeon when he selects the staples to use.

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