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To demonstrate this effect we proposed a mathematical calculation of the pressures in the two compartments of an equation with intake pressure as a function of mechanical displacement of the center of the knee.

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Strictly as per the compliance and regulations of:

The Equation of Charges in the Genu Varum and after Valgus Tibial Osteotomy: Mathematical Study

Mardy Abdelhak [α], Bouziane Ahmed [σ], Elidrissi Mohammed [ρ], Shimi Mohammed [Ѡ], Elibrahimi Abdelhalim [¥] & Elmrini Abdelmajid [§]

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I. Introduction

Internal tibial knee femoropopliteal occupies a privileged place in clinical Its treatment is not unique and requires a comprehensive care of the patient and should take into account the demands of it in terms of activity.; it to select relevant manner the most suitable solution. So; The purpose of this theoretical study is to evaluate the distribution of femoro tibial constraints imposed by a tibial osteotomy. The surgical treatment of knee osteoarthritis can be conservative (arthroscopic surgery, osteotomy) or prosthetic (unicompartmental arthroplasty or tricompartimentaire).

The tibial osteotomy proposed by JACKSON 1958 (1) be guided by technical inter trochanteric osteotomy and aims to correct a default axis.

Understanding of the biomechanics of the knee in the frontal and sagittal plane is essential for understanding the effects of osteotomy.

The Biomechanics of the knee bumped firstly modeling the forces applied to it; due to the large number of muscles acting on the knee for balance All the proposed models based either on an indirect measure of MORRISON (2); either on a mathematical analysis of MAQUET (3).

The study of surfaces and pressures Contact femorotibial uses many methods:

- either by indirect radiographic method (Kettelkamp (4); MAQUET (5) photo- elastic models (RADIN) (6) strain gauge (BOURNE (7); BLAIMONT (8).

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- is direct: in this case; it is used many methods some of which are used to assess simultaneously the surface and the contact pressure (FUKUBAYASHI (9)) .

So; The purpose of this theoretical study is to evaluate the distribution of femoro tibial constraints imposed by a tibial osteotomy.

This study has two areas of interest:

- Pathology or purpose is to observe the changes induced by the genu varum pressures.
- therapeutic: the study of changes in femorotibial constraints depending on the tibiofemoral angle trying to clarify the degree of valgus overcorrection that must be made for the osteotomy is effective.

II. Material and Methods

It is work of study and research based on mathematical theorems and concepts of solid state physics and geometry. Applications were made on models X-ray goniometer of any member in the surgical patients; in the service of Orthopaedic Surgery B4; for tibial osteotomy by internal opening technique.

a) *Methodology for calculating*

i. *Theoretical Analysis of stresses in the genu varum*

a. *Moving force R*

A decrease in strength L; that is to say a release of the lateral muscles Figure 17 (a); moves the line of action of the resultant R within. At the same time; the direction of R is slightly closer to the vertical. Increased weight increases the force P. If it is not offset by a corresponding increase in muscle strength L; it causes the same result fig17 (b). When; as can be seen at menopause shroud L muscle relaxes along the weight P increases, the displacement of the load R is even greater in Fig (c).

Moved in; load R causes stress concentration compression joint are greatly increased in that the medial knee (fig. 18)

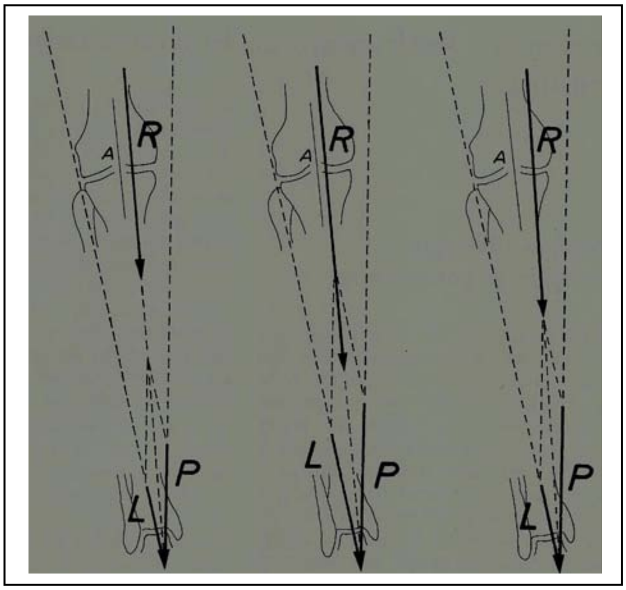


Figure 17 : Moving the resultant R (MAQUET)

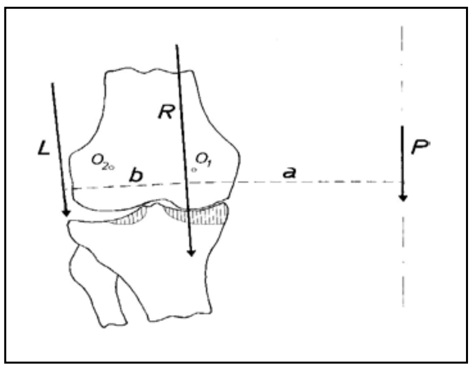
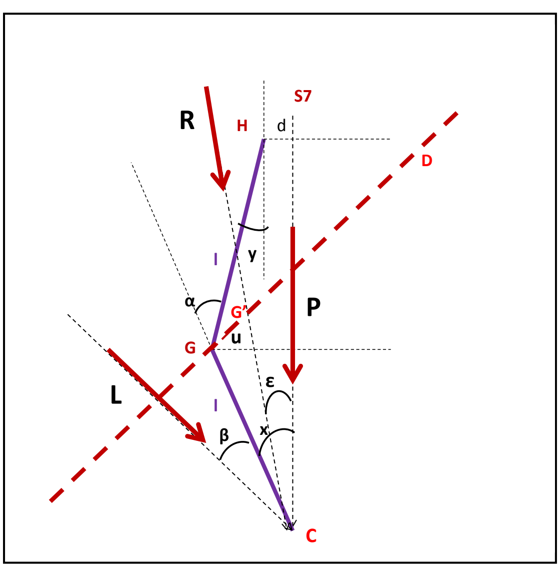


Figure 18 : Elongation of the lever arm (a) of the force P. Concentration of stresses in the medial part of the knee (MAQUET)

b. *Evolution of the joint constraint*

The magnitude and line of action of the force R is stylized in Figure 19



H: center of the femoral head
G: center of the knee
C: center of the ankle
Force P lowered S7 partial gravity center
The angle x that makes the tibia with the vertical
The angle that it makes with the vertical femur
The angle **α**: femoro tibial bypass
The **β** angle: The fact that the tibia
The angle **ε**: R makes with the vertical
D: map of the surface of the tibial plateau L:length of the femur and tibia
G ': the projection of G on the line of action of R
S7: center of gravity partial foot support

Figure 19 : Deformation in varum.la action line R intersects the axis of the knee in G 'at a distance u of G

From the previous scheme; the parallelogram of forces is constructed :(fig 20)
And shows that:

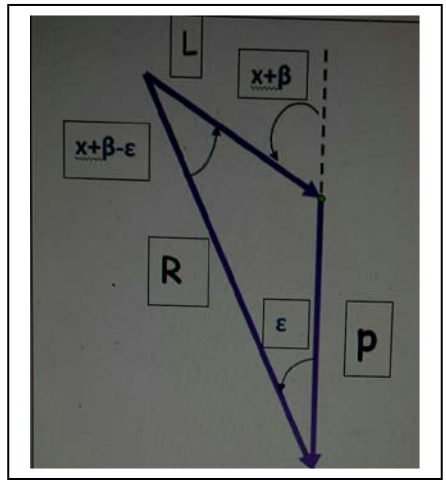
$$R = \sqrt{P^2+L^2+2PL\cos(x+\beta)}$$

$$L = P \frac{\sin\varepsilon}{\sin(x+\beta-\varepsilon)}$$

$$d = l(\sin x - \sin y)$$

$$\alpha = x+y$$

$$u = l.tg(x-\varepsilon)$$



To analyze the constraints of joint compression is considered in an orthogonal coordinate system (OX) and (OY); an area of study through the contact plane femoro tibial (D) in Figure 20;

This plan, which makes an angle **α** equal to the angle of deflection femoro tibial; has different values of the displacement of mechanical center of the knee.

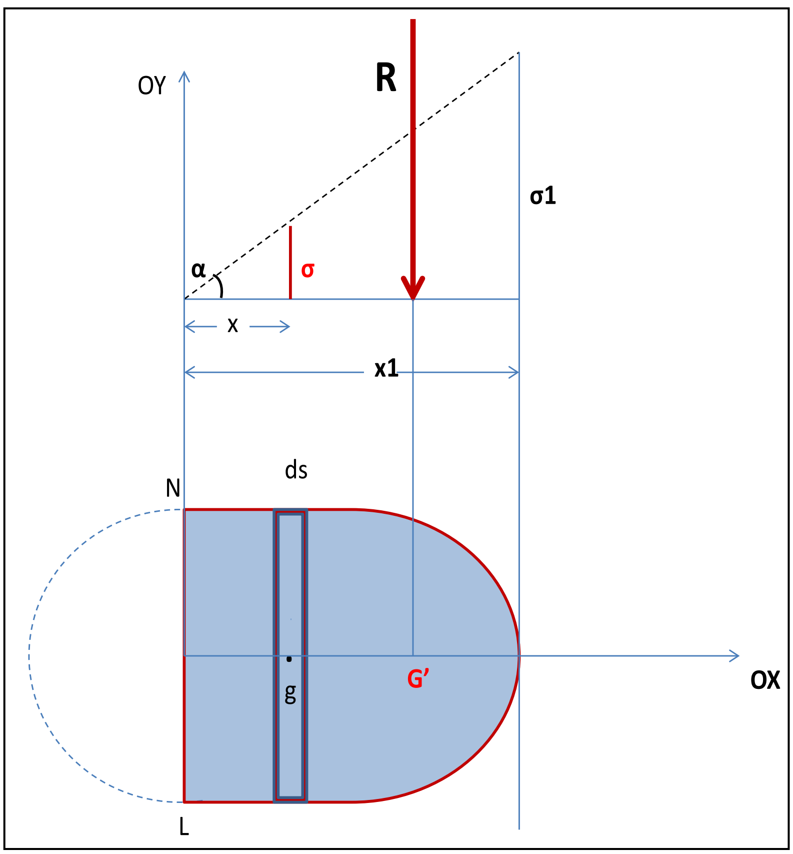


Figure 21 : Evolution of stresses as a function of displacement of the mechanical center

It is considered in this surface a scanning element ds having a center of gravity g that is moving in the axis OX

This surface element ds is affected by a strength member dr whose resultant is equal to R; This creates a compression $\sigma = dr / ds$

According to the scheme: $tg\alpha = \sigma / x$ with x the displacement of the center of gravity. Also: $tg\alpha$ $\sigma 1/x1$ with $x1$ = the maximum displacement and the maximum $\sigma 1$ applied to the edge of the contact surface stress . We deduce the equation of stress versus displacement of the mechanical center of the knee: $\sigma = x.tg\alpha$

The displacement of the mechanical center of the knee creates a non-uniform triangular distribution of joint stress with the presence of a line of zero pressure NL.

To derive the total stress in the surface of the contact femoro tibial; we must do the double integral of our equation:

$$\sigma.ds = \sigma 1.\ x/x1\ .ds = tg\alpha\ .x.ds$$

$$\iint \sigma.ds = \iint tg\alpha\ .x.ds$$

$$\iint \sigma.ds = \iint dr$$

$$\iint \sigma.ds = tg\,\alpha \iint x.ds = R$$

ii. *Calculate the effect of tibial osteotomy on the mechanical center of the knee*

The angular correction by tibial osteotomy creates an external mechanical displacement of the center of the knee fig. (22)

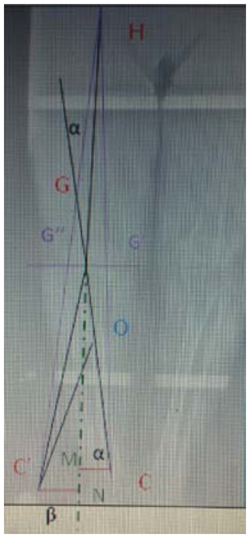
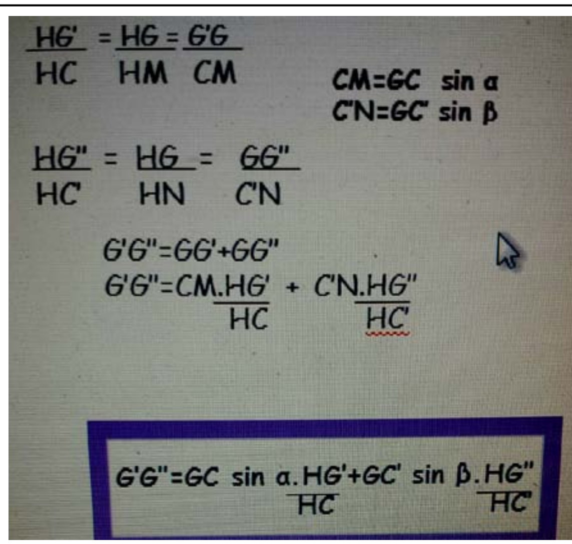


Figure 22

H: center of the femoral head
G: center of mass of the knee (anatomical center)
C: center of the talar ankle mortise
O: wedge osteotomy
G ': mechanical center of genu varum
'' G: mechanical center after correction
C ': center of the mortise after correction
α: angle deviation tibiofemoral
α + β: angle correction
M: projection of C on the perpendicular
N: projection of C 'on the perpendicular

To calculate the distance of movement of the mechanical center of the knee point G 'in G-spot"; Considering the triangles and HCM HC'N and include:



iii. *Analysis of the distribution of the stresses depending on the angle correction*

The study of the equation joint stress versus displacement of mechanical center of the knee helps to explain the stress increase if genu varum fig (23)

Moving within the mechanical center creates a concentration of charges in the medial compartment. Thus the goal of a tibial osteotomy is to transfer these loads externally according to the equation this equation:

$\sigma = x.tg(-\alpha)$

The mathematical approach to the stress distribution after a tibial osteotomy can be determined in the curve Figure (24) represents that the equation:

$\sigma = x.ch(\alpha)$

This curve is a parabolic representation of load variations; and when the mechanical center is moved in the x-axis to the left; constraints are reduced in this internal compartment is gradually increasing in the outer compartment.

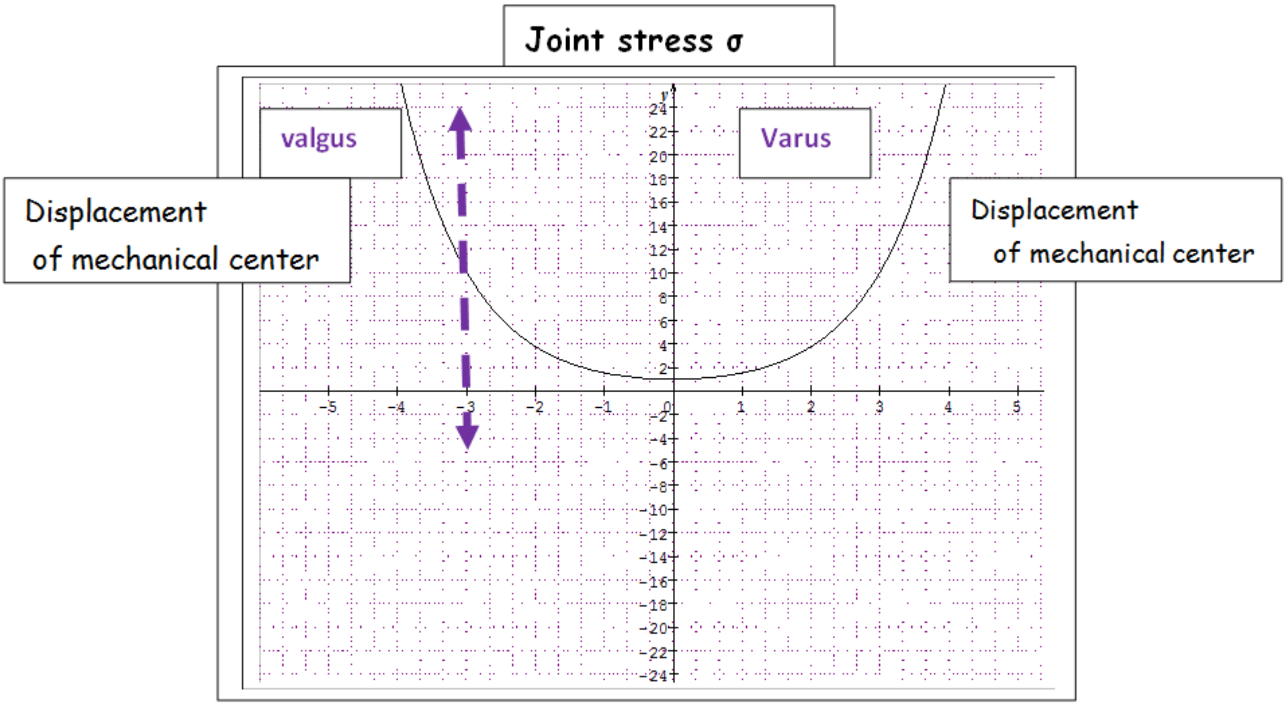


Figure 25 : Distribution of the stresses in the knee according to the deformation

It integrates the table of values of constraint equations with measurements of mechanical center; there is a knee in normo oriented ($\alpha = 0°$), the total stress is about 6.3 kg / cm ².

So; in the range (0° -6°) joint stress remains almost constant (Table Figure 26) and beyond (-6°) valgus; it increases rapidly to reach 26kg / cm ² which deteriorates the outer compartment.

Degree of correction	0°	-6°	-10°	-15°	-20°
joint constraint (kg / cm ²)	6.3	8.6	14.8	22.7	25.8

Figure 26 : Table of total joint stress variation as a function of degree of valgus

III. Discussion

a) Limit of the mathematical method

From the data of our study; analytic geometry and trigonometry used to deduce the magnitude and line of action of the forces on the knee situation foot support with the resulting R through the mechanical center of the joint.

This reasoning and mathematical formulas that can be applied to derive forces in the sagittal plane and during the various phases of walking.

The equation for the evolution of constraints based on the tibiofemoral angle and movement of the mechanical center allows one hand to explain changes in the distribution of joint stress due to permanent load shifting within the R during the genu varum, and demonstrates the effect of the correction on the angular distribution of the stresses after a unit OTV other.

This method of theoretical calculation has filled a default experimental studies of anatomical parts or synthetic model of the knee who were unaware of several factors involved in the balance of a normal subject or suffering from a deformity varus or valgus.

Among these factors; include the problem of the evaluation of the game and ligament quantification of muscular load acting on the knee . so; the results obtained are found not representative of the real state of affairs.

However; mathematical calculation is also not devoid of criticism because it ignores some data that make precision adjustments to make difficult; particularly in osteoarthritis; rotatory disorders; the existence of a femorotibial subluxation that make it difficult to calculate the mechanical center of the knee .

Other factors are related to the difficulty of quantifying the contact surfaces femoro tibial in vivo in a subject with a genu varum. The problem is further complicated by the presence of inaccuracies mathematical calculation related to errors in measuring the distance of movement of the mechanical center and the angle of femoro tibial deformity on goniometry because small changes can yield significant changes in constraints joint.

b) Overcorrection

Seems now generally accepted as critical success factor of the tibial osteotomy. Indeed; hindsight is sufficient and it is currently accepted that under correction is an important factor of recurrence of the deformity and pain relief.

i. *theoretical argument*

From our equation; valgus 3° to 6° concentrates the load in the lateral compartment which relieves the medial compartment. however; beyond this level correction; the evolution of constraints is exponential deteriorating external compartment .

ii. *Experimental argument*

If we consider that the origin of the internal genu varum gonarthrosis lies between another failure in the outer shroud; it is logical that BLAIMONT (14) has proposed a quantification of the correction to be made depending on the mechanical quality of the external shroud. This is determined by load testing cantilevered overhang. It is equal to the maximum load M (which still disappears external yawn) Load M multiplied by the lever arm b gives the muscle moment in physiological conditions must be equal to the moment gravity Pa BLAIMONT (14) is removed in the case of genu varum osteoarthritis ; muscle moment is significantly lower when gravity. MAQUET for (3) and BLAIMONT (14); it is therefore necessary for the normal axis hypervalgiser merely replace the joint in the same way as that in which developed osteoarthritis.

Kettelkamp and CHAO (17) determine on radiographs; the variation of the distribution of the contact force on the tibial plateau in accordance with the difference between tibial and femoral mechanical axis. For that; they establish a mathematical model for the purpose of simplification does not take into account; as a stabilizing element , the external and internal lateral ligaments; disregarding in the calculation of all muscle elements. In this model, the balancing constraints femorotibial a genu varum requires overcorrection of 3° to 6° of valgus.

KOSHINO scintigraphy noted a drop in the concentration of strontium in the inner compartment 85 a year after osteotomy when there is a hypervalgisation from 2° to 10°.

IV. Conclusion

Our work is a theoretical study; based on mathematical foundations; through which we could demonstrate that the angular correction by tibial osteotomy allows a charge transfer from the medial compartment to the lateral compartment.

Biomechanical goal of osteotomy is to reduce the unit pressure at the internal spacing tibiofemoral:

- reducing the overall tibiofemoral load in absolute value; by reducing the components of ground reaction by refocusing
- but also a better distribution of it between the two compartments; and within each compartment

This stress redistribution can only be obtained by transformation with overcorrection of varus to valgus.

Reference Références Referencias

1. JACKSON J.P.; WAUGH W. Tibial osteotomy for osteoarthritis of the knee. Acta Orthop. Belg.48:93-96; 1982.
2. MORRISON J Bioengineering analysis of force actions transmitted by the knee joint. Biomed.Eng.; 3:164-170;1968.
3. Maquet P. Biomécanique du genou: application à la pathogénie et au traitement chirurgical de la gonarthrose. Springer Verlag Ed.; Berlin Heidelberg;New-york;1977.
4. KETTELKAMP DB; CHAO EY A method for quantitative analysis of medial and lateral compressions forces at the knee during standing. Cling.Orthop.83:202-213;1972.
5. Maquet P. Traitement chirurgical de l'arthrose fémoro-tibiale Acta orthop.Belg.;48:172 -189;1982.
6. RADIN E.L;PAUL I.L.;LOWY M. Acomparison of dynamic force transmitting properties of subchondral bone and articular cartilage. J.Bone Joint Surg. (am);52:444-456;1970.
7. BOURNE R.B;FINLAY J.B.; In vitro strain ditribution in the proximal tibia :Effect of varus–valgus loading in the normal and osteoarthritic knee. Clin.Orthop.;188:285-292;1984.
8. BLAIMONT P.;BURNOTTE J.;HALLEUX P. Rôle des ménisques du genou dans la transmission des contraintes articulaires. Acta Orthop.Belg.;41:143-152;1975.
9. FUKUBAYASHI T.KUROSAWA H. The contact area and pressure distribution pattern of the knee-A study of normal and osteoarthritic joint. Acta Orthop. Scand.;51:871-879;1980.
10. F.PAUWELS Biomecanique de la hanche saine et pathologiqueSpringer Verlag Ed.;Berlin Heidelberg;New-york;1965.

11. BRAUNE W.; FISCHER O. The Human Gait Société de biomécanique 1936.
12. PAUL J.P Forces transmetted by joints in the human body Journal of biomech. 1980.
13. HARRINGTON I.J. A bioengineering analysis of force action at the knee in normal and pathological gait. Biomed.Eng.;11 :167.1976.
14. BLAIMONT P.;BURNOTTE J.;HALLEUX Contribution biomécanique à l'étude des conditions d'équilibre dans le genou normal et pathologique: Application au traitement de l'arthrose varisante. Acta Orthop.Belg;48:97-109;1982.
15. KUMMER B. Cinématique du genou Acta Orthop.Belg.1982.
16. Walker P.S ; ERKMAN M. The load –bearing area in the knee joint. J.Biomech.;5:581-585;1972.
17. KETTELKAMP DB.JACOBS AW. Tibio-femoral contact area-Determination and implication. J.Bone Joint Surg.(Am);54:349-356;1972.
18. RADIN E.L;DE LAMOTTE F.;MAQUET P. Role of the menici in the ditribution of stress in the knee. Clin.Orthop.;185:290-294;1984.
19. KOSHINO T.; Effect of weight bearing forces on healing process of tibial osteotomy in man observed through strontium-85 scintimetry. Clin.Orthop.; 78:286-156;1971.