Significance of the Rotational Axes of the Knee in Osteoarthritis

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ABSTRACT

An investigation of the effect of the osteoarthritis on the pathway of the instant center of rotation (ICR) of the knee joint was conducted using a video system, and a computer program developed specifically to calculate the centrode locations. Ten patients with osteoarthritis of the knee joint, and ten normal subjects were included in the study. All subjects performed the activity of getting in and out of a low height chair. The center moved 0.83 cm. in the X direction and 2.77 cm. in the Y direction in the normal group, and 3.27 cm. in the X direction and 1.45 cm. in the Y direction in the patients group. The differences in the locations of the centrodes at 15 degrees increments between the two groups were significant. This means the anterior-posterior (A-P) displacement of the tibia on the femur in the osteoarthritic patient is irregular. Treatment should focus on restoration of normal mechanics.

Key words: Knee motion, Osteoarthritis, Pathomechanics, Motion analysis, Video system.

INTRODUCTION

Active and passive movements of the knee depends on the interaction and integrity of the bony, and soft tissues structures. Knee movements are both translational, and rotational. The flexion-extension motion is predominant in most activities[1]. The axis of motion for flexion and extension of the knee changes along the arc of motion as points on the articular surfaces make contact[12]. The instant center technique can be used to describe normal and internally deranged knee joint surface motion[5,6,7]. Rolling and sliding occur concomitant with flexion and extension: the closer the instant center of rotation is to the contacting articular surfaces, the greater the rolling, the farther it is from the surfaces, the greater the sliding that takes place[8,9,12].
During motion the center of rotation moves, thus changing the existing relationships between the joints' bony and soft tissues which in turn affect the kinematics of the joint[11,13,17,18].

Osteoarthritis is generally accepted to be mechanically mediated disease process that has well-defined biomechanical, metabolic, and histologic manifestations[4]. The mechanical changes occuring in disease process could be quantified by the study of diseased knee joint surface motion. The purpose of this study was to locate the pathway of ICR of the osteoarthritic knee joint, and to determine the difference between its pathway, and that of normal knee joint; and to clarify the clinical relevance of the findings.

MATERIALS AND METHODS

Subjects :

Ten normal volunteers (8 males and 2 females) 20 to 40 years old (mean age 29 years, standard deviation, 6.48 years) participated in the study as the control group; and ten subjects (7 males and 3 females) 35 to 63 years old (mean age 49 years, standard deviation, 8.49 years) with confirmed knee osteoarthritis, voluntarily participated in the study.

Instrumentation :

a) Video camera model sony DXC 1800 (Sony Corporation, Japan).
b) Video tape VHS sony 120 (Sony Corporation, Japan).
c) Video recorder/player model Panasonic NV 8950 (Matsushita Electric Co., LTD. Central Osaka, P.O.Box 288, Japan).
d) 35mm camera model Canon FTB, with Canon FD Macro lense (Tokyo 160, Japan).
e) Positive film, Kodak Ektachrome 400 ASA (Eastman Kodak Company, Rochester, New York 14650).
f) Slide projector model Singer Carmate 3300 (Singer U.S.A.).
g) Digitizer model Summa Sketch III (Summagraphics, 8500 Cameron Road, Austin, Texas 78754-3999).
h) An IBM compatible computer.
i) Short legged chair 40 cm. hight.

Procedure :

Self adhesive markers were attached to the thigh and leg of the subject: three markers for each link on the outside surface of the lower limb. The subject then performed the activity of getting in and out of the chair. The motion was recorded on a VHS tape using the video tape recorder and the video camera, a counter was made visible in the view field to facilitate the location of the specific frames during the play back. After recording, the tape was played back on the video player that has a frame - by - frame advancement feature and still frame capabilities. Slide pictures of the video frames were taken with the 35 mm. camera at 15 degrees increments. After development, the slides were organized in order and reviewed on the projector. The position of the markers were traced on vellum paper for all the frames obtained for each subject. The vellum paper was then placed on the digitizer, which was interfaced with the computer, where data points were stored in user defined data file. A program for knee motion analysis, based on the Reuleaux method was writen and used to locate the instantaneous centers of rotation on the lateral side of the knee joint[21]. According to this method, if the femur moves relative to the fixed tibia, the intersection of the perpendicular bisectors of the lines joining two points on the femur at two consecutive positions defines the instant center of rotation for this interval of motion[6,21].

Data Analysis :

At each increment of the movement the mean and standard deviation of the loci of the instantaneous center of rotation for each group were calculated. The unpaired "t" test was used to test for significant difference at $p < .5$[10,14].

RESULTS

The results from the ICR study were summarized and presented in table, and figures. The table present the calculated loci of the center at each flexion interval. The table is accompanied by graphs showing the pathway of the loci on the lateral side of the knee joint for both groups.

Table (1) displays the average X and Y values of ICR loci at 15 degree intervals on the lateral side of the normal and osteoarthritic knees. The center moved 0.83 cm. on the X direction and 2.77 cm. in the Y direction throughout the arc of motion (0 to 120 degrees) in the normal group. The osteoarthritic group test data showed the center was moved 3.27 cm. in the X direction and 1.45 cm. in the Y direction along the arc of motion between 0 and 120 degrees. Figures 1 and 2 display a graphical representation of the ICR pathway for the normal and pathologic groups consequently. Control knees demonstrated a consistent pattern of centrode progression. Osteoarthritic knees showed marked deviation from the normal pattern. These deviations were ranging between anterior displacement of the instant centers of rotation too near the joint line, and a marked posterior displacement of the centrode to a position posterior and more proximal on the femur.

Table (1): X and Y loci (cm.) of the instant center of rotation on the lateral side of the normal and osteoarthritic knees.

ROM* deg. flex.		Normal Knees		Osteoarthritic Knees	
		Mean	S.D.	Mean	S.D.
120-105	X	3.49	0.97	2.11	0.93
	Y	1.39	0.90	3.02	0.46
105-90	X	3.54	0.99	1.80	0.23
	Y	1.42	0.88	2.34	0.54
90-75	X	4.09	0.50	1.79	0.35
	Y	1.75	0.39	2.25	0.76
75-60	X	4.09	0.58	4.12	0.43
	Y	2.37	0.47	3.25	0.63
60-45	X	3.96	0.50	0.85	0.15
	Y	3.03	0.54	3.22	0.39
45-30	X	4.08	0.54	1.78	0.28
	Y	3.55	0.54	2.36	0.63
30-15	X	4.18	0.56	1.77	0.93
	Y	3.95	0.44	3.02	0.46
15-0	X	4.38	0.53	1.71	0.59
	Y	4.16	0.38	1.80	0.94

* ROM deg. flex. = Range of motion (degrees of flexion)

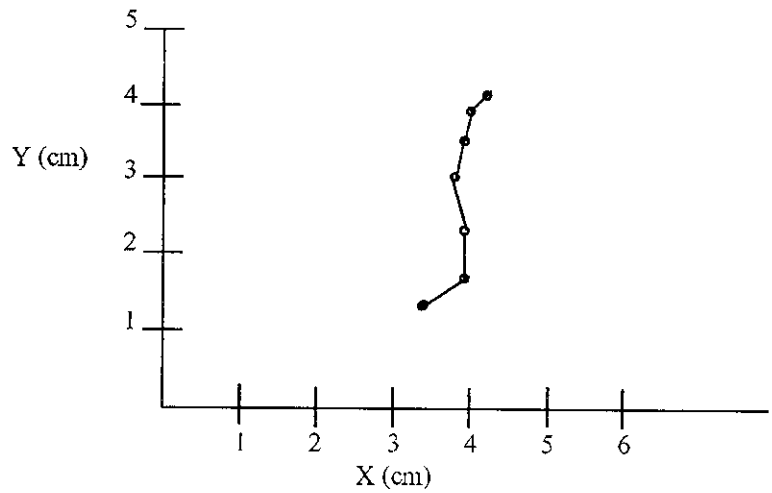

Fig. (1) : The pathway of the instant center of rotation on the lateral side of the normal knee joint.

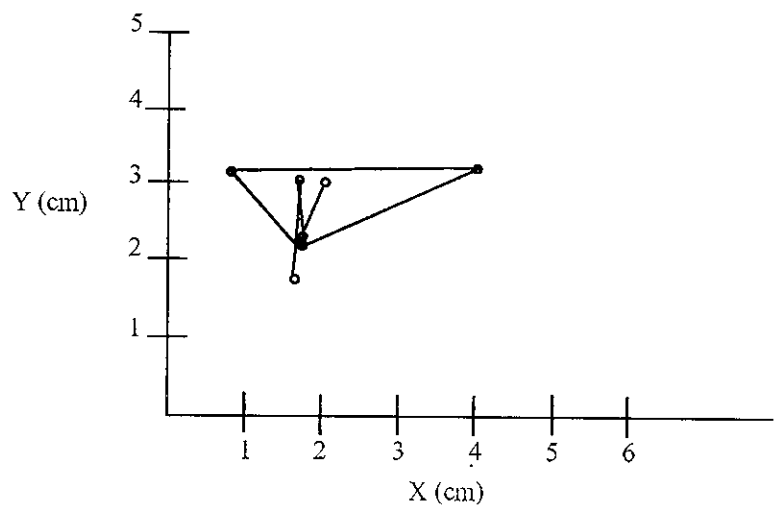

Fig. (2) : The pathway of the instant center of rotation on the lateral side of the osteoarthritic knee joint.

The difference between the locations of the centrodes along the arc of motion between the two groups were found to be significant ($p \leq .05$).

The t value for the X coordinate of the centrode locations was 5.71, and the 2-tail probability was 0.0001. These values indicated that there was a significant difference in the centrode location between the normal knees and osteoarthritic knees ($p \leq .05$). The t value for the Y coordinate of the centrode locations was 0.1019, and the 2-tail probability was 0.001. These values also indicated that there was a significant difference in the centrode location in the Y (vertical) direction between the normal, and osteoarthritic knees ($p \leq .05$).

DISCUSSION

The continuing investigations of the knee joint reflect the importance of the joint to normal lower limb function and its susceptibility to injuries. It also indicates the strong interest from a wide group of disciplines which use a variety of techniques. In the present study the pathway of the ICR on the lateral side of normal and osteoarthritic knees was tested with a video system and skin markers[20].

A considerable difference exists between the depicted pathways in figures 1, and 2 (normals and osteoarthritic patients). The amount of motion of the center was greater on the Y axis in the normal group, and contrarily was greater on the X axis in the patients group. This could be related to the normal functioning of normal knees with normal valgus and varus movements, while in the osteoarthritic knees the greater movements in X axis could explain the A-P instability of the affected knees.

The normal knee's center of rotation constantly change throughout its range of motion. This is due to a number of factors including the shape of the femoral condyles, ligamentous restraint, and muscle tension[2,3,22,24]. Rolling motion predominates if the center of rotation is located near the joint line. If the rotational center is located distally from the contact area, sliding motion predominates. Pure rolling motion takes place only if the centrode is located at the joint line[19].

The osteoarthritic knees centers of rotation showed sudden and marked displacement through the range of motion insted of the normal smooth progression. These abnormal displacements were due to a number of factors including the changes in the shape of the femoral and tibial condyles; changes in the ligamentous restraint capabilities due to changes in length-tension relationships, histological changes, and long-standing strains due to associated deformities and pathological gait; finally due to changes in the tension of the muscular system controlling the knee joint[15,16,23,25].

The abnormal displacements of the centrode in case of osteoarthritis indicate that the surface velocity vector, path of tibial motion in relation to the femur at a given instant of time, is not tangential to the joint surface at the contact area. This could cause abnormal compressive and frictional forces inside the joint, which will lead to more distruction of the cartilaginous surfaces.

Conservative or surgical treatment which does not consider the correction of the factors that may lead to abnormal displacements of the instant center of rotation, and subsequently restoration of normal joint mechanics, can not be expected to solve the problem or to prevent further destruction of the joint surfaces and structures.

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الملخص العربي

دلالة محاور دوران الركبة في الإلتهاب العظمي المفصلي

يهدف هذا البحث لدراسة ميكانيكية عمل مفصل الركبة في المرضى المصابين بالإلتهاب العظمي المفصلي . وقد أجريت الدراسة على عشرة من المرضى المتطوعين تتراوح أعمارهم بين ٣٥ ، ٦٣ عاما – منهم سبعة من الذكور وثلاثة من الإناث ، وعشرة من المتطوعين الأصحاء تتراوح أعمارهم بين ٢٠ ، ٤٠ عاما – منهم ثمانية من الذكور واثنتان من الإناث . تم استخدام نظام فيديو لتصوير جانب المفصل أثناء القيام من والجلوس على كرسي ذو إرتفاع ٤٠ سم بعد وضع علامات سطحية على جانب الفخذ والساق . ثم تم تحليل النتائج باستخدام الكمبيوتر بعد كتابة برنامج خاص لحساب مواقع محاور دوران المفصل .

وقد أثبتت نتائج البحث وجود فروق معنوية بين مواقع محاور الدوران اللحظية في كل من مجموعتي المرضى والأصحاء . كذلك أكدت على أهمية اصلاح الخلل الميكانيكي بالمفصل أولا في أي برنامج علاج تحفظي أو جراحي للمفصل .