'Cracking joints'

A bioengineering study of cavitation in the metacarpophalangeal joint

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The cracking of joints is a common phenomenon which interests patients and clinicians alike. Its exact nature has remained in doubt, as evidenced by a recent comment in the *British Medical Journal* (1969). At the knee and hip, tendons over bony prominences can cause 'clicking' which may sometimes be audible. The tensor fascia lata is particularly apt to do this over the greater trochanter. The majority of cracks do not appear to arise from this mechanism.

The only detailed study of cracking in the metacarpophalangeal joint, as far as the authors are aware, is that of Roston and Wheeler Haines (1947). Before this work bubbles had been observed in joints by Fick (1911), Dittmar (1933), and Nordheim (1938), who were interested in them as a means of obtaining radiographs of fibro-cartilage in the knee without using a contrasting medium.

In the present communication it will be shown that this bubble is not the cause but the effect of the crack, and that fluid 'cavitation' is responsible for the cracking noise. In addition, suggestions will be made to explain why some joints cannot be cracked and why, having been cracked, about 20 minutes must elapse before a joint can be cracked again.

Materials and methods

A machine was designed and built to study the effects of loading on the separation of the metacarpophalangeal joints in man (Fig. 1). The subject's arm was held in a prenyl splint attached to an adjustable table. A selection of splints was available to ensure correct alignment of the fingers to the loading mechanism. The fingers rested on an *x*-ray cassette which could slide laterally in the table.

Loads were applied by a pneumatic cylinder acting through a transducer and twine which was connected to a ring fitted around the proximal phalanx of the middle finger. A small adhesive dressing encircled the proximal interphalangeal joint to prevent the ring from slipping.

The applied loads were measured using an ultra-violet recorder whilst sequential *x*-ray exposures allowed the bone separation to be visualized.

X-ray exposures were taken at the beginning of the test before loading and at increments up to about 16 kg. If the joint cracked, the load trace was marked at the point of cracking and, after further increases in load, exposures were taken at each reduction of load to zero. Where joints did not crack the maximum load applied to the joint was 16 kg. During this series of tests, seventeen subjects were tested on the machine.

STUDY OF GEOMETRY

To apply the appropriate hydrodynamic equations for theoretical analysis, the configuration of the metacarpophalangeal joint of the middle finger was determined in nine joints. Four joints were obtained from the Department of Anatomy (having been embalmed) and five at autopsy. Silicone rubber moulds were made of the metacarpal head and the base of the proximal phalanx of each joint and acrylic plastic models were produced. These were sectioned in various planes and the radius of curvature measured at each plane using a projection microscope.

GAS ANALYSIS OF SYNOVIAL FLUID

This was carried out using a Van Slyke apparatus on synovial fluid from seven patients; one had a traumatic effusion and six had rheumatoid arthritis. The fluid was taken in a sealed syringe and each test performed as soon as possible (usually within 1 hour). In the case of one specimen, taken at operation, the sample had been exposed to the air on opening the joint.

JOINT SIMULATOR

From the data obtained from the (geometrical) study, a model was made twice this size of the metacarpophalangeal joint. The metacarpal head was made in nylon and the proximal phalanx in Perspex. This combination was used to give good photographic conditions. Synovial fluid was inserted between the surfaces and the joint placed in compression. A sudden tension was applied to the joint and a high speed ciné camera photographed the clearance space between the joint surfaces.

FIG. 1   *A machine designed to 'crack' the metacarpophalangeal joints of human subjects.*

THEORETICAL CONSIDERATIONS

Cavitation is the term used to describe the formation of vapour and gas bubbles within fluid through local reduction in pressure. When the vapour collapses on moving into a region of higher pressure, very high impact pressures can be generated. Consider a sample of fluid which suddenly has its pressure reduced. When the pressure is reduced, the vapour temperature of the fluid is also reduced; if a large pressure reduction takes place the fluid boils at ambient temperature and reduced pressure and is converted into vapour bubbles in these low pressure regions. In addition, the gas which was previously in solution forms gas cavities at reduced pressure. When these cavities or vapour-filled bubbles move into the higher pressure areas, instant collapse takes place with very high energy release which can give rise to extremely large stresses. It is this phenomenon that is responsible for the erosion of ship's propellors and the blades of hydraulic turbines, and cavitation damage in many forms of hydraulic machinery and bearings.

Results

FINGER CRACKING

Of the seventeen subjects tested, five produced cracks, seven did not, and five did not relax sufficiently to allow a test to be performed properly. This last group reacted to the applied loads by tensing the muscles and so holding the joint closed.

In all the subjects who produced a crack a crescent-shaped area of high contrast was noted in the clearance space between the articular surfaces on radiography (Fig. 2, overleaf). This was absent in subjects whose joints did not crack.

Figs 3 and 4 (overleaf) show typical load-separation curves for 'cracking' and non-cracking joints. Consider first of all Fig. 3. As the load increased, the joint separation increased also. This rise was gradual at first and in three of the five cases was linear. At a
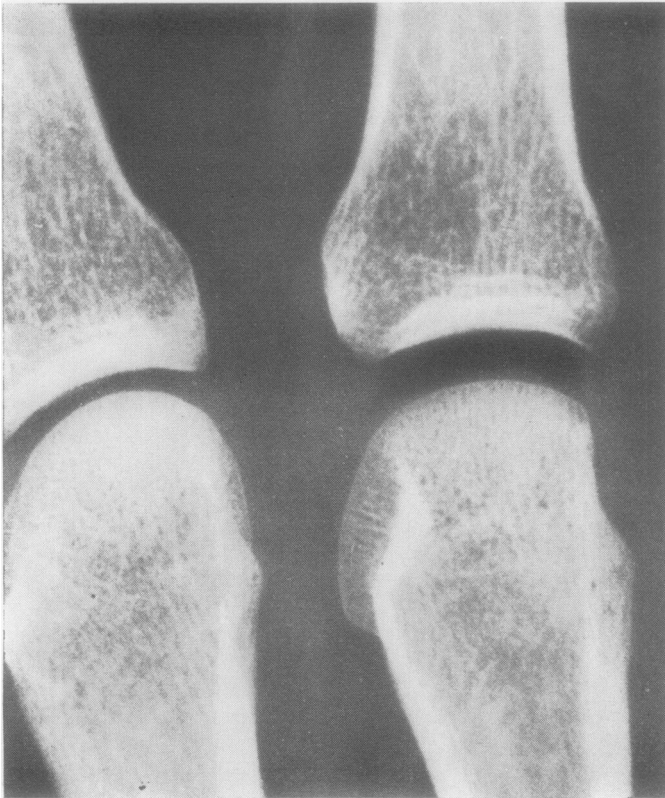
FIG. 2 *Radiograph of metacarpophalangeal joint after cracking. Note increased joint separation and contrasted area within joint space.*
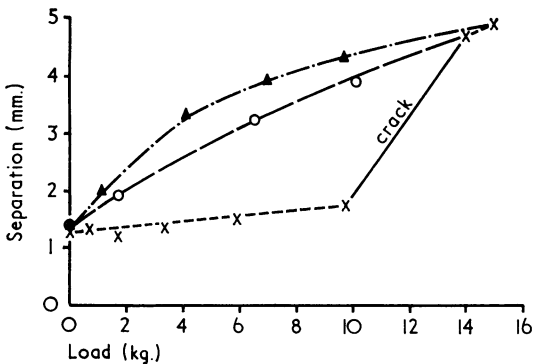

FIG. 3   *Typical load-separation curve for a cracking joint. Note similarity between upper (re-load) loop and the loop of Fig. 4.*
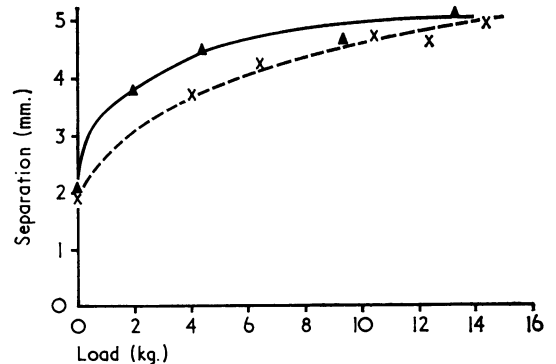

FIG. 4   *Typical load-separation curve for a non-cracking joint. Note absence of a sudden 'jump' in separation value (compared with Fig. 3).*

load between 10 and 16 kg. a crack was heard and the joint separation increased rapidly. The radiograph also showed the contrasting area within the joints. Continued loading took the separation a little higher, and on reducing the load the upper curve was followed (indicated by a broken line). On reloading immediately, the load-separation characteristics followed the middle curve and not the original (lower) one. No crack was heard on the second and subsequent loading cycles. In the

non-cracking joint (Fig. 4), different load-separation characteristics were found. Comparing the two graphs, it can be seen that the loop of Fig. 4 is similar to the upper loop of Fig. 3, and since the area of the loop represents the energy dissipated in the joint, it can be concluded that the upper loop of Fig. 3 and the area enclosed by Fig 4 represent the energy lost in extending and returning the joint. This energy is due to viscous and Coulomb losses in the joint fluid and surrounding tissue. The lower

Table I *Observations from load-separation tests in twelve subjects*

Subject no.	Sex	Age (yrs.)	Joint cracked	Dark area visible on x-ray	Resting separation (mm.)	
					Initial	Final
1	M	21	Yes	Yes	1·2	1·26
2	F	37	Yes	Yes	1·17	1·44
3	M	22	Yes	Yes	—	—
4	F	19	Yes	Yes	1·32	1·41
5	F	35	Yes	Yes	1·2	1·33
6	F	19	No	No	1·37	1·9
7	F	31	No	No	1·60	—
8	F	34	No	No	1·23	1·44
9	F	50	No	No	1·94	2·07
10	F	20	No	No	1·54	1·90
11	F	21	No	No	0·98	1·32
12	F	20	No	No	1·35	1·49

approximately triangular area of Fig. 3 represents the energy dissipated by reason of the crack itself and is about 75 per cent. of the total energy expended.

Table I shows some of the observations from the load-separation tests.

Table II *Time lapse before joint separation returns to pre-cracking value*

Time related to crack	Joint separation (mm.)
Before (resting)	0·98
At instant of cracking	2·50
5 min. after (resting)	1·40
10 min. after (resting)	0·99
15 min. after (resting)	0·98

Table II shows that, for the finger tested, a time lapse of about 15 minutes occurred before the finger joint separation returned to its pre-cracking value. This is probably due to the viscous effects of synovial fluid keeping the surfaces apart, together with elastic recovery within the cartilage.

STUDY OF GEOMETRY

Before the technique was used to study the geometry of joints, controlled tests were conducted on standard specimens. It was found that the length of a rectangular block (1 in. steel slip gauge) was reproduced within 0·7 per cent. A measurement of a steel ball of 1 in. diameter was in error by 1·6 per cent., and measurements on a glass cylinder of 0·582 in. diameter gave an error of 1·2 per cent.
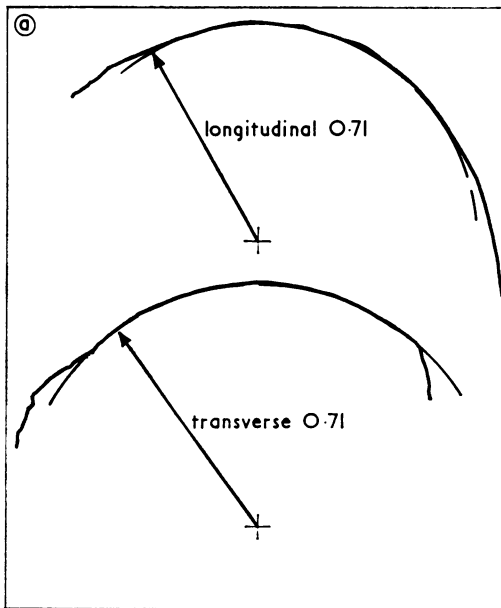

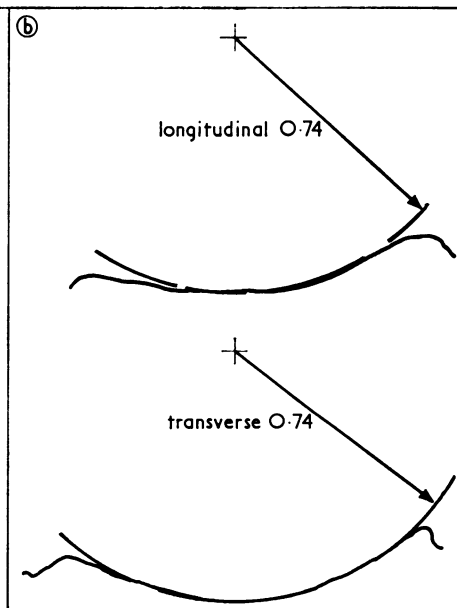FIG. 5a *Shadow graph outline of the metacarpal head with a radius superimposed.*

FIG. 5b *Shadow graph outline of the base of the proximal phalanx with a radius superimposed.*
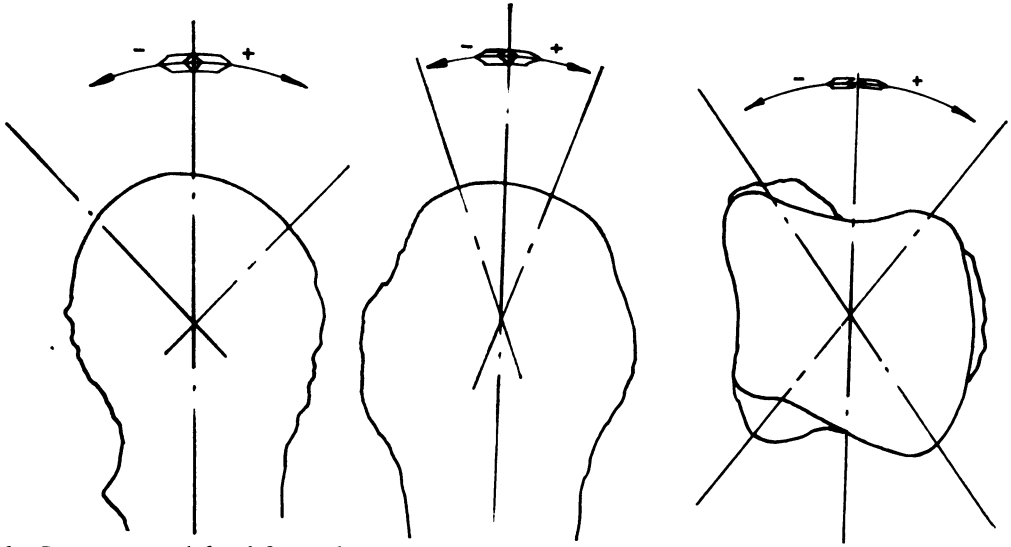
B

FIG. 6   *Convention used for defining planes of section.*

The radii of curvature of the model surfaces were determined by projecting the articulating surfaces on a projection microscope and then fitting standard radii to them (Fig. 5, previous page).

The metacarpal heads were sectioned about three axes longitudinal, transverse, and rotational defined in Fig. 6.

The results of measurements on these sections are given in Table III (opposite) and the results for the metacarpal head and proximal phalanx on the longitudinal and transverse planes in Table IV.

It was noted that, in three of the eight fingers examined, the metacarpal head was spherical over the range of motion. However, it is worth noting that two of these (F3 and F8) were spherical only by virtue of wear taking place and causing local

adjustment of the original radius of curvature (Table IV). In all the other cases the metacarpal head had a larger radius transversely than longitudinally. It therefore seems that in general the metacarpal head is not quite spherical but has a smaller radius of curvature in the coronal plane than the transverse plane. In this case the average difference in radius was 6 per cent., a small but definite difference.

Table IV shows that three of the eight specimens of proximal phalanx base had equal radii in the coronal and transverse planes (*i.e.* they were spherical). Two specimens had a greater radius in the coronal plane and three in the transverse plane. The mean difference in radius was only 1·07 per cent. and was such that the coronal plane exhibited the

Table IV   *Measurements for sections or metacarpal head and proximal phalanx in eight specimens*

Specimen no.	Longitudinal radius (mm.)		Transverse radius (mm.)		Condition of joint
	Metacarpal head	Proximal phalanx	Metacarpal head	Proximal phalanx	
F1	8·1	8·9	9·1	8·1	Good, showing slight damage
F3	8·9*	9·1	8·9	9·1	Good, some wear
F4	6·6	7·9	7·2	7·9	Good, some wear
F5	6·6	7·6	7·2	8·1	Signs of wear
F6	7·1	7·4	7·1	7·4	Good
F7	7·2	7·9	8·1	8·3	Worn locally
F8	9·1**	9·1	9·1	8·1	Worn/Good
F9	7·9	7·9	8·6	8·1	Very good

*Radius of 8·9 mm. superimposed on one of 7·2 mm.   **Radius of 9·1 mm. superimposed on one of 7.6 mm.

Table III *Measurements on sectioned metacarpal heads in six specimens*

Specimen	Longitudinal		Transverse		Rotational	
	Angle (°)	Radius (mm.)	Angle (°)	Radius (mm.)	Angle (°)	Radius (mm.)
F3	0	8·9	0	8·9	+10	8·9
	−10	8·9	+20	8·9	+20	7·6
	−20	8·9	+40	8·9	+30	7·1
	+10	8·9	+80	8·9	−10	8·6
					−20	8·9
					−30	8·9
F4	0	6·6	0	7·2	+10	7·2
	−30	6·6	20	7·2	+20	7·2
	+30	6·6	45	8·2	+30	7·2
					−10	7·2
					−20	7·6
					−30	7·9
F5	0	6·6	0	7·2	+10	7·4
	+20	6·6	15	7·2	+20	7·4
	+27	6·6	38	7·2	+30	7·4
	+32	6·4	60	7·2	−10	7·1
					−20	7·1
					−30	7·1
F6	0	7·1	0	7·1	+10	7·1
	−15	7·1	15	7·1	+20	7·1
	−40	7·1	30	7·1	+30	7·1
	+30	7·1	60	7·1	−10	6·9
					−20	6·9
					−30	7·1
F7	0	7·2	0	8·1	+10	7·7
	−25	7·2	30	7·9	+20	7·9
	−57	7·2	55	8·4	+30	8·1
	+15	7·2			−10	7·9
	+40	7·2			−20	7·6
					−30	8·1
F9	0	7·9	0	8·6	+10	8·6
	−30	7·9	−15	8·9	+20	8·6
	+26	7·9	+30	9·1	+30	8·9
	+40	7·9	+50	8·9	−10	8·9
					−20	9·4
					−30	9·4

larger radius. This observation is interesting because it appears that the base of the proximal phalanx is nearer to a sphere than the head of the metacarpal.

If the joint is now considered as a whole (*i.e.* fitted together), it is interesting to note the relative radii of curvature and hence the clearance at any point. In the coronal plane in every case the proximal phalanx was of equal or greater radius than the metacarpal head. On average this clearance or difference in radius was 0·5 mm. The transverse plane, however, showed much more scattered results. Three of the joints had larger metacarpal heads than proximal phalanx bases and five had larger bases than metacarpal heads. The average clearance in the transverse plane was small and negative. It appears that the proximal phalanx grips the metacarpal head very slightly by 0·025 mm. on

radius on average. Fig. 7 (overleaf) shows a joint in which the metacarpal head is smaller than the proximal phalanx base and Fig. 8 (overleaf) one in which the head is larger than the base in the transverse section.

Although in detail the joints are not quite spherical, for the sake of analysis they can be considered to be true spheres.

GAS ANALYSIS

This was carried out on samples of synovial fluid from seven patients (Table V, overleaf). The average gas content was 15 per cent. by volume, and over 80 per cent. of this was carbon dioxide.

In a series of experiments on four fluids, the gas was liberated and a positive pressure of 17 cm. of mercury was then applied to the column of gas above
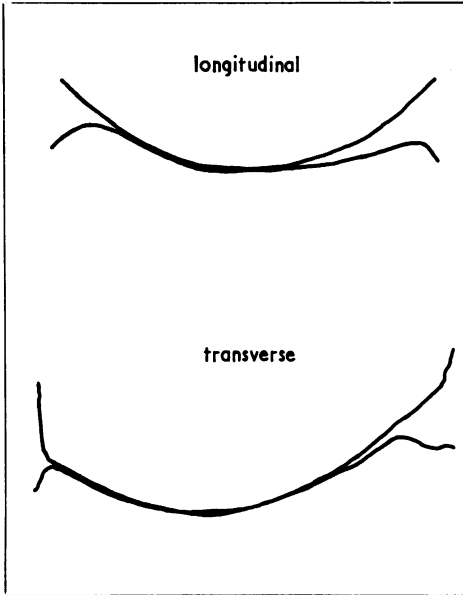
FIG. 7   *Section showing a metacarpal head smaller than the proximal base in the transverse plane.*
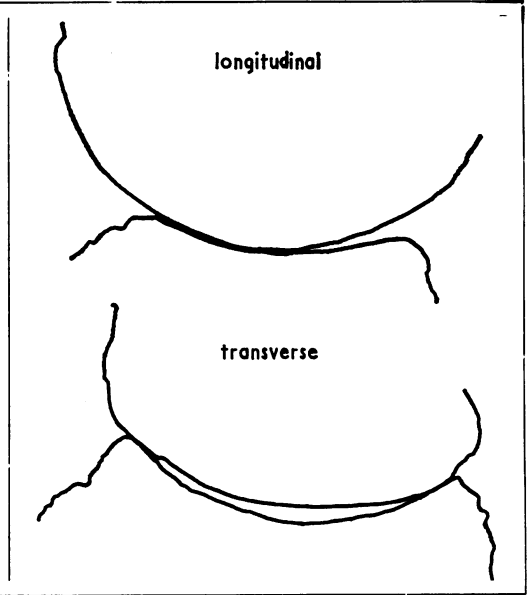
FIG. 8   *Section showing a metacarpal head larger than the proximal base in the transverse plane.*

Table V   *Results of gas analysis of synovial fluid from seven specimens*

Specimen no.	Type	Gas content (per cent. by volume)	Temperature (°C.)
S1	Rheumatoid	16	23
S2	Rheumatoid	15	23
S3	Rheumatoid	17	23
S4	Rheumatoid	16	26
S5	Rheumatoid	15	26
S6	Traumatic effusion	10	26
S7	Rheumatoid	16	26

the evacuated synovial fluid in a Van Slyke apparatus. A curve of the absorption of the gas with time was drawn for each fluid (Fig. 9). If a rough calculation is done for the reabsorption time, taking into account the difference in area of the observed bubbles in joints and the bore of the Van Slyke apparatus, then the gas reabsorption time would be of the order of 30 min. in a metacarpophalangeal joint. This is in agreement with the clinical observation that joints cannot be re-cracked within about 20 to 30 minutes.

MATHEMATICAL CONSIDERATIONS
The geometrical study of the metacarpophalangeal joint of the middle finger showed that this could be approximated to a sphere with little error (6 per
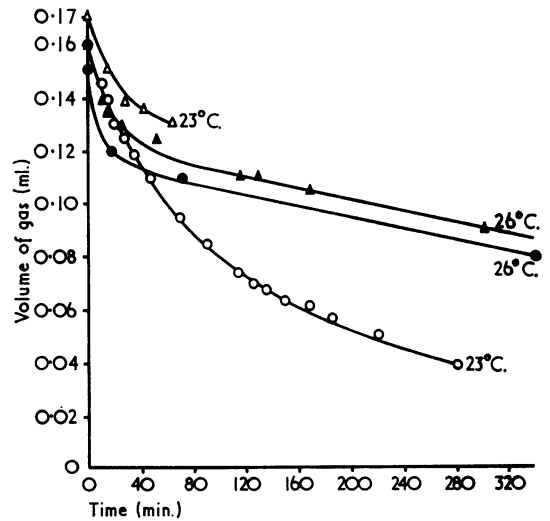

FIG. 9   *Graph of absorbtion of gas into synovial fluid against time for four samples of fluid. An arbitrary pressure of 17 cm. mercury was applied to the gas to help the process.*

cent.). The hydrodynamic equations were therefore considered for this configuration and it has been shown elsewhere (Dowson, Unsworth, and Wright, 1970) that the pressure at any point in a spherical joint under load can be written as:

$$p = \cfrac{\dfrac{W}{2\pi R_s{}^2}\left[\dfrac{1}{(1-\epsilon\cos\theta)^2} - \dfrac{1}{(1-\epsilon\cos\theta_1)^2}\right]}{\left[\dfrac{1}{\epsilon(1-\epsilon)} + \dfrac{ln\,(1-\epsilon)}{\epsilon^2} - \dfrac{\cos\theta_1}{\epsilon(1-\epsilon\cos\theta_1)} - \dfrac{ln(1-\epsilon\cos\theta_1)}{\epsilon^2} - \dfrac{\sin^2\theta_1}{2(1-\epsilon\cos\theta_1)^2}\right]}$$

where p is the pressure generated within the fluid film at the point determined by the co-ordinate θ.

W is the applied load.

R_s is the radius of the sphere representing the metacarpal head.

θ_1 is half the angular extent of the bearing.

ϵ is the eccentricity ratio e/c.

e is the displacement of the centres of the radius of the metacarpal head and the radius of the base of the proximal phalanx.

c is the difference between the radius of the proximal phalanx and the metacarpal head.

If $\theta = 0$ is substituted into this equation, then the maximum pressure will be obtained.

Conditions when $\epsilon \rightarrow 1$

When ϵ approaches unity, the maximum pressure generated approaches minus infinity when the surfaces are moving apart. The value of ϵ becomes unity when the two cartilage surfaces are in contact. When a thin film of fluid is present, the pressure generated is very low. In general, fluid containing high quantities of gas cannot support low pressures without cavitation taking place.

JOINT SIMULATOR

Using the joint simulator, an audible crack was produced by a sudden tension after the components had been compressed with synovial fluid between them. Frames from the high speed ciné film are shown in Fig. 10 (overleaf), in which the presence of vapour cavities can be seen.

Discussion

From the theoretical considerations it is clear that, subject to condition of very thin synovial fluid films existing between the cartilage surfaces of the metacarpophalangeal joint, it is likely that cavitation will take place within the fluid when tension is applied to the joint. At the instant of formation of the cavities an unstable condition is created, for the pressure within the bubble is very low while that of the surrounding fluid is nearer to ambient conditions. In addition, the joint separation increases at a high rate, allowing the net flow of fluid into the low pressure regions. This results in collapse of the vapour phase of the cavities with consequent energy release as noise (the 'crack' heard externally). The gas removed during the period of low pressure, however, returns to ambient pressure but does not reabsorb for 20 to 30 minutes. This gas is readily visible on the radiograph, particularly on extension of the joint but is not responsible for causing the crack; it is there as a consequence of the cracking phenomenon.

Roston and Wheeler Haines (1947) estimated the pressure in the joint by taking the applied load and dividing this by the area of the joint suggesting that the fluid was subjected to a tension of —2½ atmospheres. The fallacy of this calculation arises from the fact that not all of the load is taken through the fluid film (some is carried by the surrounding structures). In addition, the pressure generated within the curved surface is different in all parts of that surface, being a minimum at the centre of the contact: a fact which is vital to an understanding of the cracking phenomenon.

The load-separation results from the tests described in this communication are similar to those produced by Roston and Wheeler Haines. They differ in that the initial separation of the joint surfaces was always smaller than the final separation of the same surfaces providing the measurement was taken immediately after unloading. After about 15 minutes rest the two became equal. These are also important factors in the explanation of the phenomenon.

Nordheim (1938), when explaining the shadow on the x-ray film, used the example of a syringe with the nozzle blocked filled with water and the plunger withdrawn. This produces a low pressure area consisting of water vapour and gas extracted from the solution in the water. On this basis Roston and Wheeler Haines (1947) suggested that the sudden appearance of this low pressure bubble caused the joint to separate at a rapid rate and that the crack was caused by the sudden opening of the joint surfaces producing vibrations in the joint tissue. The present work confirms that low pressures are developed in the synovial fluid and these pressures cause vaporization and gas liberation from the fluid. At this point the joint space springs open, but the high speed ciné camera shows that the bubble forms and collapses again in about 0·01 second. It is therefore concluded that it is the *collapse* of the vapour bubble which causes the crack not its *formation*. This is borne out by mathematical considerations when the physical significance of applying tension to the joint is considered. As the joint is pulled apart, if the fluid film is very thin (*i.e.* $\epsilon \rightarrow 1$ in the equation), a very low pressure is
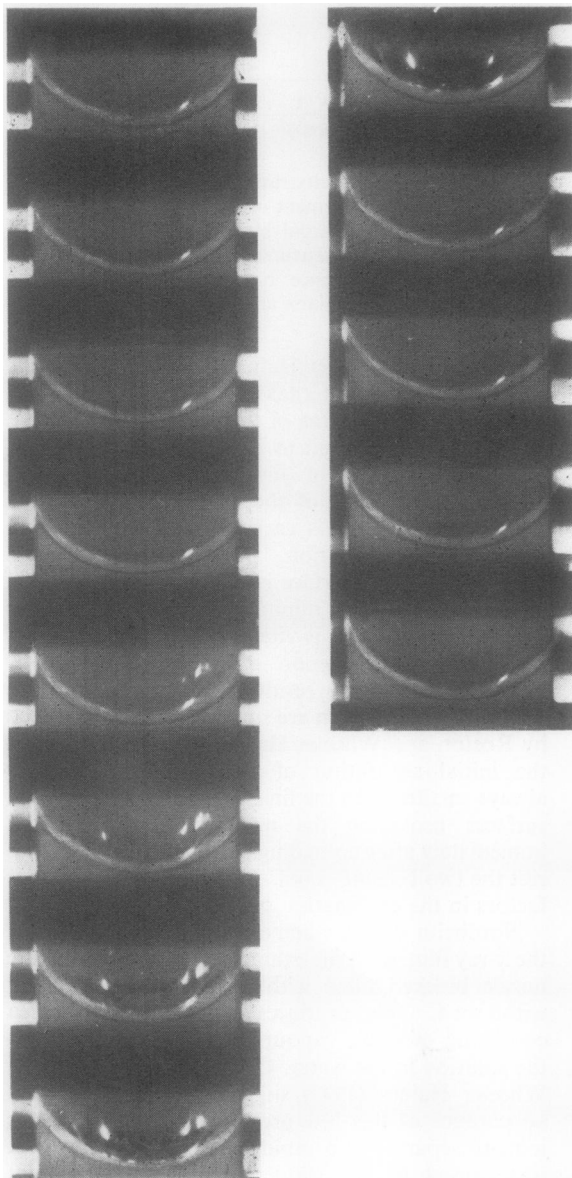
FIG. 10 *High-speed ciné frames of a Perspex and nylon simulated joint. Frames 5 to 9 show vapour formation and collapse.*

of the fluid, and this energy is manifested as noise. To look at the same problem from a mechanical point of view, as the vapour condenses the fluid surrounding the bubble tries to fill the space previously occupied by vapour and the fluid flowing from all directions meets at a point. On meeting the opposing fluid, high impact stresses occur giving rise to noise.

Joints require about 20 minutes before re-cracking can occur. This is because gas exists as nuclei for about 20 minutes after cracking (Nordheim, 1938; Roston and Wheeler Haines, 1947). Any further tension simply reduces the pressure of the gas bubbles, leaving the liquid relatively undisturbed and under no influence of the tension. However, once the gas has returned into solution, the joint is ready for re-cracking. Another factor which has not received previous comment is that the separation between the joint surfaces does not return to its pre-cracking condition for a period of 15 minutes. The surfaces must be very close to give the right conditions for cavitation at reasonable loads so that, if a joint is separated before this space has reduced fully, the pressure generated will be insufficient to cause cavitation as is apparent from the theoretical considerations. The reasons for the joint space taking so long to return are multiple, but principally the viscosity of the synovial fluid resists the forces trying to squeeze the fluid film to small proportions and this resistance causes a time delay.
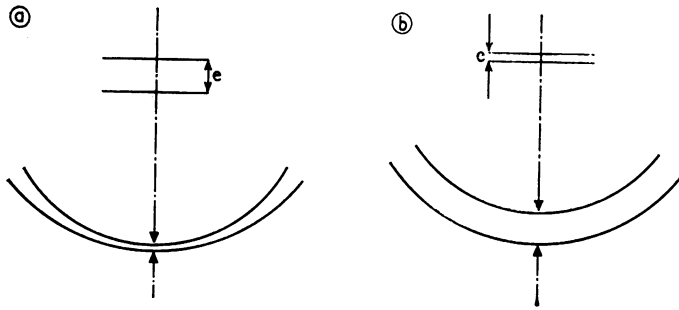
generated. This causes vapour cavities to be formed but, at the same time, gas which was previously held in solution in the fluid is released within these cavities or bubbles. Because the pressure is much lower in the middle of the contact (where the bubble is formed) than towards the joint surface extremities, a pressure-induced flow will take place to fill the cavities formed. This flow causes a sudden condensation of the vapour previously formed because the pressure rises above the vapour pressure as the fluid flows in. This phase transformation, which takes place in a very short time, gives rise to free energy equal to the latent heat of vaporization

In addition, the ligaments take some time before they can re-apply their initial loading because of the visco-elasticity of the tissue. It therefore becomes clear that joints cannot be expected to crack repeatedly if cavitation characteristics are considered.

Some joints never crack. This may be because the joint space is too great. Examining the equation, it can be seen that when ε approaches unity, application of a load such that surface separation takes place is likely to produce cavitation because of the low pressure generation. Conversely, if ε is very much less than unity, the pressure is likely to be insufficient to produce cavitation within the joint (Fig. 11).

The physical explanation of a thick fluid film being present between the articulating surfaces is that the ligaments locating the joint are not strong enough to force the two surfaces together. This point is verified by Table I which shows the resting separation of non-cracking joints to be 25 per cent. greater than that of cracking joints. Secondly, subjects may not be able to relax. In this series of tests and in those of Roston and Wheeler Haines (1947), several subjects could not relax their muscles. As the machine applied the load the subject pulled back against this by tensing the tendons spanning the joint. The result was that the joint did not open or at best opened erratically as the subject attempted to relax at intervals.

Summary

A machine has been constructed to study the load-separation characteristics of the metacarpophalangeal joint. It was demonstrated that, in joints which produce a crack, an area of high contrast was present radiologically. This is in agreement with the findings of other workers. The characteristics shown by a cracking joint were not the same as those of a non-cracking joint. However, the reloading curves for a previously cracked joint were similar to those for a non-cracking joint. Gas analysis, using a Van Slyke apparatus, showed that synovial fluid contains 15 per cent. gas on average.

Studies of geometry demonstrated that the joint surfaces were essentially spherical in the area of interest, and the hydrodynamic equations for this configuration show that, when the joint surfaces are close together, large subatmospheric pressures can be produced on separating the surfaces.

The results support the view that 'cavitation' is responsible for the phenomenon of cracking. Under subatmospheric pressures, the synovial fluid vaporizes and gas is released from solution. The collapse of the vapour cavities gives rise to the noise. This was supported by high speed photography of a Perspex and nylon simulated joint.

DISCUSSION

DR. A. G. S. HILL (*Stoke Mandeville*) Looking at that apparatus, there is really very little difference between it and mediaeval methods of persuasion except that nowadays you make measurements during the process!

PROF. WRIGHT It has a safety catch the patient can operate, and in that way it differs from the mediaeval instrument!

DR. R. GRAHAME (*London*) This radiograph from a young man in his mid-twenties, who suffered from Perthes' disease in his youth, supports Prof. Wright's hypothesis that the cracking of joints is due to release of gas within the joint. On abduction of the hip a gas bubble has appeared. I am told by my orthopaedic colleague, Mr Adrian Henry, that this induction of a gas arthrogram is known in orthopaedic circles to occur in patients with Perthes' disease. The patient in question noticed clicking in his hip on several occasions, and on one occasion when exercising. Orthopaedic surgeons have always regarded this as a nitrogen arthrogram. Is there much nitrogen in synovial fluid, or is it all carbon dioxide?

PROF. WRIGHT Our results show that it is virtually all carbon dioxide, though we have not estimated the exact nitrogen content.

DR. J. A. MATHEWS (*London*) It is gratifying to have the work of Roston and Wheeler Haines (1947) confirmed and extended, especially as we have been referring enquirers to it for some time. They demonstrated bone separation and the appearance, with a 'crack', of gas at a metacarpophalangeal joint subjected to traction.

It is also possible to separate lumbar vertebrae by applying traction. On occasions a lumbar spine can be heard to 'crack', and sometimes routine *x* rays show gas in the intervertebral space. Superimposed tracings of *x* rays taken before and during lumbar traction can show a 2 mm. separation of the bones, but I have never observed this separation accompanied by production of noise or gas. However, the intervertebral disc joint is not really analogous to the synovial joints that Professor Wright has been examining. Could spinal 'cracking' arise from apophyseal joints?

PROF. WRIGHT We are familiar with the excellent work of Roston and Wheeler Haines, and I pointed out that this communication was an extension of their studies. They had not appreciated that the noise was due to the collapse of the bubbles, and had not realized that they were observing the phenomenon of cavitation. Intervertebral joints do crack, but I think one should appreciate that not all the noises that come from the body are necessarily due to cavitation. One can, for example, have ligaments snapping over bony prominences.

DR. P. J. L. HOLT (*London*) These experiments were all done by traction in extension. Under what circumstances does this phenomenon occur in normal everyday use of the joints? Presumably it would have to be present during normal function of the joint to produce damage which Professor Wright put forward as a possibility. I wonder if it has any relationship to the boosted lubrication that he has shown in the past? Is it possible?

PROF. WRIGHT You only need some tension through gripping or lifting. This data was presented to our Medical Sciences Club in Leeds. Many of the audience have said that, now they are aware that joints crack, they have frequently noticed its occurrence. One does not have to perform sophisticated manoeuvres to crack one's joints.

DR. H. L. F. CURREY (*London*) Dr. Morris Ziff has case histories of three Negro patients who had the nervous habit of repeatedly cracking their finger joints. All had osteoarthrosis of the finger joints and he regarded this as a cause of secondary osteoarthrosis.

[Subsequent personal communication from DR. M. ZIFF (*Dallas, Texas*) I have two patients with obsessive knuckle-cracking habits, one aged 38 years and the other a teenage male. The first had undoubted osteoarthrosis, and the second had enlarged proximal interphalangeal joints but his *x* rays were only suggestive of sclerosis of the subchondral margins of the middle phalanges. The third patient was a deaf mute in her late 30s. She used her fingers constantly for sign language and had prominent Bouchard's nodes, but did not crack her knuckles.]

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