Acta orthop. scand. 45, 119–129, 1974

Orthopaedic Hospital, University of Århus, Denmark.

THE INFLUENCE OF THE INTACT FIBULA ON THE COMPRESSION OF A TIBIAL FRACTURE OR PSEUDOARTHROSIS

TORBEN EJSING JØRGENSEN

Accepted 25.v.73

For many years the resection of 2 to 3 cm of the middle part of the fibula has been a well-recommended treatment of tibial pseudoarthrosis (Sørensen 1969). Even primary resection of the fibula has been recommended at isolated tibial fractures. The principle of this was to eliminate the fibular traction on the tibial fragments by resecting the fibula.

In many cases of tibial pseudoarthrosis, the resection resulted in healing of the fracture, although it was a delayed healing. Very little is known about the importance of the fibula as regards the entire stability of the crus. The biomechanical building of the crus makes it likely that the rigid, poly-edged fibula acts as an important support to the tibia, particularly during violent bendings (Jørgensen 1972 a). From a theoretical point of view the resection of the fibula is not advisable.

The aim of this study is to examine the compressibility of a tibial fracture with intact fibula, when the fracture is exposed to an increasing compression in the longitudinal axis. The decrease of the fractural gap indicates when a compression osteosynthesis is able to adapt a tibial fracture without resection of the fibula.

The description of bone tissue as a physical material is rather complex. The physical properties differ strongly with the location of the tissue (Blaimont 1968), with age (Lindahl & Lindgren 1968) and with the immobilization period (Nilsson & Smith 1969).

Based on measurements on autopsy bone and bone pieces, Sedlin (1965) set up a model of a cortical bone. Research in this field is still being carried out by several investigators (Burstein et al. 1972).

Generally, a bone model may be described as follows.

When a bone is exposed to a small loading, a deformation will occur. Removal of the load after a brief duration will equalize the deformation completely. By small loadings of brief duration the bone behaves as an elastic body (stress and strain are proportional). A bone loaded by a certain force at once assumes a considerable elastic deformation. During the next 10 minutes a slow after-deformation will occur (strain retardation). If the deformation obtained is constant for a certain time, the necessary force will decrease (stress relaxion). Release of the loading leads to a slow decrease of the deformation. If the bone regains its original form, the deformation has been visco-elastic. If not, the deformation has been plastic. Plastic deformation of a bone does not necessarily imply micro-fracture in the bone tissue. This rheologic bone model is based on measurements performed on autopsy specimens. The physical bone properties are influenced by temperature (Sedlin 1965) and by humidity (Smith & Walmsley 1959). The changes occurring in the properties of the bone post-mortem all tend to leave the bone stiff and less elastic. Very few measurements exist on live bone, but measurements of bendings performed on healthy, live tibia confirm the fact that live bone is more bendable and elastic than dead bone (Jernberger 1970). This may be because a live bone is hydraulically strengthened by blood and interstitial liquid, and because the organic phase, represented by long protein molecules in the collagenic fibres, is not coagulated, resulting in rigidity (Knese 1958, Currey 1964, Swanson & Freemann 1966).

Provided closely realistic measurements on dead bones are wanted, these measurements must be performed as quickly as possible post-mortally. In reality no measurements can be made until 6 hours after the occurrence of death. With large amputations it is occasionally possible to measure a fresh specimen, which until recently sustained its normal function.

MATERIAL AND METHOD

The specimen, on which measurements were made, was a crus from a 17-year-old girl with an osteogenic sarcoma in the middle of the femur. The leg had to be exarticulated at the hip. A few minutes after the exarticulation the crus, which was unaffected by the femoral tumour, was amputated at the knee joint. The specimen was immediately taken to an examination room with a temperature of 22° C.

On the medial side of the tibia a Hoffmann apparatus with a sliding compression bar was mounted proximally and distally on the tibia, so that the tibial bone between the two sets of screws measured 10 cm. Two sets of screws were inserted perpendicular to the first set for the fixation of the measuring bridge (Figures 1

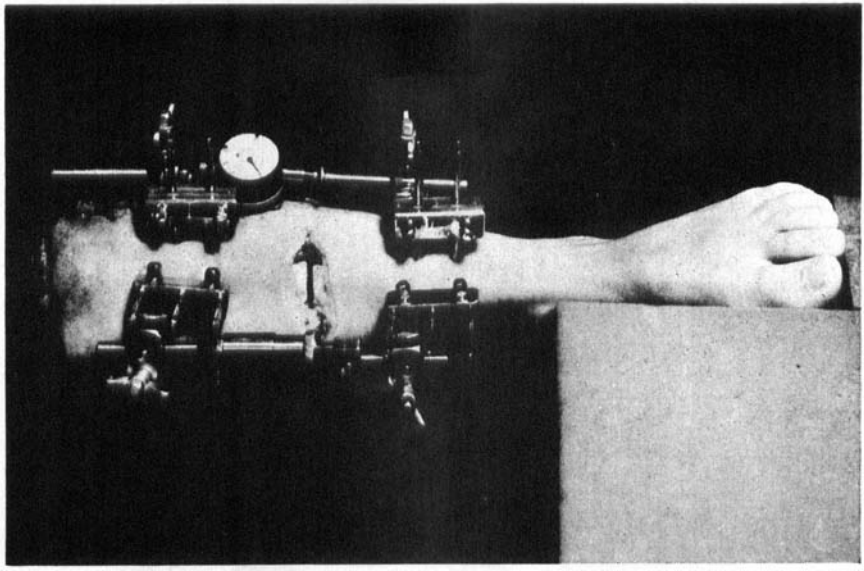

Figure 1. A crural specimen with two sets of Hoffmann's apparatus. One of the sets is used for the compression equipment, the other set for the measuring bridge. The artifical fracture is shown.

and 2). Through a minute transversal incision a 5 mm long piece of the middle of the tibia was removed (Figure 1). The compression bar consists of two steel bars which can be transposed in parallel to each other. The compression is obtained by means of a spring compressed by an adjusting unit (Figure 3). On the external mantle of the spring a dial shows the force applied. The measuring bridge consists of a dial micrometer contacting a pelotte. The dial micrometer measures directly the decrease in distance between the two tibial ends, when the compression bar is loaded. The measurements were made by initially applying a 5 kgf compression and measuring the immediate decrease of the tibial gap. Then an identical compression was maintained for 5 minutes whereupon the dial micrometer was re-read. The compression was gradually increased and the corresponding decrease in the tibial gap was measured both immediately and after 5 minutes. The measurements were continued until a compression force of 35 kgf (the maximum force of the compression bar) was obtained.

Then the decrease of the tibial gap was examined over 3 hours at a continous compression force of 35 kgf (Figure 4).

RESULTS

1) The fibula exerts a progressive and considerable resistance to the axial compression on the tibia (Figure 4).
2) By extrapolation on the curve of deformation, no immediate de-

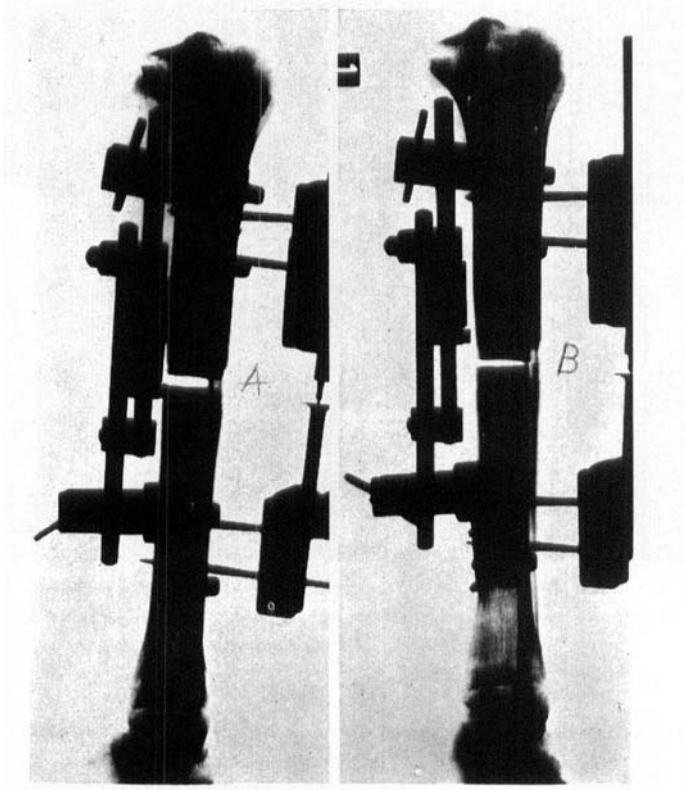

Figure 2. A) X-ray of the crural specimen with a fractural gap of 5 mm before compression. B) 3 hours after an axial compression of 35 kgf the fractural gap measures 3.5 mm.

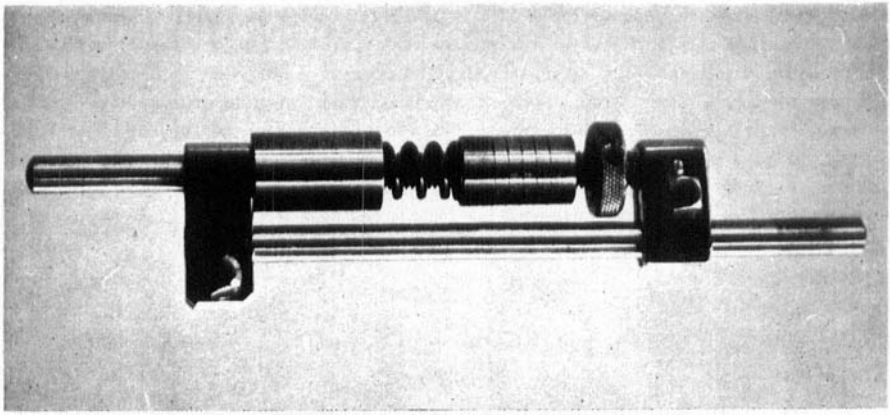

Figure 3. The spring loaded compression bar. A dial shows the force applied.

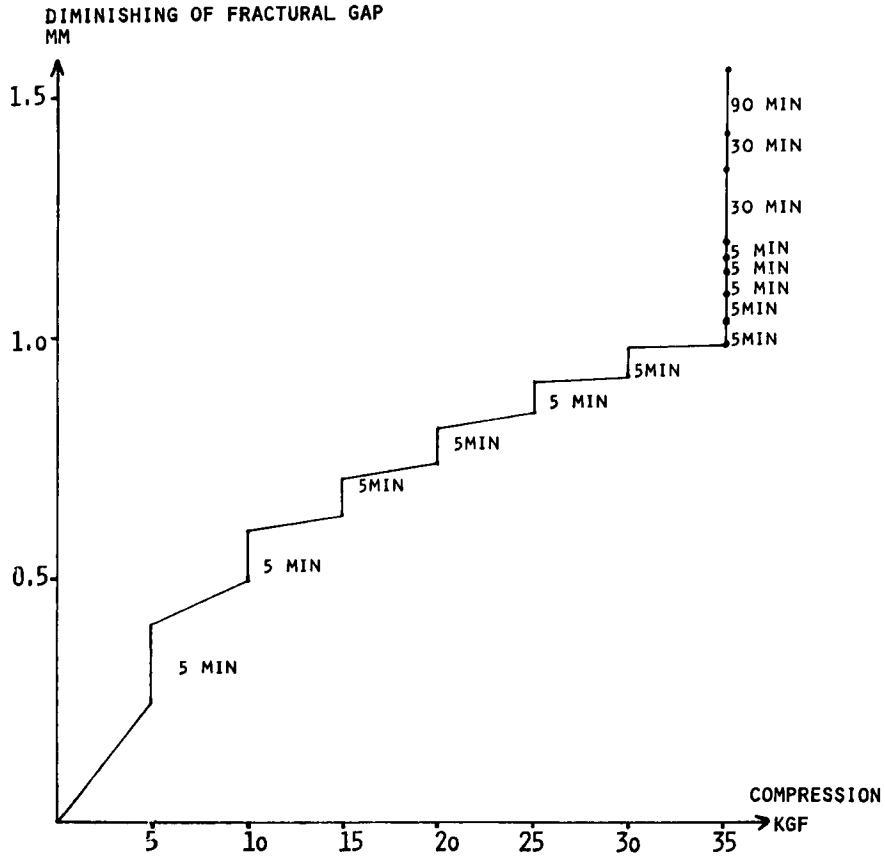

Figure 4. The ratio: Diminishing of the artifical fractural gap / Compression force. The vertical lines on the curve are due to the delayed deformation of the fibula and ligaments.

formation of any considerable size will be obtained by doubling the force of compression (Figure 4).

3) The delayed deformation seems to be considerable and develops constantly for 15 minutes at a maximum compression of 35 kgf. Then the rate of deformation decreases gradually for at least 2½ hours (Figure 5).
4) In this case the Hoffmann apparatus was able to transfer a 35 kgf compression to the tibia with intact fibula without appreciable axial shifting (Figure 2).

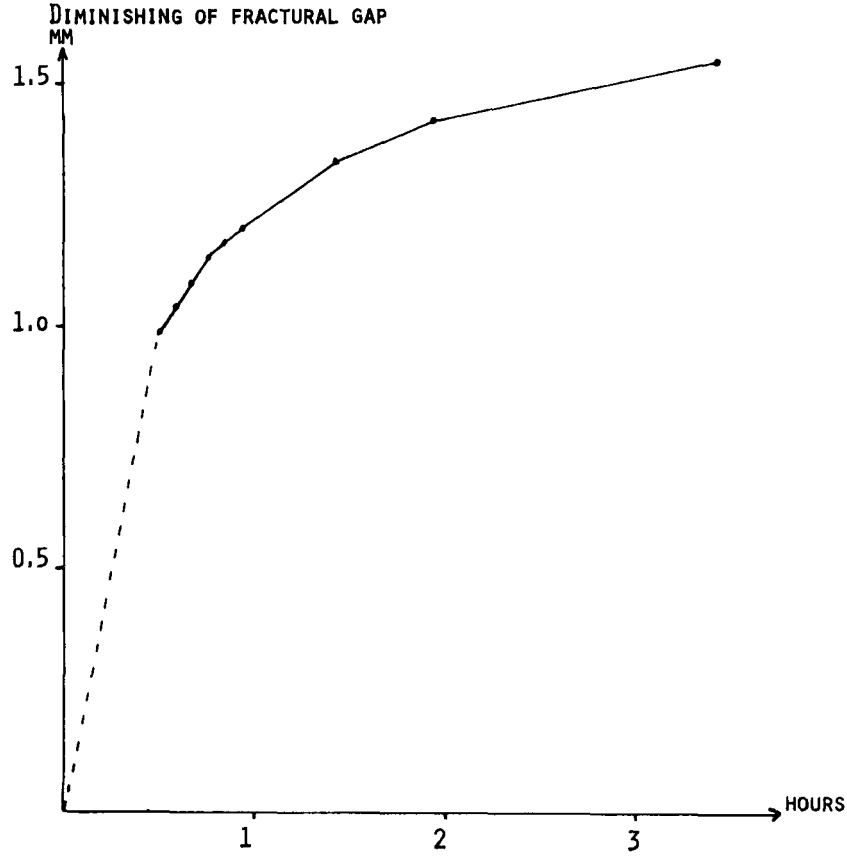

Figure 5. During a constant spring loaded compression for 3 hours the diminishing of the fractional gap slowly decreases due to the increasing resistance of the fibula and ligaments.

CLINICAL CASE

A 21-year-old man fractured the left crus, which was treated with 2 Rush pins and plaster for 6 months. Twelve months after the accident the material for the osteosynthesis was removed. During the following 18 months a clinical pseudoarthrosis developed in the fracture. The patient was transferred to the Orthopaedic Hospital, where X-ray revealed a hypertrophical pseudoarthrosis and a healed fibular fracture (Figure 6). Osteotaxis was performed with approximately 30 kgf axial compression on the tibia. An X-ray taken 24 hours after the osteotaxis revealed that the distance between the two screws closest to the fracture was 72 mm. At intervals of one to two weeks the compression bar was tightened to secure maintenance of the compression. 2½ months after the osteotaxis, the compression bar was replaced by a single steel bar, which only fixed the fracture without compression. At the

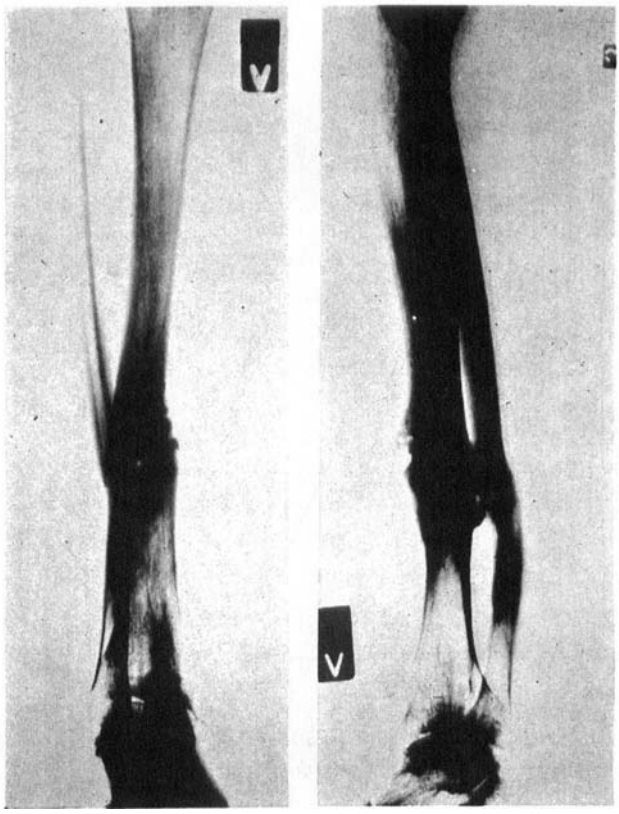

Figure 6. The clinical case of a 2.5 year old pseudoarthrosis.

same time X-ray showed that the distance between the two screws closest to the fracture was 66 mm. An X-ray taken one month later showed the same distance, and the fracture was healed. Figure 7 shows the curve of stability during the healing time (Jørgensen 1972 c). The healing curve resembles the healing curve of a normal fracture (Jørgensen 1972 b, c, d). 3½ months after the osteotaxis, the fracture presented a stiffness corresponding to that of a normal bone; the stabilizing bar was removed and the patient was allowed full weight-bearing. Follow-up measurements one month later showed that the fractural stiffness remained. After this the Hoffmann screws were removed and at the clinical check one month later the patient walked with full weight-bearing without any complaints.

RESULTS

1) From 24 hours to 2½ months after the application of compression on the pseudoarthrosis this seemed to be compressed by 6 mm.
2) This pseudoarthrosis showed a healing curve which resembles the

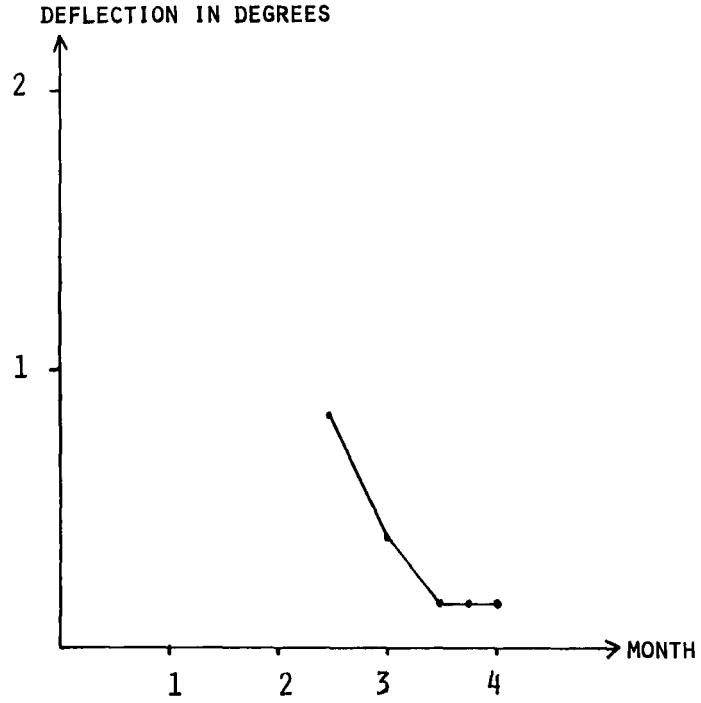

Figure 7. The healing curve of the pseudoarthrosis. The curve is obtained by measuring the fractured stiffness or deflection at a known moment of bending.

curve of a rapidly healing fresh fracture, estimated from the stiffness.

3) The pseudoarthrosis healed rapidly without resection of the fibula.

DISCUSSION

The absolute figures in the measurements on the crural specimen must be taken with a certain reservation as the measuring bridge employed was rather crude. However, X-rays taken before and after the compression indicate that the measurements are reliable (Figure 2). The measurements show that the fibula and the ligaments exert a very vigorous immediate resistance on compression of the tibia. This resistance is somewhat reduced after 2½ hours. The resistance measured is sufficient to explain the fact that even the smallest diastasis of a few millimetres in an isolated tibial fracture will require a very great, brief compression force to be eliminated. The necessary compression

force may very easily exceed the normal muscular tonus, which acts compressively on the tibia. Provided a compression plate is used on a tibial pseudoarthrosis with an intact or united fibula, the fractural fissure will only be reduced corresponding to the immediate deformation of the fibula and its ligaments. If the fracture is to be compressed more than a few millimetres, a considerable part of the force applied will have been spent on the deformation of the fibula and its ligaments. During one or two hours a stress relaxation in the fibula will occur, as well as in the visco-elastic pseudoarthrosis. A couple of hours after a compression osteosynthesis with a stiff plate has been applied to a tibial fracture with an intact fibula, only a compression of the fracture of a few millimetres has been obtained, together with the mechanical stability provided by the plate. Thus one or two hours after the application of the compression, the fractural stability will depend only on the properties of the material used for the osteosynthesis. The fractural stability aimed at by exposing the pseudoarthrosis to compression by a stiff plate is thus rather doubtful.

If it is desired to maintain the compression on a tibial pseudoarthrosis with an intact fibula, external fractural fixation is employed. This fixation allows a correction of after-deformation of the fracture and the fibula. A compression bar with a pre-stressed spring will result in maintenance of the compression force on a visco-elastic fracture and the muscular tonus of the leg is still able to produce an axial compression on the fracture. Acting as a sliding bar, the spring-loaded compression bar is slightly unstable in the lateral plane. The bar may be locked, however, so that it acts as a solid steel bar. It is therefore recommended that the fractured leg should be kept absolutely at rest during the hours or days when the spring is loaded on the compression bar. When the patient is mobilized, the compression bar is locked and thus it exerts a static compression.

The above-mentioned clinical case is one of several treated according to these principles. In this case it was found that even after a 24-hour compression the pseudoarthrosis was still compressible. This and other cases show that a pseudoarthrosis on the tibia, even when fibula is intact, may heal by a single external fixation with compression.

My personal experiences with approximately 150 diaphyseal tibial fractures or pseudoarthrosis are that the fractures have never been infected through the screw holes in the skin and bone. In 15 to 20 per cent of the cases localized secretion from the screw holes may be seen; rarely localized bone reaction (Jørgensen 1972 e, Winther & Østerby

1969, Nicoll 1964). Secretion or bone reaction was often caused by loose screws in the bone, either due to faulty technique or mechanical overloading (Jørgensen 1972 d). When the screws were loose, they could usually be removed ambulantly and the screw holes abraded with a small curette without anaesthesia. Then the wound healed in 10 days. The hospitalization required for the treatment of a pseudoarthrosis in crus amounts to 5 to 10 days. The continued checking of the apparatus may take place ambulantly every week or every other week.

SUMMARY

The object of the present study was to elucidate the problems concerning resection or no resection of the fibula at a tibial pseudoarthrosis. For that purpose a 5 mm long bone specimen was removed from the diaphysis of the tibia on a fresh crus with intact soft parts to represent a pseudoarthrosis. By means of a measuring bridge and Hoffmann apparatus with a calibrated compression bar, the reduction of the fractural gap was measured by increasing axial compression on the tibia.

The fibula appeared to exert a strong immediate resistance on compression of the fractural gap (1 mm corresponding to 35 kgf). The resistance slowly decreased during a matter of hours (1.5 mm after 3 hours at 35 kgf).

A tibial pseudoarthrosis with united fibula fracture was treated with osteotaxis a.m. Hoffmann with an adjustable compression bar. From measurements performed on X-rays the pseudoarthrosis was found to be compressed by 6 mm from 24 hours to 2½ months after the osteotaxis.

The pseudoarthrosis healed in 3½ months and the healing curve corresponded to that of a normal, rapidly healing fracture.

Provided a fibula resection is to be avoided, it is concluded that the employment of an apparatus with adjustable compression is advantageous.

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Correspondence to:

T. Ejsing Jørgensen
Agernvej 7, 8330, Beder
Denmark