Study of fracture consolidation by telethermography. Correlations with radio-clinical examinations

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SUMMARY. 40 osteotomies or fractures treated by osteosynthesis have been followed up in telethermography at regular intervals for 1 to 6 months (starting from the surgery). At the beginning, there is an important and extended hyperthermia which disappears entirely between the 3rd and the 4th month; isothermia corresponds to good bone consolidation and is in agreement with the radioclinical data in 85% of cases. The discrepancies (3 false positives and 3 false negatives) are discussed and 4 pseudoarthrosis cases are analysed.

Key words: infrared thermography; fracture evolution; radio-clinical comparisons; pseudoarthrosis.

INTRODUCTION

The criteria of fracture consolidation treated by fixed osteosynthesis are sometimes hard to appraise. In the lower limb the gauging of functional strength and then the estimation of the moment to rebegin load bearing are not always possible with absolute certainty.

This judgment is based on the analysis of clinical and radiological signs and on the observance of a conventional delay that is variable for each topographical area and corresponds to the usual time required for the consolidation of the involved bone segments. When there is doubt, two attitudes can prevail: excessive carefulness which can extend uselessly the temporary incapacity, or audacity which can risk repeat fractures. It is in these disputed cases that some additional investigations may find their place. Three possible examinations are xero-radiography, the use of isotopes (not the conventional bone scintigraphy, the results of which, it appears, are doubtful but the more conclusive medullography), and lastly, the use of « constraint gages ».

We have looked into the fourth possibility: telethermography [3]. Thus, we have undertaken to study the evolution of the process of fracture consolidation in a certain number of osteotomies and fracture foci treated by osteosynthesis.

The hyperactivity and the vascular development occuring in bone callus in formation are well known phenomena of bone reconstruction and are the local thermogenesis factors.

Judet and Lord, in 1960 [7], demonstrated this by the thermometric study of fracture foci and pseudoarthroses. In 18 patients they implanted thermosensitive needles (thermocouples). These patients were under general anaesthesia and were studied for comparative measurements at three different levels on each limb. Their conclusion was that hyperthermia is evidence of evolution at the focus and that the heat disappears during consolidation and remains in case of pseudoarthrosis. This method has scarcely ever been used afterwards but it is worthy to draw attention to the thermogenesis that takes place in fracture consolidation.

The study of callus formation by dynamic telethermography has not been the subject of numerous studies [1, 4, 5, 6]. To our knowledge it was Prats Esteve and Arandes [8, 9] who, in 1974, were the first to make known their conclusions on their experimental and clinical studies based on the use of thermography in traumatology.

In particular ,they have found that a hyperthermia was discernible at the fracture focus

level as early as the second week in the form of a « bipolar image » (corresponding to the ends of the broken bone segments). Between the fourth and sixth week, these two hot areas tend to join into a larger single hyperthermal area. Finally, there is a progressive cooling down with isothermia reappearing in one a half to three months.

METHODS

The infrared thermography device used was the high speed AGA Camera, 680 Medical type, which gives 16 pictures/second and allows taking negatives in grey scale or in colours, in real time.

Though the heat transmission is particularly good in bone tissue (we were able to evidence bone metastases located up to 10 cm depth), we have preferred to scan only the fractures or the superficial osteotomy foci that have undergone a fixed osteosynthesis and that were not plastered. If some femoral or humeral diaphyses appear in this series it is only because they were in thin patients.

The first telethermographic examination has always been performed after the 30th post-operative day; thus, we have gotten rid of the indirect thermogenesis effects caused by the repair of soft tissue and the scarring of the skin.

If it happened that during the healing period there was a local septic complication, then we systematically eliminated this case from the study, being unable to know the difference between the heat that was due to the infection and that due to the fracture evolution.

Each time, the skin of the involved area has been cleaned of what could cause artefacts and be prejudicial to the measurement sensitivity (dressings, stitches, crusts, and in particular all traces of greasy pomade able to form a thermal screen).

Prior to each examination, the limb has been cooled down by simple exposure to ambient air, at 20°C±1°C, for 10 to 15 minutes; the negatives were taken in sitting or standing up positions.

The examinations have been repeated at regular monthly intervals, for at least three or four occasions and sometimes more (5 to 6 times). They were always made under the same technical conditions in order for them to be easily comparable.

Indeed, we believe that we must lay stress on that point: each time, the distance between the examined limb and the camera must be similar. It is also necessary that the angles of incidence under which an area is scanned be always alike, as should the sensitivity scales (usually 1°C per colour).

Also to appreciate with accuracy the thermal rise compared to the healthy surrounding areas (Δ 1), the image should include the biggest possible affected segment, as well as the contralateral healthy limb to the same extent (to permit measurement of Δ 2 by reference). Then, we will have more and varied reasons to make deductions of value. Finally, the colour negatives (8 tones in Ektachrome, 7 tones in polaroid) have been found to be much more useful for analysis than the negatives in grey scale; indeed, they allow a direct reading of relative differences in temperature while leaving an objective record.

MATERIAL

We have scanned by telethermography and submitted to classical radio-clinical examinatons 68 subjects having fractures or treated by osteotomy. 26 patients did not have the perserverance in undergoing all the examinations which they had been urged to. Of the ramaining 42 cases, 2 were excluded because a septic complication had occurred, so that finally 40 records were subjected to a complete analysis.

They are divided as follows:

Limb fractures: 23 upper limb: 5; lower limb: 18

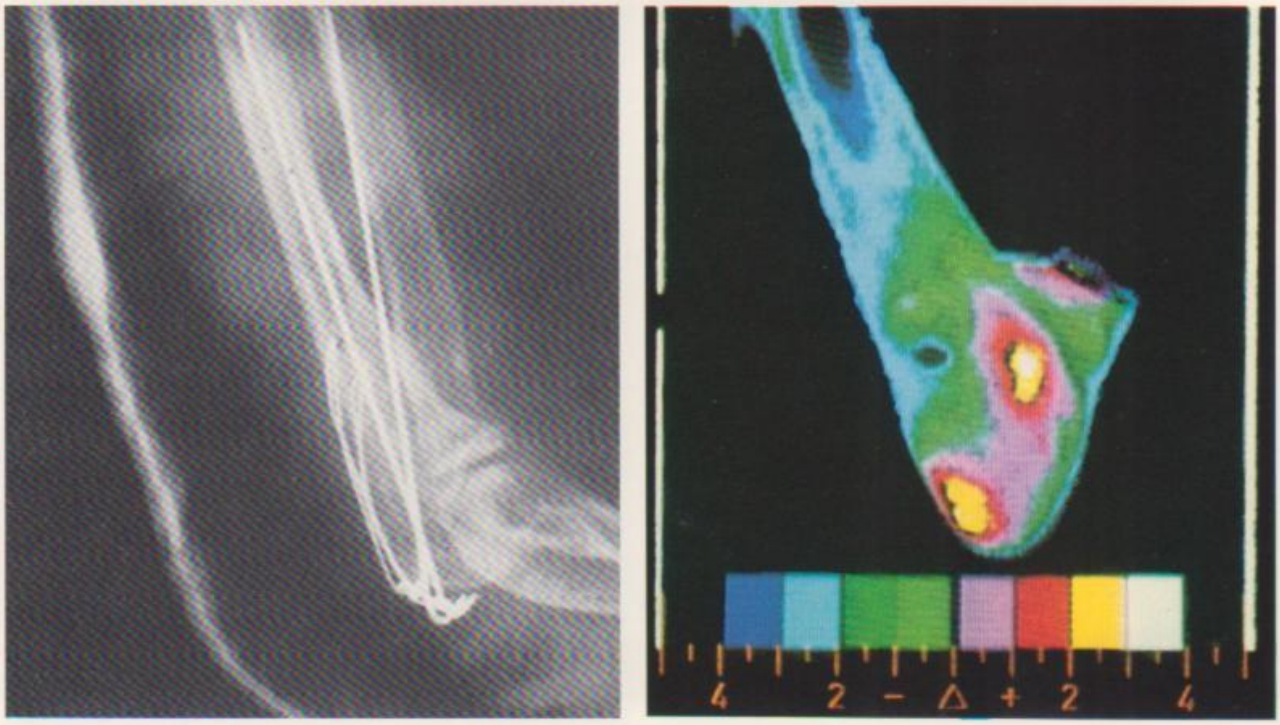
Osteotomies: 13 tibial metaphysis: 10; femoral metaphysis: 3

Knee arthrodesis: 1

Femoral pseudoarthroses: 3 (seen before surgical treatment and followed up later on, after its application).

RESULTS

In each case, the results of thermographic examinations have been compared to those of



A B

Fig. 1 A-B. (A) Fracture of olecranon treated by osteosynthesis. (B) Telethermography of same patient, 1 month after, evidencing 2 clearly divided hot spots = « bipolar image ».

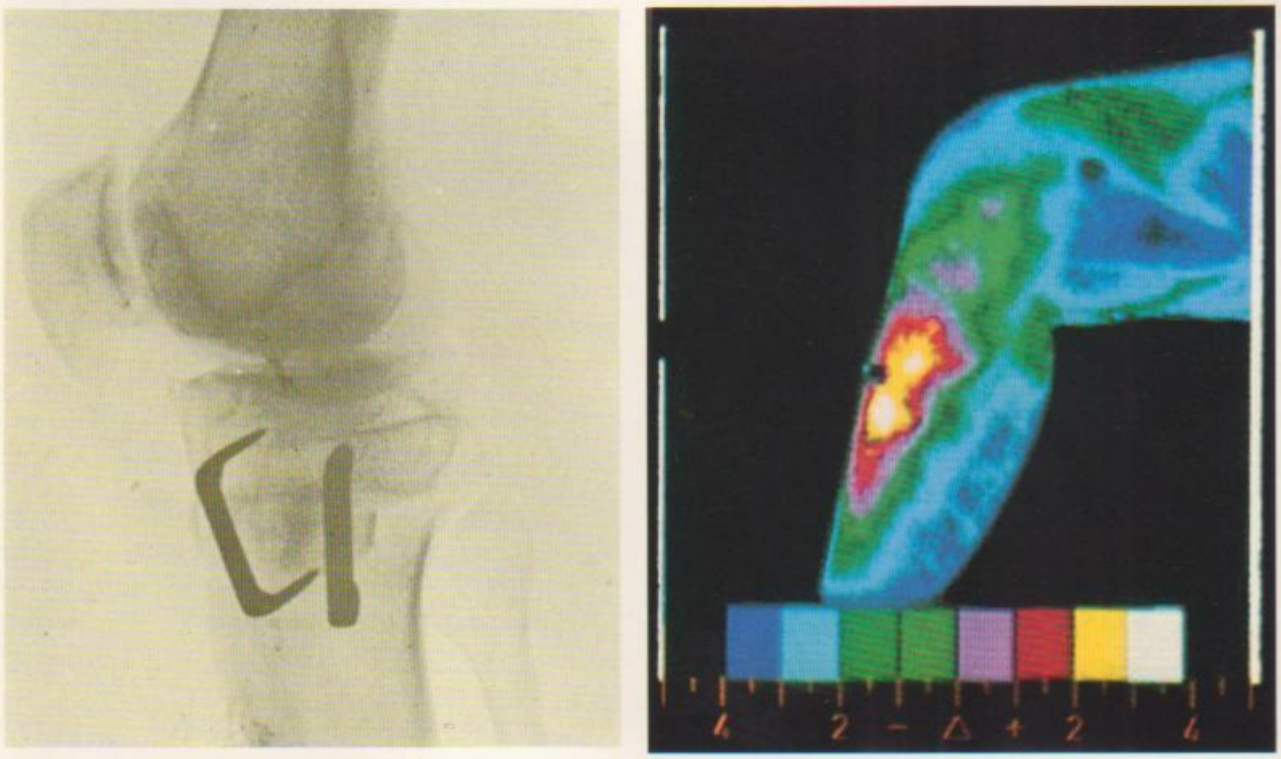


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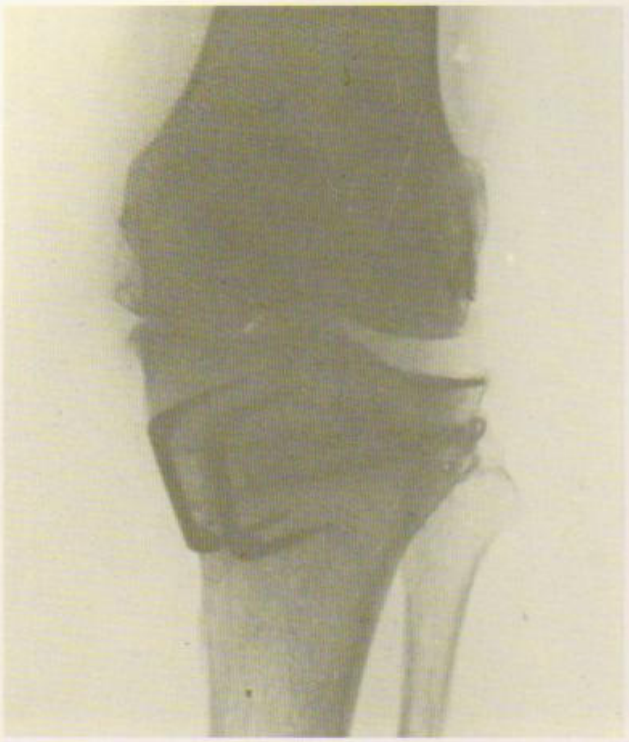
Fig. 2 A-B. (A) Osteotomy of tibial tray. (B) Telethermography of same patient, 1 month later, showing 2 coupled hyperthermal areas forming a « *diabolo* ».



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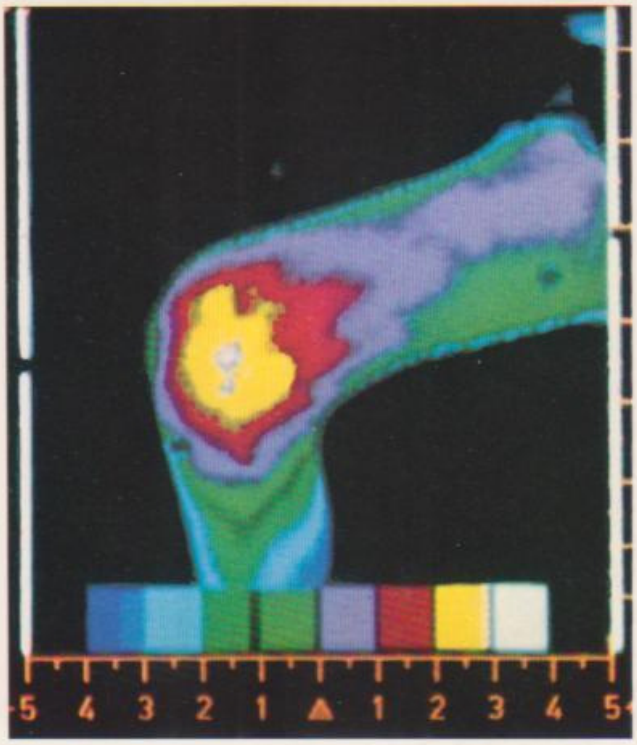

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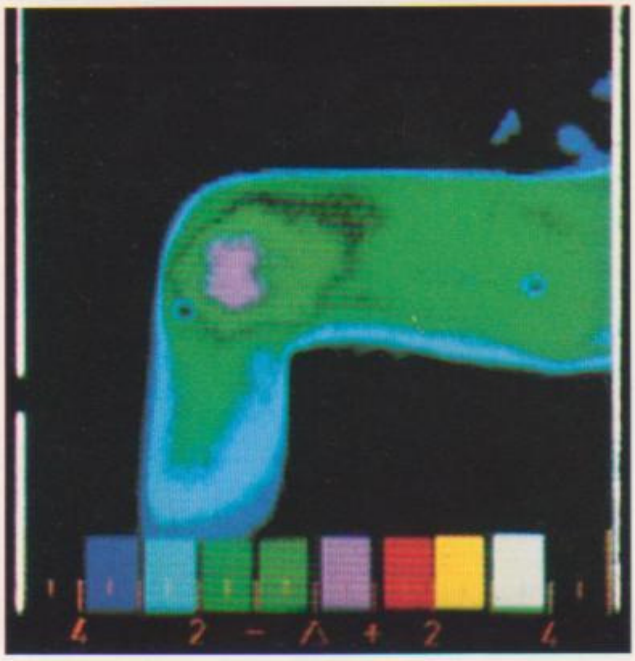

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Fig. 3 A-B-C. (A) Osteotomy of the upper end of the tibia. (B) Same patient, 1 month later. Telethermography shows a huge hot area with irregular outlines and a thermal rise of + 3°C. (C) Same patient 3 months after surgery: almost full regression of hyperthermia. Good radio-clinical bone consolidation.

the usual radio-clinical examinations and their analysis has led us to draw some inferences.

Usual evolution of a fracture focus:

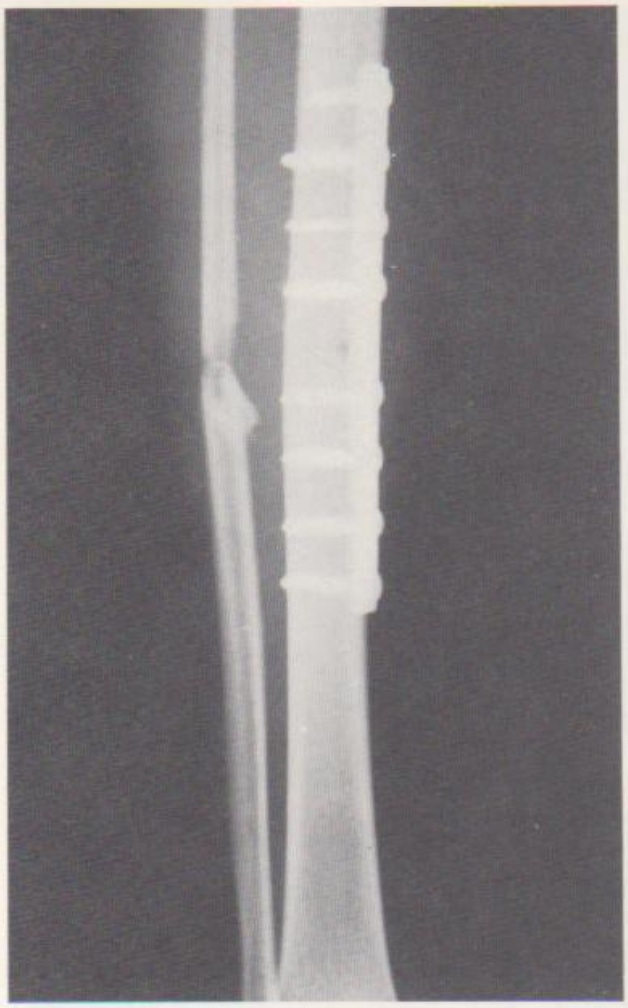
At the end of the first month, while there was no other local hyperthermia, we noted a thermal increase of 2° to 3°C on a surface extending widely up and down the area of the fracture or osteotomy; we have only observed at that time a real bipolar image (Fig. 1B) and 3 confluent images in « diabolo » or sand-box (Fig. 2B). The hot area has often more or less irregular outlines and shows in the middle, most of time, one or several hotter foci by 1°C in average (Fig. 3B, 5B, 6B).

During the next two months the thermal elevation and the hot area persist but to a lesser degree. In fact, they decrease clearly starting from the third examination to disappear as a

general rule during the fourth month (Fig. 3B, C and Fig. 4B, C), rarely later on (Fig. 5B, C).

Most of time, the normalization of the thermal map coincided with the bone consolidation such as we could assert it by other means of clinical and radiological analysis. The correlation between the information they provide and those given by telethermography is rather regular. Out of the 40 retained cases, the thermal normalization has been seen in 34 cases; that is *more than eight times out of ten* (85%).

However, we had 6 results that did not follow this pattern and for which we cannot make a satisfactory interpretation.



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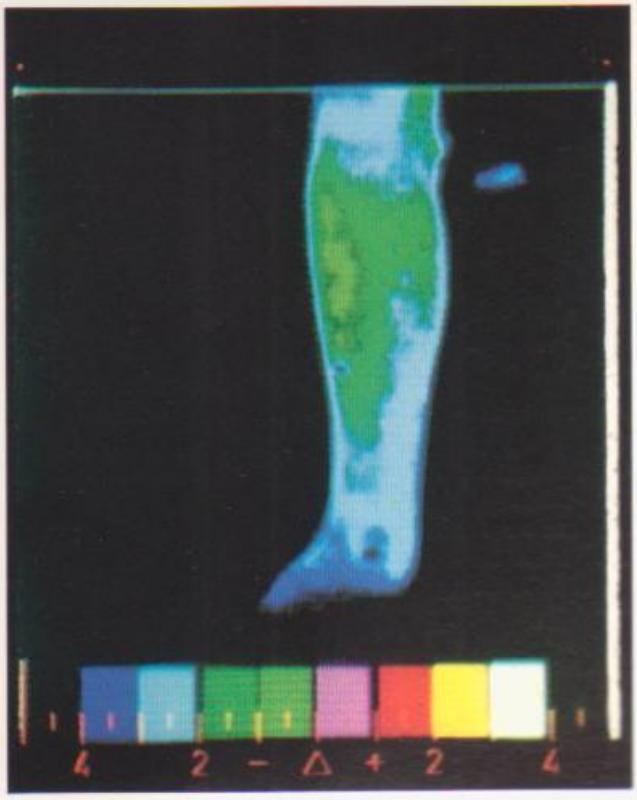

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Fig. 4 A-B-C. (A) Fracture of the median third of tibia treated by osteosynthesis. (B) Telethermography of same patient, 1 month later: very extended hot area with a local thermal rise of + 3°C. (C) Same patient 3 months and a half after surgery: complete disappearance of hyperthermia: the radio-clinical data confirm the fracture consolidation.

We have noted 3 cases with persisting hyperthermia while the radio-clinical consolidation was not in doubt. Did it concern a thermogenesis giving evidence of a remodelling or perhaps of a reorganization of 3 osteotomy foci of the tibia by addition? We cannot say so.

We have also seen 3 cases with an absolutely « flat » evolution without thermal gradient. We have always found this isothermia in cases where the osteosynthesis was made under compression, therefore where the consolidation did not necessitate an intermediate step of callus formation. However, we have also

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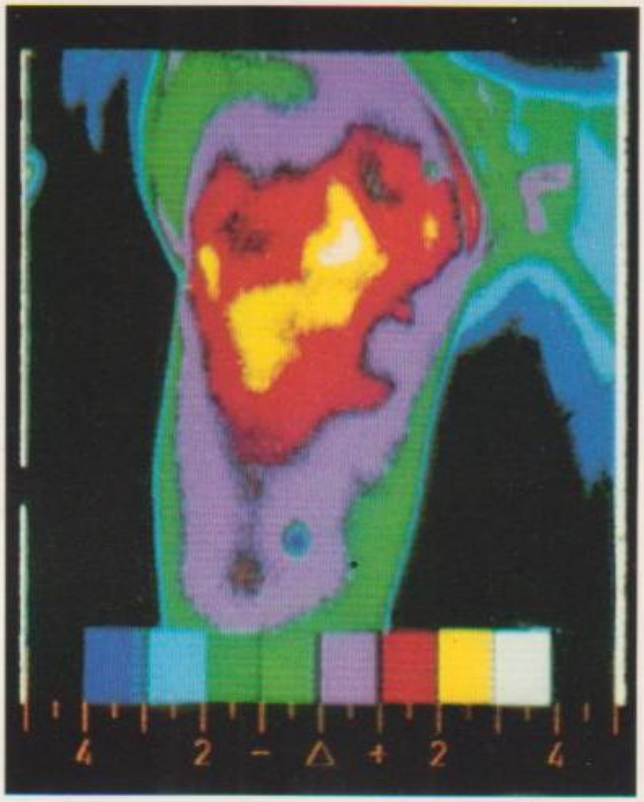

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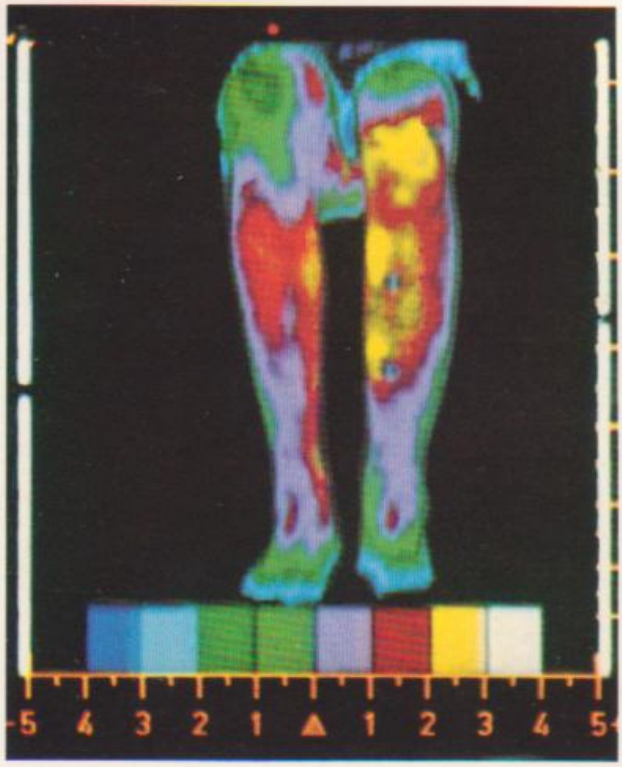
Fig. 5 A-B-C. (A) Tibial tray osteotomy. (B) Same patient 45 days later. The infrared thermography shows an important hyperthermia with irregular outlines (thermal rise: + 3°C). (C) Same patient 4 months after osteotomy: the hot area is reduced but there remain 2 clear foci with an even higher thermal rise (2,5°C), indicating a delay in consolidation.

noted an initial hyperthermia then a progressive decrease for fractures having undergone the same treatment; therefore, we do not venture an interpretation; we merely observe the existence of 3 false positives and 3 false negatives.

Analysis of pseudoarthroses

We had the opportunity to study 4 pseudoarthroses in telethermography. 3 of them showed a pattern of hyperthermia (Fig. 6A, B, C); in each of these cases, the surgery showed a well vascularized bone with hyperemia. It



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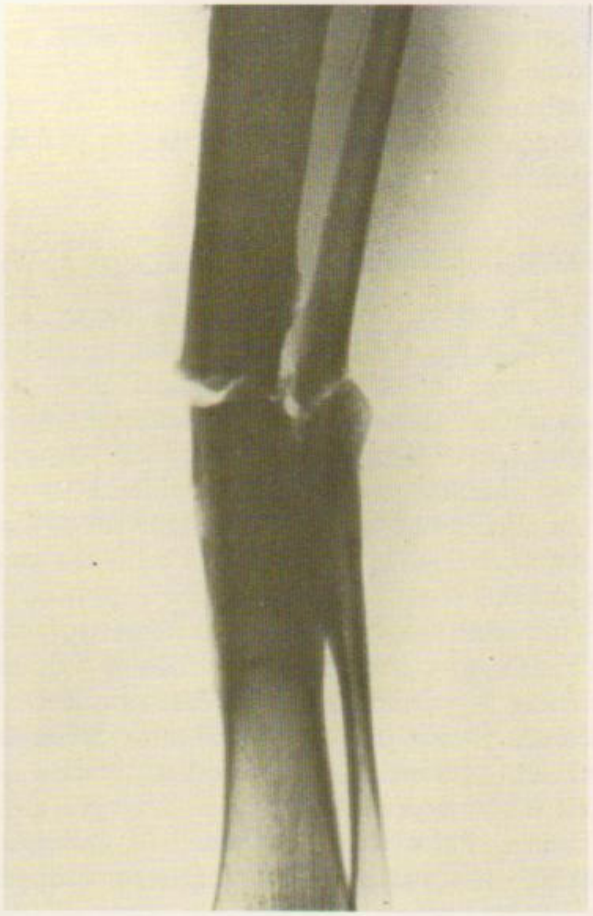

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Fig. 6 A-B-C. (A) Fracture of the median third of the tibia and fibula. Telethermography performed 4 months after orthopedic treatment shows a persisting hyperthermal area with irregular outlines. (B) Telethermography of same patient at the 5th month: extended persisting hyperthermia with a high thermal rise (2 to 3°C depending on areas), indicating a hyperthermal pseudoarthrosis. (C) Radiographic pattern of this pseudoarthrosis which has been verified surgically (« hypervascular pseudoarthrosis »).

involved « hypervascular pseudoarthroses » [7] for which the thermal gradient even higher immediately became normalized regularly during the following months to disappear at the consolidation.

An older pseudoarthrosis appeared as *isothermal*. During the surgery, the bone appeared inert and really threatened with necrosis. This was, in our opinion, an « avascular pseudoarthrosis » [7] then « cold ». Of course, this is only an hypothesis, its frailty is due to the small number of studied cases and we will take care not to give advice regarding pseudoarthroses.

CONCLUSIONS

The study of fracture consolidation by telethermography and the comparison of results with those of usual radio-clinical data has shown that there was a correlation between them in more than 8 times out of ten. The rise of the thermal gradient gives evidence of the bone changes at the fracture focus level. The thermal normalization coincides with the consolidation.

However, the existence of contradictory results (fracture obviously consolidated but remaining hyperthermal, and isothermal fracture all during the evolution) must incite us to interpret the thermographic examination results with much caution.

It should always be compared with the radio-clinical examinations; however, in some disputed cases where precisly the conventional means of analysis do not lead to a conclusion, telethermography may furnish additional information affording a more accurate diagnostic or prognostic orientation.

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