

A Unique Case of a Titanium Plate Failure Following Osteosynthesis of a Forearm Fracture

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transverse fatigue fracture.

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INTRODUCTION

Implant design for fracture fixation has undergone a gradual evolution over the years as orthopaedic researchers have tried to facilitate healing and decrease complication rates. One recent innovation in the manufacture of plate fixation systems has been the use of commercially pure titanium rather than stainless steel^[1]. Titanium, either pure or alloyed has been established as the material of choice in orthopaedic implant manufacturing since it combines excellent mechanical performance with corrosion resistance and high biocompatibility^[2]. Offsetting these advantages are some disadvantages, among which titanium's brittleness and softness that have been implicated in an increased rate of implant failure^[1].

We hereby present a case of an extremely rare mode of a titanium plate failure, where both a longitudinal crack that was attributed to a brittle fracture, as well as a subsequent transverse crack as a result of fatigue fracture was present.

CASE REPORT

A 52-year-old woman that had been involved in a car accident had suffered a grade I open comminuted fracture of the middle third of both radius and ulna following a direct blow on her forearm (Figure 1). Since the fracture was unstable, surgical treatment was decided.

Following satisfactory open reduction the radius was stabilized

ABSTRACT

A 52-year-old woman suffered comminuted fractures of both the radius and ulna that were treated surgically with internal fixation with titanium plates and screws. The immediate postoperative X-rays revealed a longitudinal crack of the proximal part of the ulnar plate without loss of reduction. Therefore a protective above-elbow splint was applied for 2 months in order to facilitate fracture healing. Follow-up radiographs displayed propagation of the crack finally leading to a transverse fracture in the middle of the plate and subsequent pseudarthrosis of the ulnar fracture that required a new fixation and grafting. Plate analysis failed to reveal any material defect. Electron microscope scanning showed that appearance of the longitudinal crack was typical of a brittle fracture, while the transverse crack displayed characteristics of a fatigue fracture. Titanium brittleness and softness have been implicated in titanium implant failure. The above described configuration and especially the longitudinal crack is extremely unusual. Experimental evidence suggests that the longitudinal crack was the result of a brittle fracture. This eventually caused implant failure that subsequently led to the



Figure 1 Fracture of the middle third of both radius and ulna, suffered by a 52-year-old woman involved in a car accident.

with an one third 7-hole titanium plate (Synthes, Solothurn, Switzerland), while a similar plate was applied to the ulna. Intraoperatively, the surgeon had the feeling that the proximal screw of the ulnar plate had been somewhat over-tightened, but there were no further worrying signs, nor episcopal signs of implant insufficiency or failure.

The immediate postoperative X-rays revealed a longitudinal crack beginning at the proximal part of the ulnar plate end passing through the two proximal plate holes and reaching the third hole (Figure 2).



Figure 2 The immediate postoperative X-rays revealed a longitudinal crack beginning at the proximal part of the ulnar plate end passing through the two proximal plate holes and reaching the third hole.

Since there was no loss of reduction or displacement of the plate and screws we decided against an immediate revision of the osteosynthesis and a protective above-elbow splint was applied for 2 months in order to facilitate fracture healing.

Three months postoperatively, the radiological picture of the ulna remained unchanged, the patient was asymptomatic, and any additional surgical intervention was precluded, although there were no signs of fracture consolidation.

On six-month follow-up, X-ray control revealed that there was an additional transverse crack through the third hole, causing a complete separation of the plate fragments and leading to a complete loss of contact between the proximal plate and screws (Figure 3).

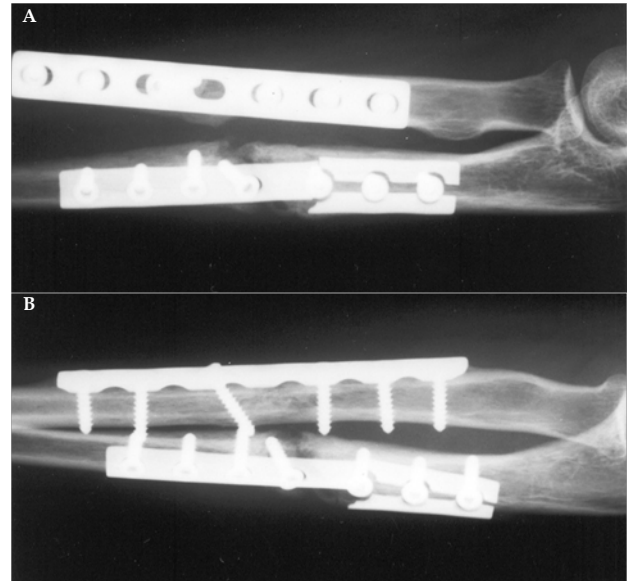


Figure 3 X-ray control on six-month follow-up revealed that there was an additional transverse crack through the third hole, causing a complete separation of the plate fragments.

Since there was radiologic evidence of pseudarthrosis at the fracture site and the osteosynthesis had failed, revision surgery was decided (Figure 4).

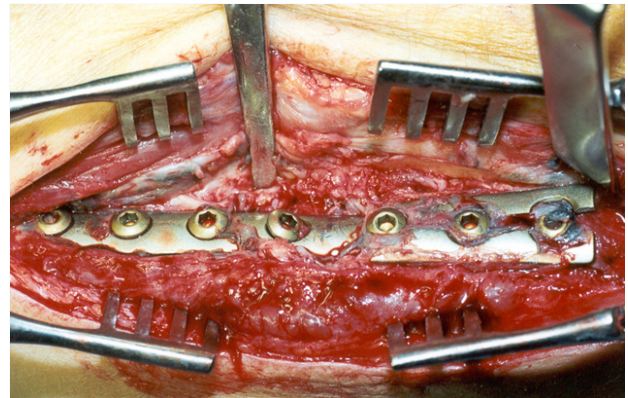


Figure 4 Intraoperative picture of the fragmented plate.

The broken plate and the screws were removed and a new osteosynthesis was performed with a stronger 9-hole LC-DCP titanium plate (Synthes, Solothurn, Switzerland) and was augmented with autologous bone graft.

Three months postoperatively, there was radiologic evidence of solid fracture consolidation and the patient was free of symptoms with unrestricted upper-limb use.

The broken plate was subjected to detailed laboratory analysis in order to elucidate the above described unusual mode of failure. Qualitative and quantitative determination of the plate composition and structure with spectrometry failed to reveal any defect and concluded that the plate was manufactured according to the appropriate standards.

Moreover, scanning of the plate's surfaces at the fragmentation site with electronic microscope showed that appearance of the longitudinal crack was granular and typical of a brittle fracture (Figure 5), with no evidence of plastic deformation.

On the contrary, the transverse crack displayed characteristics of a fatigue fracture with a smooth, burnished surface (Figure 6).

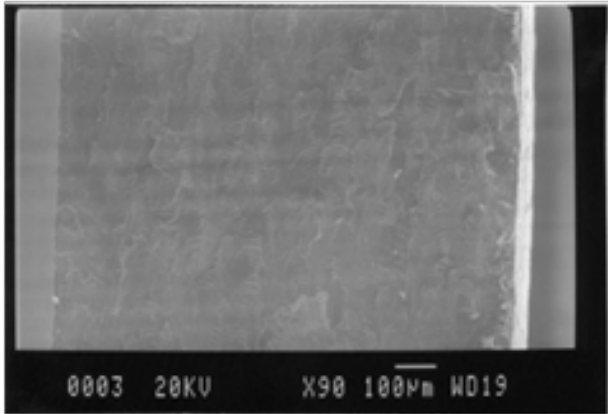


Figure 5 Electronic microscope scanning showed that appearance of the longitudinal crack was granular and typical of a brittle fracture.

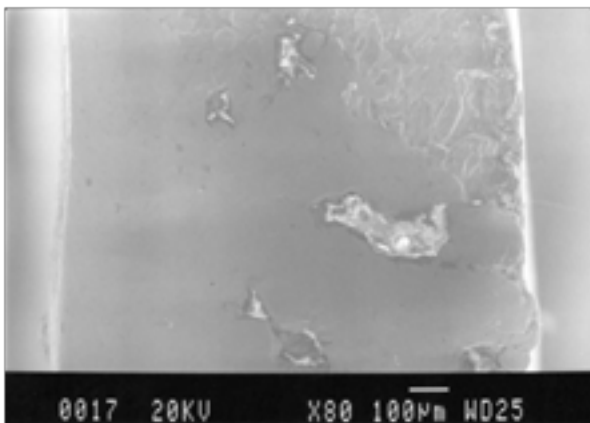


Figure 6 Electronic microscope scanning revealed that the transverse crack was a fatigue fracture with a smooth, burnished surface.

DISCUSSION

A number of cases of postoperative implant failures have been reported in the literature and various failure mechanisms have been described^[3-8]. It is argued that implant failure should not be attributed to a single failure mechanism, but it is rather a multi-factorial process related to the implant, the procedure and the patient^[9]. In a large retrospective series reporting on postoperative implant failures, there was a failure rate of 13% in the titanium implant group compared to 1% of stainless steel implants ($p < 0.001$)^[1].

Mechanically, titanium has a lower modulus of elasticity compared to stainless steel, meaning that implants of the same dimensions are less stiff^[1]. This lower stiffness of titanium may improve load sharing with the bone, thus preventing stress shielding, but on the other hand it may be implicated in increased implant failure rates due to fatigue fracture^[1]. The later are usually observed in comparatively soft metals like titanium^[10].

A brittle fracture usually occurs because of the presence of cracks in the structure of the material that are either due to tiny defects resulting from a manufacture deficiency or they develop later following implant loading. In this case, over-tightening of the proximal screw may have triggered crack initiation. This highlights another possible disadvantage of titanium implants, since Titanium's lower ductility gives less tactile warning when screws are over-

tightened^[11].

Such a crack can extend rapidly at applied load levels, which are nominally well within the linear load-displacement response of the component. Since the immediate appearance of the crack could not be due to a possible fatigue fracture and its propagation parallel to the implant's long axis could not be attributed to increased shear or bending forces, both were evidently the result of a brittle fracture.

The transverse crack became apparent one year postoperatively, nine months after the last radiographic control where it was not evident. This crack displayed the characteristics of a fatigue fracture. A fatigue fracture is usually the result of cyclic loading, where the applied force exceeds the resistance of the material. In a fatigue fracture there are signs of plastic deformation of the material, which precedes the initiation and propagation of the crack. A fatigue fracture will have two distinct regions; one being smooth or burnished as a result of the rubbing of the bottom and top of the crack. The second is granular, due to the rapid failure of the material that resembles a brittle fracture.

In this case the preceding brittle fracture has rendered the plate more prone to a possible fatigue fracture. The failure of the fracture to unite, in the absence of adequate stability in the fracture site, resulted in increased instability and the implant was subsequently led to complete failure.

Although our paper could rather not be described as a novel or innovative work since it is a clinical case report, we believe that it significantly contributes to the understanding and treating of a common clinical problem, namely implant failure. The strength of our paper lies on the detailed and over a longer period of time clinical documentation, combined with the adequate laboratory investigation of a very unusual case of implant failure. Our work tries to shed some light in the often not well understood field of the causative factors and resulting patterns of implant failure, an effort that bears quite some clinical significance.

CONCLUSION

In conclusion, our experimental evidence suggests that the longitudinal crack was the result of a brittle fracture that might have been triggered by screw over-tightening. This subsequently led to the transverse fatigue fracture as the result of the increased and sustained cyclic loading.

For everyday clinical practice, our findings indicate that surgeons should be extremely cautious when tightening titanium screws in order to avoid overtightening. Moreover, the appearance of even a minor crack in the immediate or early postoperative radiographs may represent an implant brittle fracture with a highly unpredictable pattern of progression. In such a case, the decision for an immediate revision procedure may be justified.

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