Physical Analysis of Failed Orthopaedic Plates Used in long bone fractures

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Abstract

Background: **Orthopaedic implants are devices produced to replace bones or support broken bones. The use of metal devices is one of the greatest achievements in orthopaedic history. Orthopaedic devices such as joint prostheses and internal fixators are the most used implants. These implants are constructed of a variety of metals.** ***Aim:*** **This study aimed to analyze the physical and chemical properties of failed orthopaedic plates to improve surgical outcomes of patients.** ***Methods:*** **The present study was designed as an analytical cross-sectional study that included a total of 17 samples of broken orthopaedic plates used in the fixation of long bone fractures (titanium or stainless steel). The study was performed at Suez Canal university teaching hospital, Ismailia general hospital where the orthopaedic operation takes place as well as Port-Said general hospital as it is the referral hospital for orthopaedic operations in the governorate, samples analysis was carried out at the Faculty of Engineering Port Said University and the central metallurgical research and development institute.** ***Results:*** **Regarding femoral plates, titanium plates had higher Young's modulus (3.39 ± 2.36) than stainless plates (2.52 ± 1.04). On the other hand, titanium plates had a lower peak load (28.2 ± 9.39) than stainless plates (33.9 ± 0.12). Additionally, titanium plates had lower strain at the break (0.159 ± 0.05) than stainless plates (0.211 ± 0.11). Regarding ulnar plates, reconstruction plates had lower Young's modulus values significantly lower than tubular 1/3 and proximal plates. On the other hand, tubular 1/3 plates had significantly higher peak load values than reconstruction and proximal plates. In addition, reconstruction plates had significantly higher strain at the break value than tubular 1/3 plates and proximal plates.** ***Conclusion:*** **The findings of the study were that some plates did not fulfil the physical criteria (41.1%) and chemical composition (14.3% of titanium plates) for standard plates which play a major role in plates failure, also study showed that there was a difference in criteria in-between the same type of the plates according to the source of the plates.**

Keywords: Orthopaedic Plates, Failure, Physical analysis.

Introduction

Implants for orthopaedic use are made to support or replace shattered bones. One of the greatest accomplishments in orthopaedic history is the use of metal devices. The most often utilised implants are orthopaedic ones, such as joint prostheses and internal fixators. A number of metals are used to make these implants. Orthopaedic implants should be created to have longer life

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spans due to the significant increase in human life expectancy. Additionally, the usage of top-notch implants is required due to the rise in traffic accidents. Therefore, it is crucial to consider the biomechanical characteristics of corrosion/erosion resistance and biological environment adaption. Implants are made from metals like cobalt chrome alloy, stainless steel, titanium, and their alloys because they have good biological adaptability, resistance to corrosion and erosion, mechanical hardness, and are reasonably priced. Several elements are necessary for successful implantation, all of which should be carefully examined. (1) According to the underlying theories, the majority of fractures could be fixed using a number of techniques; nevertheless, internal fixators give a flexible fixation, permit long-term therapy, in addition to giving the bone its fundamental strength. Internal fixation provides the best articular anatomy, patients treated with it have a lower risk of developing secondary osteoarthritis and using it healing occurs successfully despite the fact that it disrupts the biologic environment and allows for early functional mobilisation with at least partial weight bearing. (2) Wires, nails, pins, screws, and plates are some of the tools that can be used for internal fixing. Among all of these implants, plates are currently the most widely utilised because they can withstand bending, rotational, compression, and shearing stresses. Additionally, it comes in a variety of shapes, sizes, and styles. After World War II, the biomaterial for plates saw substantial improvement. It is presently recognised as a synthetic or organic substance utilised in the construction of replacements for missing or damaged biological structures in an effort to restore its form and functionality. Biofunctionality and biocompatibility are two factors that affect how effective it is. Mechanical characteristics are referred to as "biofunctional," whilst a material's compatibility with the human body is referred to as "biocompatibility”. (2)

Failure of the implant lengthens the healing process, adds new issues for the patient, and raises costs. The healing process is complicated by the fact that an implant failure frequently results in a re-fracture. Sometimes additional, frequently more difficult repeat procedures are required. These issues highlight the value of determining the root causes of this issue. (1) Implant failure can be caused by a flaw in the implant itself or by outside variables such the operation itself, the degree of union, and patient non-compliance with post-operative instructions. According to a 2007 study conducted in Argentina, the quality of many implants made there is not as great as that of implants made in Brazil and European nations. In those nations, just a small portion of implants fail. Due to the rising usage of implants, it is crucial to look into how they affect patients and how much money they cost the national health system. (1)

Surgical implants may experience premature failure due to the severe operating conditions they are subjected to, including corrosion, wear, and mechanical loads (both static and dynamic). These failures are affected by things including the choice of materials, manufacturing techniques, medical installation methods, postoperative problems, and patient abuse. The methodical examination of surgical implants that have been removed from use advances our understanding of clinical implant performance, demonstrates the interaction between implants and bodies, lays the groundwork for the creation of biocompatible implant materials, promotes design improvement, and supports device research. [3] Implants for intramedullary osteosynthesis fail for a variety of reasons. Different nail varieties respond to different situations in different ways. Orthopaedic implants can fail for a variety of reasons, including improper design, insufficient testing before to use, processing problems, poor surgical technique during insertion and extraction that can result in scratches or cracks, and more. The nails had been there for somewhere between 10 and 12 months. They were all eliminated due to underlying conditions such implant-related discomfort, non-union, and implant failure. [4] Multiple biological parameters are impacted by the reactivity of the metallic ions that leak from the implant owing to corrosion in the human body. When a substance begins to corrode, the disintegration of the metal will cause erosion, which will eventually cause the implant to become brittle and fracture. Due to an increase in exposed surface area and the loss of the protective oxide layer once the material fractures, corrosion accelerates. If the metal particles are not surgically removed, they may dissolve and fragment even more, which could cause irritation in the tissues around them. [5]

The association between the hypersensitive response and implant failure has been a major focus of the literature on metal implant hypersensitivity. Following joint replacement, especially in individuals who have suffered implant slippage, circulating metal ions rise. This rise has been attributed to the buildup and ongoing release of metal ions into the surrounding tissue as a result of the corrosive process, which is unavoidable. A localised inflammatory reaction that is brought on by these metal ions may result in implant failure. [6]

Through metallurgical investigation using a scanning electron microscope (SEM), it was discovered that 25% of failures demonstrated fatigue via ductile type failure, 16.5% exhibited signs of manufacturing impurities, and 42% of failures occurred owing to corrosion + erosion-corrosion. [3]

Through the course of the study, we hope to identify the physical factors that contribute to implant failure and enhance the results of orthopaedic procedures. The study aimed to analyse the physical and chemical properties of orthopaedic plates to improve surgical outcomes of patients.

Patients and methods

Study design:

Analytical cross-sectional study

Study Setting:

As the referral hospital for orthopaedic operations in the governorate, Port-Said General Hospital, Ismailia General Hospital, Suez Canal University Teaching Hospital, samples were analysed at the faculty of engineering at Port Said University, and the central metallurgical research and development institute at Helwan.

Target Population:

Patients presented to hospitals in Suez Canal area with broken orthopaedic plates.

Inclusion Criteria:

1- Patients with broken plates both upper and lower limbs.
2- Both sex.
3- Age between 16 and 70 years.

4- Patients with long bone fractures

Exclusion Criteria:

1- Patients with recent traumatic event upon already placed plates.
2- Patients with recurrent plates failure.
3- Patients with infected plates.
4- Patients with pathological fractures due to bone tumours.
5- Patients with osteoprotic bone fractures

All patients received counselling regarding their involvement in the study as well as information about the study's objectives, examination procedures, and methodologies. As a result, each patient gave their informed permission.

Study tools\procedures:

Prior to taking a detailed history, doing an examination, and ordering any necessary investigations, we first chose our patients based on the aforementioned criteria. Then, a few patients were prepared for the removal of plates (made by the same company) and the treatment of any difficulties that might have arisen from plate breaking. The following tests were then performed on all of the removed plates to determine their chemical composition and physical specifications.

1-Chemical analysis:

The "Foundry Master Pro" optical emission spectrometer, which is used as a metal analyzer and produces high resolution and detailed results of the sample composition, was used to perform chemical analysis of the samples at the central metallurgical research and development institute's foundry department.

Test done under the following environmental conditions:

Temperature 24.9^{o} C Humidity 39%

2-Hardness test:

Hardness testing are also carried out at the central metallurgical research and development institute's mechanical tests section to determine the hardness of the plates.

Since the needed calculations are independent of the size of the indenter and the indenter may be used for all materials regardless of hardness, the Vickers hardness tester was employed, which is frequently simpler to use than other hardness tests.

Like all conventional measures of hardness, the Vickers hardness tester's fundamental measuring principle is to look at how well a material can withstand plastic deformation from a known source.

All metals can be tested with the Vickers test, which also has one of the broadest scales of any hardness test. The Vickers Pyramid Number (HV) or Diamond Pyramid Hardness is the measure of the test's hardness (DPH).

3-Tensile test:

We tested the tensile strength of our samples in the engineering faculty lab at Port Said University. A tensile test's fundamental concept is to clamp a sample of a material between two fixtures known as "grips." The substance's length and cross-sectional measurements are known. While holding the other end fixed, we start to apply load to the material that is held at one end. As we continue to apply more force or load, we measure how much the sample's length has changed. measuring the length change as you increase the load till the item starts to strain and then breaks. Results of the test represented by a load (amount of load) vs strain graph (amount of stretch).

Since the size and characteristics of the material determine the amount of load required to stretch it.

When engineering a material to withstand specific forces, the ability to make accurate comparisons can be crucial. In order to compare different materials without regard to their size, we also need to be able to divide the applied load by the starting cross-sectional area and the amount of stretch by the initial length.

We may compare the strength of various materials, regardless of their sizes, using the engineering stress-strain response of a material. Tests were conducted using a 0.08 mm/min strain rate.

Statistical analysis

Statistical Package of Social Sciences (SPSS) version 20 was used to manage the data.

Statistical significance tests were performed, and at the 95% level of confidence, a P value of less than or equal to (0.05) was deemed statistically significant.

For continuous endpoints, means and standard deviations (SD, normal data) were largely used, while frequencies were used for categorical endpoints. The t-test or Mann-Whitney U test was used to compare continuous endpoints between the patient group and the control group, and the Chi-Square test was used to compare categorical endpoints.

Results

In our study we categorized the samples according to anatomical site of the plate (femoral and ulnar), chemical composition of the plates (Titanium and Stainless) as well as different types of plates used for ulnar fractures as shown in table 1.

Table 1: Types of femoral plates (distal femoral plates) according to chemical composition either titanium or stainless steel.

Variables	**n = 17**
Site of the plate	
Femoral	12 (70.6)
Ulnar	5 (29.4)
Types of femoral plates (n= 12), n (%)	
Stainless	5 (41.6)
Titanium	7 (58.4)
Types of ulnar plates (n= 5), n (%)	
Reconstruction	2 (40)
Tubular 1/3	2 (40)
Proximal	1 (20)
Data are presented as number (%) or mean and SD.	

Physical analysis of femoral plates samples showed that femoral titanium plates had lower peak load (28.2 ± 9.39) than femoral stainless plates (33.9 ± 0.12). Femoral titanium plates had lower strain at the break (0.159 ± 0.05) than femoral stainless plates (0.211 ± 0.11), while femoral titanium plates had lower shore hardness (240.5 ± 43.1) than femoral stainless plates (275.2 ± 57.7) as shown in table 2.

Table 2. Comparison between titanium and stainless femoral plates regarding Young's modulus, strength of material, Strain at the break and Shore hardiness			
Variables	Types of femoral plate		p-value
	Titanium (n = 7)	Stainless (n = 5)	
Young's modulus			
mean ± SD	3.39 ± 2.36	2.52 ± 1.04	0.46
median (range)	2.7 (1.17 – 7.4)	1.78 (1.73 – 3.71)	
Strength of material (load)			
mean ± SD	28.2 ± 9.39	33.9 ± 0.12	0.21
median (range)	32.8 (13.5 – 35.17)	33.9 (33.7 – 34.01)	
Strain at the break			
mean ± SD	0.159 ± 0.05	0.211 ± 0.11	0.27
median (range)	0.146 (0.100 – 0.299)	0.252 (0.027 – 0.264)	
Shore hardiness (HV)			
mean ± SD	240.5 ± 43.1	275.2 ± 57.7	0.25
median (range)	226 (220 – 338)	315 (211 – 320)	

[a] p-values are based on Mann-Whitney test. Statistical significance at P < 0.05
P-value 0.46 statistically insignificant between two types

Physical analysis of the samples showed that reconstruction plates had lower Young's modulus value significantly lower than tubular 1/3 and proximal plates. Tubular 1/3 plates had significantly higher peak load value than reconstruction and proximal ulnar plates. Reconstruction plates had significantly higher strain at the break value than tubular 1/3 plates and proximal plates. Proximal plates had significantly higher shore hardness value than tubular 1/3 plates and reconstruction plates as shown in table

Table 3. Comparison between ulnar plates regarding Young's modulus, strength of material, Strain at the break and Shore hardiness				
Variables	Types of ulnar plates			p-value
	Reconstruction (n=2)	Tubular 1/3 (n=2)	Proximal (n=1)	
Young's modulus				
mean ± SD	0.906 ± 0.007	1.700 ± 0.001	1.701 ± 0.0	**<0.001***
median (range)	0.906 (0.906 – 0.907	1.700 (1.69 – 1.701)	1.701 (1.701 –1.701)	
Strength of material (load)				
mean ± SD	6.338 ± 0.009	15.58 ± 0.001	8.254 ± 0.0	**<0.001***
median (range)	6.338 (6.332 –6.345)	15.58 (15.587 –15.589)	8.254 (8.254 – 8.254)	
Strain at the break				
mean ± SD	0.555 ± 0.002	0.377 ± 0.007	0.377 ± 0.0	**<0.001***
median (range)	0.555 (0.554 –0.557)	0.377 (0.377 –0.378)	0.377 (0.377-0.377)	
Shore hardiness (HV)				
mean ± SD	172.5 ± 2.1	191.1 ± 1.4	221.0 ± 0.0	**0.004***
median (range)	172.5 (171 – 174)	191 (190 – 192)	221 (221 – 221)	

[a] p-values are based on Kruskal Wallis test. Statistical significance at P < 0.05
P-value< 0.001 statically significant between ulnar plates

Physical analysis of the samples showed the overall Mechanical characteristics of broken orthopaedic plates, Regarding femoral plates, titanium plates had higher Young's modulus (3.39 ± 2.36) than stainless plates (2.52 ± 1.04). On the other hand, titanium plates had lower peak load (28.2 ± 9.39) than stainless plates (33.9 ± 0.12). Additionally, titanium plates had lower strain at the break (0.159 ± 0.05) than stainless plates (0.211 ± 0.11). Regarding ulnar plates, reconstruction plates had lower Young's modulus value significantly lower than tubular 1/3 and proximal plates. On the other hand, tubular 1/3 plates had significantly higher peak load value than reconstruction and proximal plates. In addition, reconstruction plates had significantly higher strain at the break value than tubular 1/3 plates and proximal plates as shown in table 4.

Table 4. Mechanical characteristics of the plates

Mechanical parameter	Samples				
	Types of femoral plate		Types of ulnar plate		
	Titanium (n=7)	Stainless (n=5)	Reconstruction (n=2)	Tubular 1/3 (n=2)	Proximal (n=1)
Young's modulus					
mean ± SD	3.39 ± 2.36	2.52 ± 1.04	0.906 ± 0.007	1.700 ± 0.001	1.701 ± 0.0
median (range)	2.7 (1.17 – 7.4)	1.78 (1.73 – 3.71)	0.906 (0.906 – 0.907)	1.700 (1.69 – 1.701)	1.701 (1.701 –1.701)
Tensile Strength					
mean ± SD	28.2 ± 9.39	33.9 ± 0.12	6.338 ± 0.009	15.58 ± 0.001	8.254 ± 0.0
median (range)	32.8 (13.5 – 35.17)	33.9 (33.7 – 34.01)	6.338 (6.332 – 6.345)	15.58 (15.58 – 15.58)	8.254 (8.254 – 8.254)
Elongation at break					
mean ± SD	0.159 ± 0.05	0.211 ± 0.11	0.555 ± 0.002	0.377 ± 0.007	0.377 ± 0.0
median (range)	0.146 (0.100 – 0.299)	0.252 (0.027 – 0.26)	0.555 (0.554 – 0.557)	0.377 (0.377 – 0.378)	0.377 (0.377 – 0.377)
Hardness					
mean ± SD	240.5 ± 43.1	275.2 ± 57.7	172.5 ± 2.1	191.1 ± 1.4	221.0 ± 0.0
median (range)	226 (220 – 338)	315 (211 – 320)	172.5 (171 – 174)	191 (190 – 192)	221 (221 – 221)

Regarding physical characters, **P-value** is statistically significant between ulnar plates but insignificant between femoral plates.

Chemical composition of different plates according to chemical analysis done at central metallurgical institute for research and development at Helwan showed that: in titanium plates, percent of titanium found to be more than 99.7% except for one sample 91.18%, while percent of Fe in stainless steel plates ranges from 63.3 to 68. Shown in tables (5-7).

Table 5: chemical composition of Femoral titanium samples							
Chemical composition	**Sample1**	**Sample2**	**Sample3**	**Sample4**	**Sample5**	**Sample6**	**Sample7**
Si	0.007	0.007	0.007	0.014	0.009	0.007	0.007
Mn	0.015	0.015	0.015	0.013	0.013	0.015	0.015
Cr	0.002	0.002	0.002	0.03	0.002	0.002	0.003
Mo	0.004	0.004	0.004	0.022	0.013	0.004	0.004
Ni	**0.001**	**0.001**	**0.001**	**0.034**	**0.001**	**0.001**	**0.001**
Al	0.001	0.001	0.001	4.43	0.001	0.001	0.001
Cu	0.046	0.056	0.056	0.035	0.012	0.056	0.045
Nb	0.001	0.002	0.001	0.001	0.001	0.001	0.002
Ti	**99.7**	**99.7**	**99.71**	**91.18**	**99.82**	**99.7**	**99.7**
V	0.016	0.016	0.016	4.07	0.022	0.015	0.016
W	0.025	0.025	0.025	0.025	0.025	0.026	0.025
Pb	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Sn	0.028	0.028	0.028	0.01	0.009	0.027	0.028
Ru	0.002	0.002	0.002	0.002	0.002	0.003	0.002
Zr	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Fe	**0.156**	**0.168**	**0.156**	**0.168**	**0.076**	**0.156**	**0.156**

Table 6: chemical composition of Femoral stainless samples					
Chemical composition	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**
C	0.025	0.013	0.012	0.029	0.013
Si	0.648	0.249	0.249	0.646	0.247
Mn	1.76	1.71	1.71	1.76	1.73
P	0.032	0.018	0.019	0.032	0.021
S	0.0007	0.003	0.003	0.007	0.003
Cr	16.9	17.2	17.1	16.9	17.1
Mo	2.04	2.85	2.85	2.04	2.86
Ni	10.4	14.5	14.4	10.3	14.3
Al	0.001	0.023	0.023	0.003	1
Co	0.198	0.031	0.031	0.198	0.03
Cu	0.525	0.03	0.03	0.525	0.03
Nb	0.045	0.029	0.029	0.045	0.029
Ti	0.004	0.016	0.017	0.003	0.016
V	0.063	0.04	0.04	0.64	0.04
W	0.052	0.01	0.01	0.052	0.01
Pb	0.005	0.005	0.005	0.005	0.005
B	0.001	0.0006	0.0006	0.001	0.0006
Ta	0.043	0.02	0.02	0.043	0.02
N	0.0526	0.0262	0.0262	0.0526	0.0262
Fe	67.3	63.3	63.4	67.4	63.1

Table 7: Chemical composition of ulnar plates samples					
	Proximal ulnar plate	Reconstruction 1	Reconstruction 2	Tubular 1\3 1	Tubular 1\3 2
Si	0.033	0.075	0.073	0.054	0.052
Mn	0.633	0.422	0.462	0.52	0.52
P	0.922	1.33	1.32	1.14	1.13
S	0.013	0.007	0.007	0.012	0.014
Cr	0.003	0.003	0.003	0.003	0.003
Mo	16.8	17.2	17.2	17.1	17.3
Ni	1.99	1.84	1.85	2.11	2.13
Al	**10.6**	**11**	**11**	**10.2**	**10.2**
Co	0.001	0.01	0.01	0.001	0.001
Cu	0.183	0.13	0.14	0.148	0.148
Nb	0.505	0.302	0.302	0.0422	0.0421
Ti	0.028	0.036	0.036	0.045	0.045
V	**0.028**	**0.226**	**0.216**	**0.15**	**0.05**
W	0.033	0.84	0.84	0.054	0.054
Pb	0.021	0.051	0.051	0.037	0.037
B	0.005	0.008	0.008	0.005	0.005
Ta	0.0001	0.0005	0.005	0.0001	0.0002
N	0.05	0.042	0.041	0.04	0.04
Sn	0.012	0.344	0.0343	0.0527	0.0527

Discussion

The results of our investigation could be presented as a physical and chemical analysis of orthopaedic plates for discussion.

In our investigation, the chemical composition of the plates revealed that the titanium content in the plates was over 99.7% in 85.7% of samples and 91.8% in 14.3% of samples. On the other hand, Pinto, et, al. discovered that titanium plates contain 99.7% of the minimum allowed amount of Ti. which show the differences in chemical and later physical characteristics between plates of the same type. (7)

In our investigation on stainless steel plates, the percentage of Fe was determined to be between 63 and 68%, along with nickel and chromium, which represent 10.2-14.4% and 16.9-17.3%, respectively. This value is comparable to the commercial percentage that the AO foundation has allowed. (8)

Similar to our study, Jian Han (9) found that the Fe content in stainless steel plates was determined to be between 65 and 70 percent, along with nickel and chromium between 10-15% and 17%, respectively.

Regarding physical criteria, in our study, we found that femoral titanium plates had higher Young's modulus (3.39 ± 2.36) than femoral stainless-steel plates (2.52 ± 1.04).

These finding are contradictory to those of the previous literature. (10,11) In comparison to stainless steel, the modulus of elasticity of alloys based on titanium is lower and more analogous to that of bone, making them more suitable for long-term uses.

This outcome may be explained by the fact that samples had variability in physical requirements, as indicated by high titanium plate standard deviations of 2.36 and high ranges of (1.17–7.4) GPa. It is crucial to underline that the samples came from various businesses.

According to our findings, femoral stainless plates had a beach hardiness of 275.2 ± 57.7, whereas femoral titanium plates had a shore hardiness of 240.5 43.1. Furthermore, femoral titanium plates showed a lower peak load than femoral stainless plates (33.9 ± 0.12) (28.2 ± 9.39). Additionally, femoral titanium plates showed a lower strain at the break than femoral stainless-steel plates (0.211 ± 0.11) (0.159 ± 0.05).

Similar to our study Amalraju et al. However, it is discovered that load has no effect on implant failure as the value of deformation is insignificant. It was discovered that the mean bending stiffness was much higher for stainless steel plates. Titanium plates are perfect for use in orthopaedic surgery due to its low density, outstanding mechanical, and biocompatible characteristics. [10]

Findings from earlier studies that were similar to ours showed that stainless steel plates had greater strength metrics than titanium plates. Co-Cr alloys and stainless-steel exhibit good wear resistance and comparatively high strength. Compared to other traditional metallic implant materials like stainless steel or Co-Cr-Mo alloys, titanium and its alloys have a significantly lower stiffness. Ti-based alloys are suitable biomaterials for long-term implantation because of their comparatively low Young's modulus, good fatigue resistance, and superior biological passivity compared to stainless steel and Co-Cr alloys. [10]

In addition to, Raffaele et al. found that the mean load to failure pre-fatigue was higher for titanium than stainless steel, whereas the mean bending stiffness pre-fatigue was much higher for stainless steel. Therefore, titanium plates are more recommended for patients with higher functional requirements due to their significantly higher load to failure rate. [12]

Our research on proximal ulnar fractures revealed that reconstruction plates had a lower modulus than proximal ulnar plates and 1/3 tubular plates. Additionally, the 1/3 tubular plates had the maximum hardness among the reconstruction plates and proximal ulnar plates, Similar to our study lars Eden [13] found that proximal ulnar plate indicates higher biomechanical stability compared to reconstruction plates, which were shown to considerably demonstrate lower stiffness values and early evidence of plastic deformation that could cause plate insufficiency.

discovered that proximal ulnar plate demonstrated greater biomechanical stability compared to reconstruction plates, showing lower stiffness value and early indicators of plastic deformation that may cause plate insufficiency, Geert et al. found that in comminuted olecranon fractures, locking compression plating and tubular 1/3 plating have the same stiffness and load to failure. [14]

Conclusion

Fracture healing is a complicated physiological process that involves a series of actions and is multifactorial in nature, dependent on the type of fracture, the patient, the surgeon's judgement and expertise, and the calibre of the implant. The study's findings indicated that some plates did not meet the physical criteria (41.1%) and chemical criteria (14.3% of titanium plates) for standard plates (according to AO criteria for implant properities), which were significant factors in plate failure. The study also revealed that there were variations in criteria among plates of the same type depending on their source. It is advised that future researchers expand the scope of their study and use different kinds of plates.

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