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IP International Journal of Maxillofacial Imaging

Journal homepage: https://www.ijmi.in/

Original Research Article

Evaluation of surface changes of stainless steel miniplates and screws following retrieval

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ARTICLE INFO

Article history:
Received 04-03-2022
Accepted 09-03-2022
Available online 07-04-2022

Keywords:
Bone loss
Implant failure
Stainless-steel miniplates and screws
Surface hardness
Tensile strength

ABSTRACT

Aims and Objectives: The objective of the present study is to evaluate the surface changes like corrosion, surface roughness, micro-fractures and tensile strength of stainless-steel mini plates and screws.
Materials and Methods: The study was carried out at the Department of Oral and Maxillofacial Surgery, Meghna Institute of Dental Sciences, Nizamabad for a duration of three years. Around 34 stainless steel miniplates and 101 stainless steel screws complied to treat maxillofacial fractures of 20 patients for the rigid internal fixation were retrieved. Then the surface changes like corrosion, surface roughness, micro-fractures were evaluated using stereo microscope and scanning electron microscope whereas the tensile strength was measured using a universal testing machine.
Results: The surface roughness and micro-fractures were seen in 100% of the stainless steel miniplates and screws whereas corrosion degradation was seen in 65%. Thereafter, when the tensile strength was evaluated, a mean value of 497N was found to be exhibited by the retrieved miniplates which was enough to withstand the masticatory forces.
Conclusion: Through our study, we emphasize the need for the proper handling techniques at the time of implant placements so as to avoid implants failures and occurring of other biogenic complications.

1. Introduction

From past few decades miniplates were used very often to facilitate the stability between fractured segments of bone in the Maxillo-Facial region. But now a days it is the most common preferential method used especially for stabilization of about two-thirds of mandibular fractures.[1] Then among all, it's the stainless steel miniplates and screws (Fe-Cr-Ni-Mo alloys) which are most commonly used in India.

However, these metal implants are found to be possessing corrosive degardation in body fluids which has been already demonstarted in various laboratory tests, both under simulated clinical conditions and by electrochemical methods, as well as in studies of retrieved metal implants.[2,3] And a high frequency of interfacial corrosion defects has been reported in multicomponent stainless steel orthopedic fixation devices. Apart from them, an overall higher frequency of handling defects such as scratches, drilling defects, metal tongue formation and splinters were also

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https://doi.org/10.18231/j.ijmi.2022.001

observed.[4]

In situ degradation of these metal-alloy implants is very much undesirable as it leads to loss of the structural integrity of the implant and also the release of these degradation productsmay elicit an adverse biological reaction in the host.[5,6] These unwanted biological changes in the tissues adjacent to implants occurs secondary to the accumulation of various corrosion and wear products either as metal ions or particles and often manifested as hypersensitivity reactions, mild fibrosis, infection and/or necrosis.[7]

In spite of the successful reports of stability attained by metal implants, stainless steel miniplates and screws, they are also associated with certain drawbacks occurring as a consequence to the unwanted interactions occurring between electrochemical and mechanical processes. These interactions may lead to stress corrosion cracking, corrosion fatigueand fretting corrosion etc. and accelerates the release of corrosion and wear products causing premature structural failure and ultimate bone loss.[8]

Thus, the adverse reactions secondary to corrosion products of implanted devices has become the growing concern and initiated a discussion of whether to remove plates and screws after healing or not.[9]The aim of the present study is to evaluate the surface changes for corrosion, surface roughness, micro-fractures and tensile strength of stainless-steel miniplates and screws retrieved retrieved from 20 patients which were used as rigid internal fixation in management of maxillofacial fractures.

Table 1: Surface analysis of stainless-steel mini plates and screws

No of patients	Surface roughness and microfractures	Corrosion degradation
20	20/20 100%	13/20 65%
Reason	No. of patients	%
Palpability	0	0%
Sinus opening	1	5%
Pain	1	5%
Plate exposure	1	5%
Swelling	3	15%
Patient's request	14	70%

Table 2: Sites of plate removal

Site	No. of plates	Rate
Fronto-zygomatic suture	0	0%
Maxilla	10	29.41%
Symphysis of mandible	0	0%
Parasymphysis of mandible	7	20.58%
Body of mandible	17	50%
Angle of mandible	0	0%

2. Aims and Objectives of The Study

The aims and objectives of the present study is to evaluate the surface changes like

Fig. 1: Implant retrieval

Fig. 2: Scanning electron microscope (Tescan; Model: Vega 3LMU)

Fig. 3: Stereomicroscope

Fig. 4: Universal testing machine (Dak Systems Inc.'s Series 9000)

Fig. 5: Miniplates tested for tensile strength.

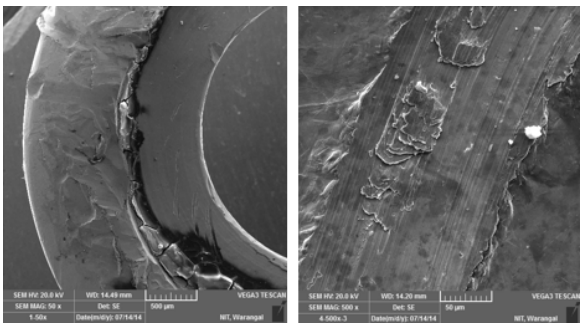

Fig. 6: Scanning electron microscope- corrosion of stainless steel miniplates

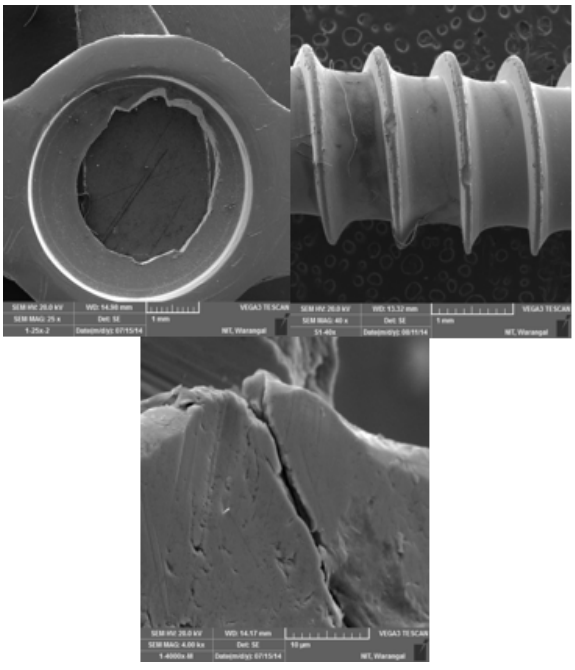

Fig. 7: Scanning electron microscope- surface roughness and micro-fractures

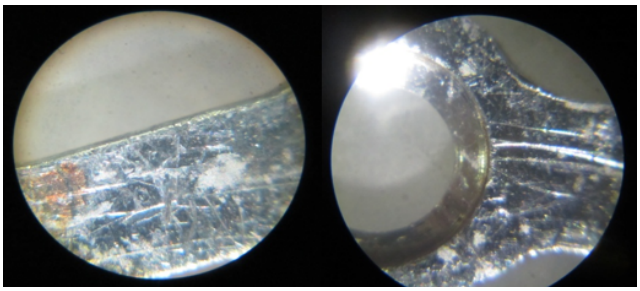

Fig. 8: Stereomicroscope images

Table 3: Tensile strength of mini plates

Plates	Ultimate tensile strenght N/sq.mm
Plate 1	492
Plate 2	449
Plate 3	468
Plate 4	518
Plate 5	510
Plate 6	503
Plate 7	516
Plate 8	511
Plate 9	511
Plate 10	476
Plate 11	519
Plate 12	482
Plate 13	446
Plate 14	465
Plate 15	517
Plate 16	506
Plate 17	508
Plate 18	511
Plate 19	509
Plate 20	521
Plate 21	467
Plate 22	519
Plate 23	511
Plate 24	502
Plate 25	515
Plate 26	511
Plate 27	522
Plate 28	475
Plate 29	519
Plate 30	493
Plate 31	442
Plate 32	466
Plate 33	512
Plate 34	515
Mean	497

1. Corrosion
2. Surface roughness,
3. Micro fractures,
4. Tensile strength of stainless steel miniplates and screws retrieved from 20 patients which were used as rigid internal fixation in the treatment of maxillofacial fractures.

3. Materials and Methods

After the concerned ethical committee approval and informed consent, 20 patients treated for maxillofacial trauma at the Department of Oral and Maxillofacial Surgery, Meghna Institute of Dental Sciences, Nizamabad were selected. From them stainless-steel bone plates and screws were retrieved through intraoral approach which were cleaned under running water, dried and stored in a sterilized container for further evaluation (Figure 1).

3.1. Inclusion criteria

1. Those patients in which stainless steel miniplates and screws were used as rigid internal fixation in the management of Maxillofacial fracture.
2. Symptomatic patients with complains of
   (a) Presence of infection, intra-oral sinus or extra oral sinus opening
   (b) Dehiscence at the operated site
   (c) Palpability of the plates
   (d) Exposure of plates
   (e) Thermal sensitivity
   (f) Patient discomfort and psychological reasons
   (g) Patient personal willingness for removal
   (h) Completed bone healing as evident on radiographs

3.2. Exclusion criteria

1. Medically compromised patients
2. Patients unwilling for second surgery

3.3. Evaluation of surface changes like corrosion, surface roughness, micro-fractures

The retrieved implants were evaluated for the surface changes like corrosion, surface roughness and micro-fractures using stereomicroscope and scanning electron microscope where the initial evaluation was done under scanning electron microscope (Tescan; Model: Vega3LMU) at the Department of Metallurgical and Material Engineering, National Institute of Technology, Warangal, Telangana State (Figure 2). Then another evaluation was done under stereo microscope at the Department of Oral and Maxillofacial Pathology, Meghna Institute of Dental Sciences Nizamabad (Figure 3).

3.4. Evaluation of tensile strength

After the surface change evaluation, the implants were subjected to the universal testing machine (Dak Systems Inc.'s Series 9000) to measure the tensile strength where the plates were mounted onto the jaws of the testing machine and tested at a constant cross head speed of 2mm/min. Finally, the peak load at which the plates failed in tension was noted down as ultimate stress (Figures 4 and 5).

4. Observation and Results

On microscopic examination of 34 stainless steel miniplates and 101 stainless steel screws retrieved from 20 patients, the primary cause for the surface roughness and micro-fractures was found to be due to the handling errors, bending of plates while placement and drilling injuries at the countersink areas. Corrosion degradation were seen in the countersink areas, often with break in the continuity of the metallic surface appearing as patches often localized to the counter sink areas or involving one or two countersinks within the same plate. Corrosion never extended onto the free surface outside the countersink area. Bone tissue covering parts of the countersink region was seen associated with a screw hole in two of the stainless-steel plates (Figures 6, 7 and 8).

Among the total sample of 20 patients, the surface roughness and microfractures were seen in all of them (100%) whereas corrosion degradation was seen in 65% of patients (Table 1). When the reason for the plate removal was analysed, it was ought to be removed on patient's request followed by onset of swelling and other complications (Table 2). Then among the various sites of fractures included in the study, from which plates were retrieved, the majority of them are contributed by body of mandible followed by maxillary fractures and Para symphysis fractures (Table 3). Similarly, when tensile strength of miniplates was evaluated, a mean tensile strength of 497 N/sq.mm was found.

5. Discussion

Stainless steel miniplates and screws are used for rigid internal fixation to immobilize fractures of the maxillofacial skeleton. But should the non-functional miniplates and screws be removed after a few years or not is still debatable amongst the Oral and Maxillofacial Surgeons.[10] According to literature the decision to leave miniplates in situ may be influenced by factors such as biocompatibility of the material and the implication of a second procedure to remove miniplates.[11]

In present study 34 stainless steel miniplates and 101 stainless steels screws retrieved from 20 patients were evaluated. Surface roughness on the surface of a majority of the plates could be observed usually as sharp-edged scratches on the free surfaces as well as on the counter sink areas of the plates. Micro-fractures were seen in the countersink regions sometimes leaving metal tongue formation or splinters. The surface roughness and micro-fractures were due to handling errors and bending of plates during placement and also during drilling injuries in the countersink areas.

Corrosion degradation was seen in the countersink areas, often with break in the continuity of the metallic surface, appearing as patches often localized to the counter sink areas or involving one or two countersinks within the same plate. In present study surface roughness and micro-fractures were seen in all 100% of the stainless steel miniplates and screws whereas corrosion degradation was seen in 65 % of stainless steel miniplates. The above findings were in correlation with the studies of S. Torgersen et al. and then in 1994 S. Torgerson et al. while working on surface changes exhibited by stainless steel plates, using scanning electron microscopy and stereo microscopy, they found it to be present in the form of sharp-edged scratches. Similar mechanical surface defects were also found in the countersink regions along with corrosive degradation and an occasional metal tongue formations or splinters evident at the periphery of screw holes. However, the corrosion defects were found to be present localized to the countersink areas, appearing as restricted and patchy areas or often involves one or two countersinks within the same plate. The other visible defects exhibited are minor scratches on the screw heads, on the chamfer underside of the screw head and along the screw threads. These defects were found to be exhibited by all the 100 % stainless-steel plates and screws whereas 19% of the miniplates showed corrosion and 7% of screws showed corrosion.[12] In 1999 M.S. Ray et al. in their scanning electron microscopic and stereo microscopic study of 15 stainless steel plates and 60 screws, they found the surface roughness exhibited in the form of few gouges' marks adherent to metal particles as well as rough metallic edges and protuberances presenting around the circumference of several screws' holes in the counter sink areas.[13] In present study of tensile strength of 34 stainless steel miniplates was evaluated, a mean value of 497N was exhibited by the retrieved miniplates which was enough to withstand the masticatory forces. The maximum masticatory forces in healthy young individuals have been measured as 660N in molar region and 290N in incisor region. However, these forces are probably higher than forces exhibited during post-operative period. This finding is in acceptance with that of R.A. Loukota et al. in 1995. Who made a mechanical analysis of miniplates which showed ultimate tensile properties of above 500N and said that plates are rarely exposed to actual tension.[14]

The present study results through scanning electron microscopy and stereo microscopy showed surface roughness, micro-fractures and corrosion. However tensile strength was not affected when the plates were in situ. Thus, following the symptoms of retained stainless steel plates

and screws, we recommend their removal after the purposes of rigid fixation have been fulfilled.

6. Summary and Conclusion

1. Metal implants become a useless foreign body and a potential source of problems once their purpose is served. For this reason, miniplate retrieval should be advised on routine basis after bone healing has occurred as it is better and easier to retrieve asymptomatic implants than symptomatic implants. Release of metal particles into tissues from miniplates and screws is undesirable and may be minimized by careful surgical technique. In addition, metal implants should be free from of rough edges or protuberances on the surfaces to minimize the risk of detachment and deposition of particles into surrounding tissues.
2. Implant failure is multifactorial which mainly depends upon the quality control by the manufacturer and use of the proper technique by the surgeon.
3. In present study, surface roughness and micro-fractures were found in all the stainless steel miniplates and screws that is 100% and corrosion degradation of stainless steel miniplates was found in 13 of 20 patients that is 65%. In present study of tensile strength of 34 stainless steel miniplates, a mean value of 497N was exhibited by the retrieved miniplates which was enough to withstand the masticatory forces.

This small study recommends the retrieval of stainless miniplates and screws after their purpose of rigid fixation is served. However long-term studies need to be carried out for further supporting the results.

7. Source of Funding

None.

8. Conflict of Interest

None.

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Cite this article: Pantham D, Shakuntala Soujanya V, Abhishek Reddy N, Vinuthna M, Kranthi K, Durga Keerthi P. Evaluation of surface changes of stainless steel miniplates and screws following retrieval. *IP Int J Maxillofac Imaging* 2022;8(1):1-6.