



HAL
open science

Mechanical investigation of assembled osteosynthesis plates: experimental and numerical approaches

L. Revol, A. Gilbin, A. Levillain, B. Billottet, Y. Lafon, N. Boudeau, T. Barrière

► To cite this version:

L. Revol, A. Gilbin, A. Levillain, B. Billottet, Y. Lafon, et al.. Mechanical investigation of assembled osteosynthesis plates: experimental and numerical approaches. 2024. hal-04738033

HAL Id: hal-04738033

<https://hal.science/hal-04738033v1>

Preprint submitted on 15 Oct 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License

Mechanical investigation of assembled osteosynthesis plates: experimental and numerical approaches

L. Revol^{1,2,3,4}, A. Gilbin², A. Levillain³, B. Billottet¹, Y. Lafon³, N. Boudeau², T. Barrière⁴

1: *ennoia, Besançon, France*

2: *SUPMICROTECH, CNRS, institut FEMTO-ST, F-25000 Besançon, France*

3: *Univ Eiffel, Univ Lyon 1, LBMC UMR_T 9406, F-69622 Lyon, France*

4: *Université de Franche-Comté, CNRS, institut Femto-ST, F25000 Besançon, France*

*Corresponding author. Email: laura.revol@ennoia-med.fr

Keywords: osteosynthesis plate; numerical simulations; experimental tests; veterinary

1. Introduction

Osteosynthesis plates are widely used in veterinary orthopaedic surgery (Lee et al, 2022). However, bone plates are usually not suitable for all clinical cases due to species variability in terms of sizes and geometries. To facilitate surgical accessibility and adapt the length according to the clinical case our approach proposes assembled plates system. It consists of two short plates that are separately fixed on each side of bone fragments with an assembly system to join them. Some patents of such system have already been published (ex: Destainville et al, 2019), however, none of them is currently on the market.

The assembly system is the critical part that mostly determines the mechanical behaviour, yet no study except one numerical static study (Subasi et al. 2021) has investigated their mechanical properties. To ensure adequate performances before extensive use, numerical results need to be validated with experiments including fatigue behavior investigation. However, comparing mechanical performances of bone plates based on published information is difficult. As discussed in publications: “the biomechanical literature for bone plates is diverse, inconsistent and heterogeneous” (Schorler et al. 2017). The aim of this study was to propose a reliable approach to evaluate the mechanical performance in comparison with existing plates, using both experiments and simulations.

2. Methods

2.1 Reference plate and prototype definition

A reference bone plate (10*150*3,5mm³ and 3,5 mm for the holes) for which geometry corresponds to that of commercial plates has been designed to mimic osteosynthesis plates used for large dogs. The prototype based on assembled plates has identical dimensions to the reference plate (figure 1). The references plates and the prototypes were made in 316L steel.

2.2 Finite element (FE) models

FE models of the reference plate and the prototype were designed and their performance compared by simulating 4 points bending tests in linear static analysis (SolidWorks Simulation v.2023), following the ASTM F382 standard (ASTM F382-17, 2017). Distance h between support rollers was 40 mm and distance a between loading rollers was 50 mm (figure 1). Contact and bold connectors with preload (0,5 Nm) and friction coefficient (0,2) were defined. A force of 40 N was applied on each upper loading roller. The final mesh (28577 tetrahedral elements) was defined after a convergence study (1% of error on displacement).

2.3 Verification and calibration of the FE models

Tensile test samples were extracted from the material plate to calibrate the material properties for the FE model (Young Modulus, Poisson ratio). The reference plates and the prototypes were machined with a HASS OM2 milling machine. They were physically tested in static loading following the ASTM F382, as for the simulation. The bending stiffness (BS) was extracted from both the experiments and the simulations to evaluate the FE model. BS (N/mm) was defined as the slope of the linear region of the force - displacement curve.

2.4 Design improvement using FE simulations

The prototype geometry was then numerically modified using design of experiments to minimize the difference regarding the BS and the maximal Von Mises stress between the reference and the prototype. The maximal Von Mises stress was also checked to stay below the Yield stress defined by the Wöhler relationship to consider fatigue (200 MPa).

2.5 Experiments

The reference plates (n=6) and the retained prototype (n=1) were finally tested using electrodynamic system (ElectroPuls E1000) following the ASTM F382, both in static and cyclic loading. Displacement was recorded with a laser sensor (optoNCDT). The maximum cyclic load was defined according to the percentage of the reference plate proof load: 200N with R-ratio of 0,1 for 1 million cycles. The proof load

corresponds of the load reached at 0.2% of the offset displacement (ASTM method). The number of cycles before failure was recorded.

3. Results and discussion

The challenge was to obtain appropriate stiffness and ensuring satisfactory cyclic life during bone healing. Figure 1 displays the force-displacement curves for the prototype and the reference plates, while Table 1 reports the preliminary mechanical criteria. The difference on BS between experimental and numerical is less than 10%. Static tests indicate that the retained prototype provides a slightly lower bending elastic stiffness in comparison to the reference plate, but a larger proof load. Reducing the BS could be benefit, because it could also help to reduce the “stress shielding” effect (Frost, 1994).

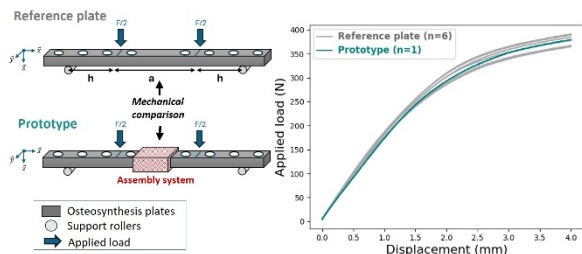


Figure 1. Mechanical comparison of the reference plate and the prototype, credit: L. Revol

Cyclic tests enable to confirm the fatigue performance of the prototype which succeeds in reaching the reference’s cycles to failure.

Table 1. Results from static and cyclic loadings, credit: L. Revol

Performance criteria	Reference plate (n=6)	Prototype (n=1)
Numerical BS. (N/mm)	192	186
Experimental BS (N/mm)	190 ± 5,2†	173
Proof load (N)	200 ± 4†	235
Cycles to failure	1 E 6	1 E 6

† means ± standard deviation

These preliminary results have to be evaluated and confirmed on a larger set of physical devices for different sizes. Moreover, only bending performances have been explored, while osteosynthesis plates have to respect torsion behaviour, for which no standard is defined (Schorler et al. 2017). Finally, the entire fixation system (i.e. the plate fixed to the bone by screws) needs to be assessed.

4. Conclusions

The study presents a method for evaluating the mechanical properties of assembled osteosynthesis plates, using a combination of simulation and experimentation, to achieve performance equivalent to

that of reference plates. The encouraging preliminary results need to be confirmed by further tests.

Acknowledgements

The authors would like to thank Stani Carbillet for his help to define the experimental setup and the AMETISTE and MIFySTO platforms.

Funding

The study was supported by ennoïa and the ANRT (Association Nationale de la Recherche et de la Technologie) with a CIFRE fellowship granted to 2022.001.

Conflict of Interest Statement

ennoïa has no financial interest related to the results of this study.

References

- ASTM International (2017). F382-17 ASTM-Standard specification and test method for metallic bone plates. West Conshohocken
- Destainville, A., Richart, O., (2019) Module for a modular bone plate, modular bone plate of this construction, and system comprising said plate, (WO 2019/243703 A1), *WIPO*.
- Frost, H.M. (1994). Wolff’s Law and bone’s structural adaptations to mechanical usage: an overview for clinicians. *Angle Orthodontist*. 64(3), 175–188.
- Lee, S., Ahmad, N., Corriveau, K., Himel, C., Silva, D. F., & Shamsaei, N. (2022). Bending properties of additively manufactured commercially pure titanium (CPTi) limited contact dynamic compression plate (LC-DCP) constructs: Effect of surface treatment. *Journal of the Mechanical Behavior of Biomedical Materials*, 126, 105042.
- Schorler, H., Capanni, F., Gaashan, M., Wendlandt, R., Jürgens, C., & Schulz, A. P. (2017). Bone plates for osteosynthesis—a systematic review of test methods and parameters for biomechanical testing. *Biomedical Engineering*, 62(3), 235-243.
- Subasi, O., Oral, A., Noyan, S., Tuncozgun, O., & Lazoglu, I. (2021). In silico analysis of modular bone plates. *Journal of the Mechanical Behavior of Biomedical Materials*, 124, 104847.

Received date:05/04/2024

Accepted date: 28/06/2024

Published date: XX/XX/2024

Volume: 1

Publication year: 2024