Proceedings of the 3rd Pan American Materials Congress

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The Minerals, Metals & Materials Series

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Preface

The Pan American Materials Congress (PAMC) is in its third iteration and was originally initiated from a partnership between the Associação Brasileira de Metalurgia, Materiais e Mineração (ABM) located in Brazil and The Minerals, Metals & Materials Society (TMS) located in the United States. This partnership produced two previously successful materials science and engineering conferences, titled "Pan American Materials Congress" occurring in 2010 and 2014 and held in conjunction with ABM's large annual conference. These events were co-chaired by Prof. Sergio Neves Monteiro, ABM's incoming President. The 3rd PAMC, hosted by TMS, includes nine participating professional societies, and is co-located with the TMS 2017 Annual Meeting & Exhibition. It is the first time that this international materials science and engineering conference is held in North America, with TMS in the role of host society. A program covering a variety of materials science topics has been created based on the input from leading scientists and engineers representing eight countries and nine international materials, metals, and minerals societies listed below:

1. Argentina: Asociación Argentina de Materiales (SAM)
2. Brazil: Associação Brasileira de Metalurgia, Materiais e Mineração (ABM)
3. Peru: Asociación Peruana de Metalurgia, Materiales Y Minerales (APMMM)
4. Colombia: Colombian Materials Society
5. Chile: Instituto de Ingenieros de Minas de Chile (IIMCh)
6. Canada: Metallurgy and Materials Society (MetSoc), Canadian Institute of Mining, Metallurgy, and Petroleum (CIM)
7. Chile: Sociedad Chilena de Metalurgia y Materiales (SOCHIM)
8. Mexico: Sociedad Mexicana de Materiales (SMM)
9. United States: The Minerals, Metals & Materials Society (TMS; Host Society)

The participation of additional materials societies throughout the Americas is being sought and is under discussion. The organizers of this congress seek to provide an international Pan American focused program to address the needs of the materials science and engineering communities as they relate to government, academic, and industrial institutions, while providing an intimate setting for professionals to interact with and form strategic partnerships with their peers. Student participation is strongly encouraged and is a focus for the lead organizers of this event. Additionally, as far as we are aware, this is the only international materials science conference where the emphasis is exclusively on North and South America.

The 3rd PAMC technical programming encompasses a wide range of materials, metals, and minerals with applications specific to the international communities that are represented, including symposia on materials for transportation and infrastructure, materials for the oil and gas industry, and minerals extraction and processing. These proceedings contain the following sections, which correspond to the themes of the conference:

Advanced Biomaterials
Advanced Manufacturing
Materials for Green Energy
Materials for Infrastructure
Materials for the Oil and Gas Industry
Materials for Transportation and Lightweighing
Minerals Extraction and Processing
Nanocrystalline & Ultra-fine Grain Materials & Bulk Metallic Glasses
Steels

From this program, it is expected that rich discussions and collaborative opportunities will result, heavily focused on the Americas. The congress is scheduled to run for three consecutive days, with sessions in both the morning and afternoon. Special attention has been paid to communications and complementary planning between the congress organizers and TMS staff, and TMS 2017 symposia organizers and volunteers, to ensure that the sessions are synergistic and not duplicative of the TMS 2017 Annual Meeting & Exhibition programming.

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About the Editors

Marc André Meyers is Distinguished Professor in the University of California, San Diego. This is the highest professorial level in the UC system and represents an honor that is reserved for only a small fraction of the tenured faculty. He has had visiting professorships at the University of Karlsruhe (Institute of Technology), University of Metz, and Cambridge University (Cavendish Laboratory). He is also a life member of Clare Hall, Cambridge. He is currently supported by the major U.S. funding organizations: National Science Foundation, the Office of Naval Research (MURI), Lawrence Livermore National Laboratory, University of California Office of the President, and DARPA.

Throughout his career, he received a number of important awards. The most prestigious of these, the Acta Materialia Materials and Society Award, which was bestowed in 2010, has a most distinguished list of recipients that includes global leaders in the materials science field. Other awards are from Europe (Humboldt Society Senior Scientist Award in Metal Physics, Germany, Heyn Medal, German Materials Society, J.S. Rinehart Award from the DYMAT Association, and *Materials Science and Engineering: A* Journal Prize), China (Lee Hsun Lecture Award from the Institute of Metal Research, Chinese Academy of Sciences) and U.S. (ASM Barrett Silver Medal, TMS-Educator Award, ASM Albert Sauveur Accomplishment Award, Albert White Educator Award, SMD/TMS Distinguished Scientist and Distinguished Service Awards). He is a Fellow of TMS, APS, and ASM International. In 2011 he was elected Corresponding Member of the Brazilian Academy of Sciences. Marc Meyers is the author of more than 400 papers, four technical books, as well as the editor of eight books.

Hector Alfredo Calderon Benavides is Professor of Applied Physics and Electron Microscopy at the Physics Department at ESFM-IPN (National Polytechnic Institute). He has a Ph.D. in Materials Science and Engineering from Northwestern University since 1985. He joined the Institut für Angewandte Physic from 1986 to 1994 at the ETH-Zürich. Since 1995 his work has been done at IPN in Mexico. His research focuses on theory and application of aberration-corrected and high resolution analytical electron microscopy, with particular emphasis on the application of aberration-corrected low dose electron microscopy. Dr. Calderon studies the structure and properties of materials, nanowires and nanoparticles as related to the application of nanomaterials to sustainable energy technologies. The main trust of his research is the development of devices to transform solar energy into a fuel. He has authored numerous publications on synthesis and characterization of materials and chapters of books.

Sonia P. Brühl has a doctoral degree in Physics from National University of Rosario, Argentina (1995). She is currently working as Full Professor at the National University of Technology (UTN), Faculty of Concepción del Uruguay, in Argentina. She has also been head of the Surface Engineering Group since 1999.

Dr. Brühl is an experienced researcher in the field of Plasma Surface Engineering and she has a vast teaching experience in physics and surface engineering, in both graduate and postgraduate engineering programs. Today, her R&D work is devoted to CVD and PVD coatings over stainless steel to achieve wear and corrosion resistance, and plasma diffusion treatments such ion nitriding, nitrocarburizing or carburizing on steels. She is actively involved in surface characterization, adhesion and wear tests, and corrosion resistance of modified layers and coatings. She is an active participant in national and international R&D programs, adviser in HR training for R&D, and also leader in program coordination. As such, she regularly attends international materials conferences and publishes in peer-reviewed journals, such as *Surface and Coatings Technology*, among others, where she has also taken part as invited editor. Dr. Brühl has experience in the organization of congresses and workshops and at present she is involved in the directive board of the Argentine Materials Association (SAM), as well as in the coordination of the doctoral program in materials science and engineering of UTN.

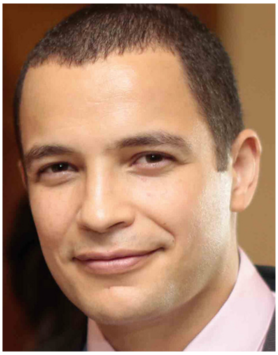
Henry A. Colorado is a full-time faculty member from the School of Engineering at the Universidad de Antioquia at Medellin, Colombia. He is a founder member and vice-president of the recently created Colombian Materials Society.

His research mainly includes new materials and composites fabricated with hazardous wastes, traditional ceramics and additive manufacturing for structural materials. Dr. Colorado is the director of CCComposites Lab at Universidad de Antioquia. Other area of research includes materials in arts, with several projects going on in collaboration between Engineering and the Arts Schools at Universidad de Antioquia.

Dr. Colorado obtained a B.S. and M.S. in Mechanical Science and Engineering from Universidad Nacional de Colombia (with honors) in 2005, and M.S. from the University of California, Los Angeles. He finished his Ph.D. in Materials Sciences at UCLA in June 2013. Other experiences include 5 months in Argonne National Lab working in hazardous wastes, 5 months in Centro Atomico Bariloche (Argentina), and training in nuclear materials at Idaho National Lab and Oak Ridge National Lab. Dr. Colorado has currently active collaboration with faculty from several schools abroad the world. He also is founder and a business partner of I+D Recycling Solutions, a start-up company located in Colombia for the processing of hazardous wastes.

Elvi Dalgaard holds a B.Eng. in Metallurgical Engineering from McGill University, as well as a Master's in Materials Engineering focusing on automotive alloy development and a Ph.D. in Materials Engineering with the research focused on the solid state welding of aerospace alloys, from the same institution. She has extensive experience in the characterization of advanced materials, including SEM, EDS, EBSD, TEM and XRD techniques. Her recent work includes initiating and managing research projects in the aerospace industry in the areas of metals, alloys, joining, thermoplastic composites, coatings, and advanced manufacturing including additive manufacturing. She is very active in Canadian and international professional societies, holding a board position in both ASM International (Montreal Chapter) and the Metallurgical Society of Canada (MetSoc). Dr. Dalgaard has a strong interest in encouraging young people, especially young women, in the scientific and engineering fields, and has participated in numerous mentoring and teaching activities such as being a mentor with the Chaire Marianne Mareschal (promotion du genie auprès des femmes), and organizing the ASM Materials Mini-Camp for high school students.

Carlos Nelson Elias



Roberto B. Figueiredo is Assistant Professor at the Federal University of Minas Gerais, in Brazil, where he graduated in mechanical engineering. He obtained his Ph.D. at the University of Southern California with a CAPES-Fulbright fellowship. He was a postdoctoral research associate at the University of Southampton and a postdoctoral visiting researcher at the University of Southern California. He joined the faculty of the Federal University of Minas Gerais in 2011. He has worked extensively on severe plastic deformation processing, both experimentally and using computer modeling, and on characterization of structure and mechanical properties of ultrafine-grained metallic materials. He received the NanoSPD Young Researcher Award in 2014.

Omar Garcia-Rincon earned a B.S. degree in Metallurgy (1997), M.Sc. in Materials Science (1999) both from Universidad Autonoma de Nuevo Leon (Mexico), and Ph.D. in Materials Science (2006) from the University of Sheffield (U.K.). Currently he is a product technologist in TERNIUM MEXICO SA de CV since 2008 where his work has focused on the optimization and design of steel products for different end use applications including automotive, appliances, construction, oil and gas among others. Main research focus in physical and mechanical metallurgy, phase transformation and relationships between microstructure and properties.

Megumi Kawasaki is Associate Professor in the Division of Materials Science & Engineering at Hanyang University, South Korea, where she joined the faculty as Assistant Professor in 2012. At present, she holds an adjunct research associate professorship in aerospace and mechanical engineering at USC.

Megumi obtained her B.Eng. degree in Metallurgy and Materials Science from Osaka Prefecture University in Japan in 2002 and then received an M.S. degree in 2004 and Ph.D. degree in 2007 in Materials Science at the University of Southern California, USA.

Her research interests lie in the area of the synthesis and characterizing unique properties of hybrid UFG metals and nanocomposites processed by HPT. She has collaborated actively with many researchers around the world and has published over 100 papers in peer-reviewed journals in the last 10 years. She has received an Early Career Award from the Korean Institute of Metals and Materials in April 2016.

Terence G. Langdon is Professor of Engineering Emeritus at the University of Southern California and Professor of Materials Science at the University of Southampton in the U.K. He graduated in physics from the University of Bristol, obtained his Ph.D. in Metallurgy from Imperial College of the University of London and received a D.Sc. in Physics from the University of Bristol. He is a fellow of the Royal Academy of Engineering, the European Academy of Sciences and Academia Europaea. He received honorary doctorates from the Russian Academy of Sciences in 2003 and Peter the Great Saint Petersburg Polytechnic University in 2016. He was awarded the Blaise Pascal Medal by the European Academy of Sciences in 2008, the Lee Hsun Award from the Chinese Academy of Sciences in 2009, the Honorary Medal "De Scientia et Humanitate Optime Meritis" from the Academy of Sciences of the Czech Republic in 2009, the Acta Materialia Gold Medal in 2012 and the State Prize in Science and Technology of the Republic of Bashkortostan (Russia) in 2015. He is a fellow of TMS, ASM, MRS, AAAS and the American Ceramic Society and an honorary member of the Japan Institute of Metals. He is listed on Web of Science with more than 1000 peer-reviewed papers, more than 40,000 citations, and an h-index of 103.

R. V. Mangalaraja is Professor in the Department of Materials Engineering, University of Concepción at Concepcion, Chile. He served as the director of the Department of Materials Engineering from 2010 to 2016. He is the current president of the Chilean Metallurgy and Materials Society (SOCHIMM). He is a life member of Indian Ceramic Society (ICS) and Indian Institute of Ceramics (IIC). Dr. Mangalaraja earned his B.Sc. degree in Physics from Madurai Kamaraj University in 1993 and received his M.Sc. degree in Materials Science in 1995 and M.Tech. in Ceramic Technology and Ph.D. in Technology in 2003 from Anna University-Chennai, India. He has post-doctoral experiences from AIST, Nagoya, Japan; Lulea University of Technology, Lulea, Sweden; and Anna University, Chennai, India. His primary research interests are focused in the areas of nanotechnology-driven advanced ceramics (functional ceramics for energy and environmental applications) and micro–nano-structure–property relationship of ceramics and metallic materials. He is the author or coauthor of more than 120 refereed journal publications, four book chapters, and more than 110 research presentations in several international conferences.

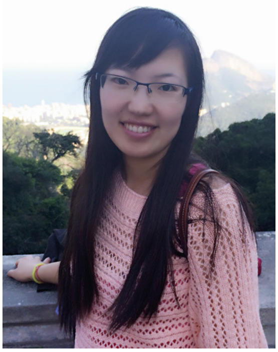
Mery Cecilia Gomez Marroquin

Adriana da Cunha Rocha obtained a Bachelor of Science degree in Materials Sciences and Metallurgical Engineering from the Pontificia Universidade Catolica do Rio de Janeiro (PUC-Rio) and both M.S. and Ph.D. degrees in Materials Sciences at the same university. During the years 2003–2005 she held a postdoctoral appointment at the Materials Sciences Division of the Lawrence Berkeley National Laboratory (LBNL) in Berkeley, California, working in the areas of high temperature corrosion and fuel cells. She is currently adjunct professor at the Federal University of Rio de Janeiro (COPPE/UFRJ) at the Metallurgical and Materials Engineering Program (PEMM) and a collaborator researcher of the Laboratory of Non-Destructive Testing, Welding and Corrosion (LNDC—COPPE/UFRJ), which is dedicated to the research of materials for the oil and gas industry.

Julie M. Schoenung is Professor of Materials Science and engineering at UC Irvine. She received her Ph.D. in 1987 and M.S. in 1985 in materials engineering from the Massachusetts Institute of Technology, and a B.S. in ceramic engineering from the University of Illinois, Urbana-Champaign. Dr. Schoenung was recently selected to be the recipient of the 2018 ASM Edward DeMille Campbell Memorial Lectureship and the 2016 *Acta Materialia* Holloman Award for Materials & Society. She was appointed as a co-editor-in-chief for the *Journal of Sustainable Metallurgy*, and has served for many years as a key reader for *Metallurgical and Materials Transactions A* (2003–present). In 2016, she was elected as a fellow of Alpha Sigma Mu, the materials honor society. In 2012, she was elected as an ASM Fellow and selected as a recipient of the Chime Bell Award, Hubei Province, China. In 2002, she became an AT&T industrial-ecology faculty fellow. Dr. Schoenung's research activities seek to provide fundamental insight into structure–processing–property mechanistic relationships in material systems for a variety of applications. Innovative synthesis and consolidation processes are combined to fabricate material systems that exhibit unique behavior, thereby providing new knowledge into the mechanisms that govern the observed behavior. Dr. Schoenung also has many years of experience in studying the materials-selection process in a variety of applications. She also conducts research into the analysis of factors that guide the materials-selection decision-making process, such as economics, environmental impact and toxicity, cost-performance trade-offs, and market potential. Dr. Schoenung uses tools and datasets from several disciplines, including management theory, process economics, life cycle assessment, and environmental economics in her research approach.

Andre Costa e Silva

Mary Wells is Associate Dean of Outreach and Professor with the Faculty of Engineering, University of Waterloo, and Professor of Materials in the Department of Mechanical and Mechatronics Engineering at the same university. Dr. Wells's research interests include mathematical modeling of industrial metallurgical operations including casting, extrusion, forging, and computation modeling of the interdependency between processing, microstructure, and properties.



Wen Yang obtained her Ph.D. from Northeastern University, China, in 2010, working in the Shenyang National Laboratory for Materials Science, which is operated by Institute of Metal Research of the Chinese Academy of Sciences. She was one of the first researchers studying the biological seashells in China.

From 2011 to 2013, Dr. Yang worked in the United States as a postdoctoral researcher on the mechanical behavior of biological materials in the group of Prof. Marc Meyers and Prof. Joanna McKittrick at UC San Diego, collaborating with Prof. Robert Ritchie at the Lawrence Berkeley National Laboratory and Markus J. Buehler at MIT. Since 2014, she has been a postdoctoral researcher in the Complex Materials group at ETH Zürich. Her interests include the characterization and mechanical behavior of biological and bio-inspired structural materials, collaborating with different groups and institutes including Max Plank Institute, Cambridge University, Imperial College, and institutes in the Chinese Academy of Sciences.

Since 2010, Dr. Yang has been a member of the Biomaterials Committee of TMS. She has co-organized two symposia for TMS (2016 and 2017) as well as helped organize the *6th International Conference on Mechanics of Biomaterials and Tissues* (*ICMOBT*) in 2015. Dr. Yang is on the editorial board of *Journal of Mechanical Behavior of Biomedical Materials* (*JMBBM*) and Austin Biomolecules. She is invited editor of two special issues of *JMBBM* and an independent reviewer for seven journals. She was evaluated as a valued reviewer in *Acta Biomaterialia* and *Materials Science and Engineering C*. She has published 25 papers with 436 citations and has an h-index of 12.

Part I
Advanced Biomaterials

Analysis of Biomimetic Surgical Clip Using Finite Element Modeling for Geometry Improvement and Biomaterials Selection

Thays Obando Brito, Bianca Bastos Dos Santos, Leonardo Sales Araújo, Luiz Henrique De Almeida and Marysilvia Ferreira Da Costa

Abstract An absorbable suture clip (MU9102934-1) for surgical applications was designed based on the bite mechanism of ant *Atta laevigata*. In order to emulate the behavior of the ant mandible, the clip was designed to naturally fall after some time, relieving the inconvenience of the clip removal process. The structure consists of a metallic handle and an absorbable polymeric tip. This study aims to optimize its geometry and select the best biomaterials to the handle structure, by analyzing its mechanical performance using the finite element method (FEM). The biomaterials selected for the simulations of the handle were AISI 316L and AISI 420 stainless steels. FEM analysis was performed using ANSYS FE software. The stress and strain distributions for each material and geometry changes were analyzed. From the analysis performed, the clip was optimized in order to be applied in a less traumatic form.

Keywords Surgical clip · Biomaterials · *Atta laevigata* · FEM

Introduction

Suture is used to help the healing process of the epithelial tissues, leading to a better and faster result, through the approximation of the edges of an injury, sealing blood vessels [1–3]. The approximation of the skin edges can be done by suture yarn, adhesive or metal clip [2]. Despite the constant improvement of the suture modes, they still have limitations concerning, due to the material used, the high cost, the shape, the placement and release mechanisms or the traumatic placing and healing process.

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About 1000 years B.C. the use of jaws of ants for suture was reported in the Indian medical text *Charaka Samhita* [2]. The use of an ant jaw as a suture component permits the approximation of the edges and, during healing period, the jaw degrades and the remaining parts fall from the skin [4]. This technique is illustrated in Fig. 1.

According to the technique based on this bioinspired mechanism of suture using an ant mandible, a bioabsorbable surgical clip was developed based on the *Atta laevigata* bite mechanism, which resulted in technological patent type utility model [5], as shown in Fig. 2.

The innovative aspect of this clip is that there is no need for the patient to return to the hospital for the removal of the stitches, leading to a less traumatic and more comfortable technique for both the patient and the healthcare professional. This is because the product has a subsystem as an absorbable biomaterial. The absorbable surgical clip design is composed by the subsystems: handle structure, approach structure and cover, Fig. 2b. The handle structure is composed by a metallic material and a bioabsorbable polymer attachment structure. Figure 3 shows the main dimensions of the absorbable suture clip. The handle has to be capable of having a dimensional span to open and close the approach structure by means of the elastic properties of the metallic material, at the same time having high elastic modulus to provide enough for to permit the penetration of the approach structure in the skin.

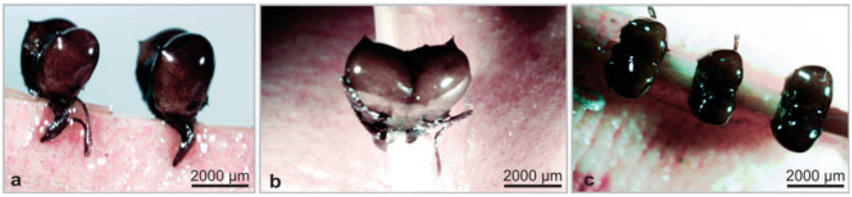

Fig. 1 Suture performed with jaw ant *Atta*. Ant jaw approximating the tissue edges (**b**). Ant jaw as suture points (**c**). Adapted from [7]

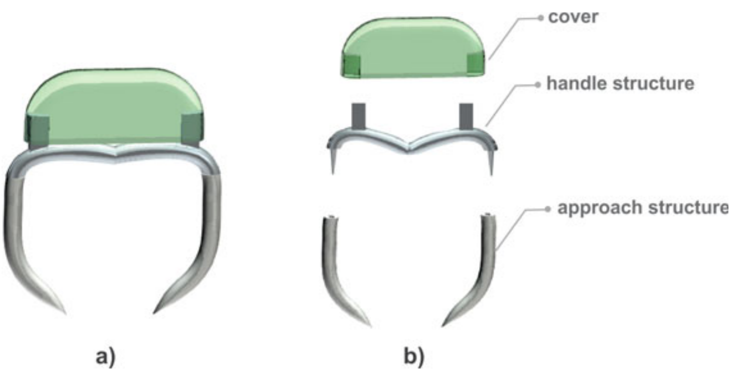

Fig. 2 Design of bioabsorbable suture clip (**a**) and their subsystems (**b**). Adapted from [8, 5]

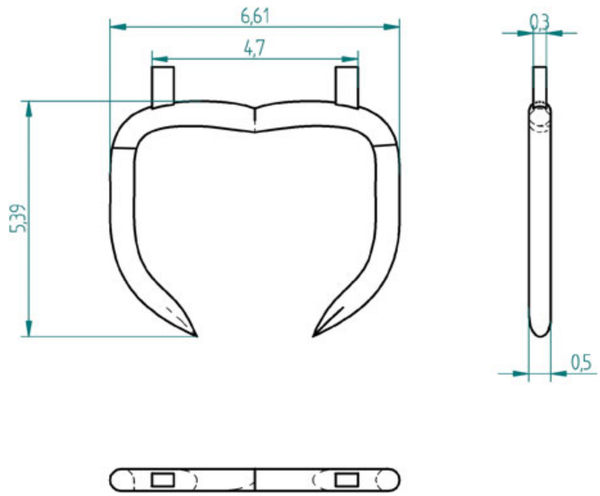

Fig. 3 The technical design of bioabsorbable suture clip. Adapted from [5]

The aim of this research is to optimize the geometry, dimensions and analysis the biomaterials, polymer and metal, for the surgical clip, estimating their mechanical performance using the Finite Element Method (FEM).

Materials and Methods

Two biomaterials, already used as medical applications, were selected for this analyses: stainless steel AISI 316L (austenitic) and AISI 420 (martensitic). The clip was modeled by Solid Edge software by two pieces of metal and polymer. The opening mechanism of the clip was simulated using the software ANSYS 17.2®. The element used is SOLID185 with 4-nodes tetrahedral configuration.

The primary analysis was geometric to prescribe displacement. After that, nonlinear quasi static analysis was made at the handle structure of the surgical clip to verify the stress and strain distribution in the surgical clip. According to these, the design of clip and selection of the best biomaterial for the perfect functioning of that can be optimized.

Results and Discussion

The geometric analysis was performed on the handle structure and the approach structure to prescribe large displacement. An angle of 15° was set from the calculation of height of the handle structure and the clip design of the plane of symmetry, defining the opening of the clip. It results in the displacement of 0.05 mm for X and Y directions, equivalent to a force of 30 N. Figure 4 shows the 15° angle and the resultant opening span of the clip.

After defining the opening span for the clip, FE simulations were performed using the selected metallic materials for the handle (AISI 316L and AISI 420). An elastic modulus of 200 GPa was set for AISI 420 and 192 GPa [6] was used for AISI 316L. The Poisson's ratio used for both steels was 0.3. Figure 5 shows the location of prescribed offset of 0.05 mm and the stress distribution in the handle structure of AISI 316L stainless steel material.

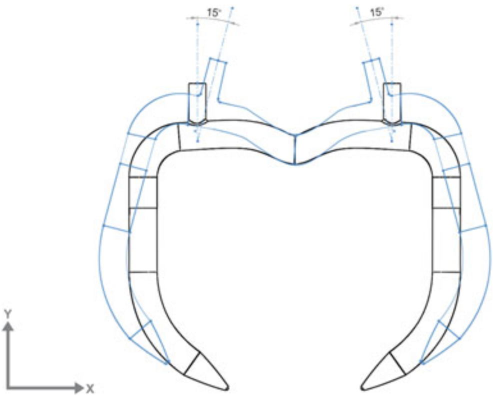

Fig. 4 Schematic of the clip opening geometry with a 15° angle

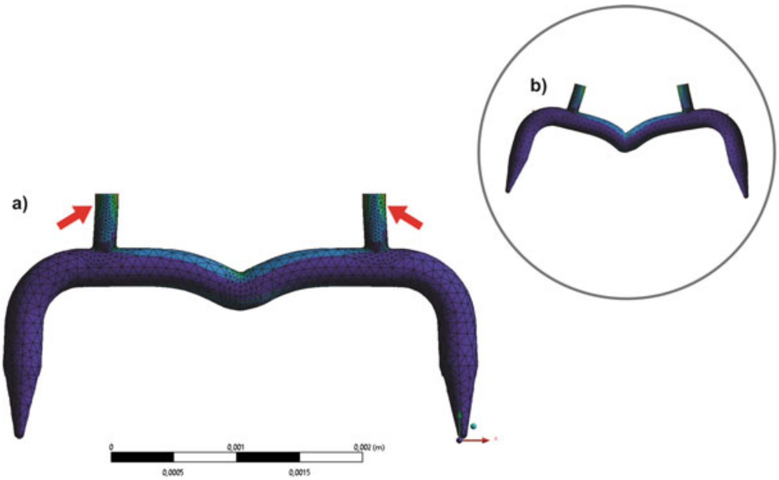

Fig. 5 Identification of boundary conditions (prescribe displacement) on the of handle structure (**a**) and open clip (b)

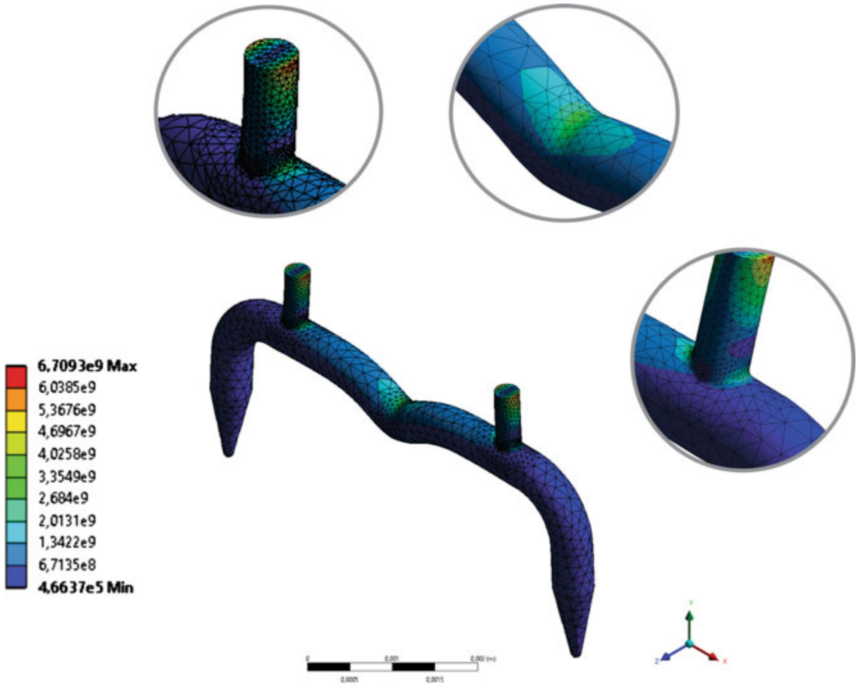

Fig. 6 Identification of stress concentration on the handle structure of the AISI 316L surgical clip

For the design considered, the more intense stress concentrations were located at point of contact between the opening tool (at the upper part of the handle) and at the joint responsible for the elastic opening of the handle. The stress concentration at these points are far above the yield strength and ultimate tensile strength of both steels. For AISI 316L the relevant stress concentration is identified as shown in Fig. 6, approaching 3 GPa. This indicates that plastic deformation and possible rupture of the material will occur, especially at the joint, where there is an angle of 110°.

It has also been established the same displacement to the handle opening of stainless steel AISI 420. Figure 7 shows the clip simulation AISI 420 with the tension distribution to identifying regions of clip handle structure.

The stress concentration in the steel AISI 420 handle structure was also predominant in the central region, as identified in Fig. 7, reaching a pressure of about 3GPa. This also far exceeds its strength, equivalent to 967 MPa [6], indicating that fracture should occur in this region.