Prosthetic osseointegration worldwide: from ground-breaking treatment to standard of care!

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Prof Laurent Frossard is a bionic limbs scientist who is passionate about developing ground-breaking prosthetic solutions to improve the lives of individuals suffering from limb loss. He is internationally recognized as a researcher and an independent expert for his unique expertise in bionic limbs. He approaches bionic solutions from a holistic perspective, by integrating the prosthetic biomechanics, clinical benefits, service delivery, and health economics. Prof Frossard has over 25 years of experience, both in academia and in private industries in Australia, Canada, and Europe. He has collaborated with over 100 organizations worldwide.
He is currently a Professor of Bionics at the Griffith University, the Director and Chief Scientist Officer at YourResearchProject Pty Ltd, and Adjunct Professor at the Queensland University of Technology and the University of Sunshine Coast in Australia.

Summary

This presentation provides a summary of evidence of efficacy and safety of some bionic solutions. Particularly, this presentation will provide relevant information about bionics solutions that might be relevant to former and active military Service Members.

Background

Walking with an artificial limb is essential to restore mobility, return to active duty, and maintain the quality of life of military Service Members, Veterans and beneficiaries suffering from lower limb loss.[1-13]

Bionic prostheses should, at least mimic, and possibly amplify, the functions of a missing limb through better connections with bones, muscles, nerves and skin.[14-20] Most common bionic solutions involve fitting of a bone-anchored prosthesis with advanced components attached to an osseointegrated implant.[3, 19, 21-38]

Choosing a bionic solution for active Service Members could be overwhelming because of the complexity of information to consider, particular when aiming at staying or,

possibly, return to active duty.[19, 23, 25, 26, 39-54]

Objectives

This objectives of this presentation were to summarize efficacy and safety of bionic solutions and to highlight future scientific developments that might increase suitability of bionics solutions for former and active military Service Members.[25, 39, 40, 43].

Methods

The literature review focused articles presenting the benefits and harms as well as the opinion papers pointing out future development of bionic solutions.[25, 27, 29, 31, 32, 39-41, 43, 55-75]

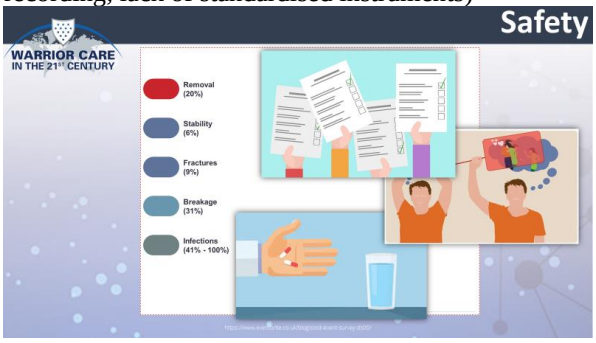
Results

Bone-anchored prostheses improves quality of life by 17% compared to typical socket prostheses (e.g., prosthetic use, embodiment, range of motion, sitting comfort, donning and doffing, osseoperception). However, evidence of efficacy is often biased by "three boosters": placebo effect, predetermined favourable opinion on the treatment and fitting of high-end components (Figure 1).[76]

Figure 1. Overview of the factors "bosting" benefits of bone-anchored prosthesis (e.g., placebo effect, predetermined favourable opinion on the treatment, fitting of high-end components).

The bone/implant coupling is prone to risks of loosening (6%), periprosthetic fractures (9%), mechanical failure of implant parts (31%) as well as deep (41%) and superficial (100%) infections that could lead to the removal of the implant in up to 20% of cases.[43] We know little about the true intake of pain killers and antibiotics to fight infections, mainly because of bias recording and lack of standardised instruments to record medication history (Figure 2). These adverse events could cause residuum pain, disturb the lifestyle and cost money.

Figure 2. Overview of the harms discarded when looking at safety of bone-anchored prosthesis (e.g., intake of pain killers and antibiotics, issues bias recording, lack of standardised instruments)



Discussion

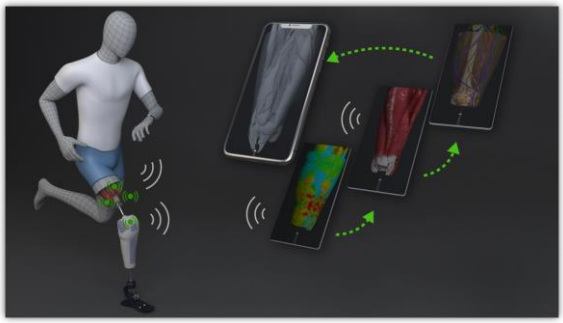
Based on these outcomes, choosing osseointegration as a method to attach a prosthesis might come down resolving the "20/20 dilemma". The quality of life is likely to improve by 17% to 20%. This biggest risk of failure is up to 20%. There is also uncertainty around the capacity of active Service Member to perform military duty when fitted with bone-anchored prostheses (e.g., loading tolerance of bone implant coupling).[53, 77-99]

Future developments of bionics solutions, we will require a diagnostic device combing (Figure 3):

- Measurements of the mechanical loading applied to the residuum using portable wireless sensors, [53, 77-99]
- Measurement of the tissue distribution within the residuum made by the newly developed Dynamic Anatomical Ultrasonography,

- Neuromusculoskeletal modelling or "digital twinning" of the residuum for a real-time personalized animation of the residuum during static and dynamic loading conditions.

Figure 3. Role of diagnostic tool to assess and maintain the health residuum of individuals with lower limb loss.



Conclusion

Developments of bionics solutions suitable for active Service Members are promising. However, more basic and applied research work is need, particularly those focusing on digital twin of the residuum. This is required to improve efficacy and safety of bionic solutions for increasing population of individuals suffering from limb loss choosing bionic solutions.

Conflict of interest

The author is in the view that these competing interests do not conflict with the content of this manuscript.

Laurent Frossard, Director and Chief Scientist Officer of YourResearchProject Pty Ltd, has worked as consultant for several organisations on non-related educational programs and projects of research focusing on recording loading data, developing of database to record clinical outcomes as well as drafting grants and manuscripts for Cognitive Institute, Exercise & Sports Science Australia, Griffith University, iPug Pty Ltd, Middlesex University, New Zealand Artificial Limb Service, Osseointegration Group of Australia Pty Ltd, OSSUR, Poly-Orthodox International, Queensland Artificial Limb Service, Queensland University of Technology, Return to Work-South Australia, South Australia Health, Tequir S.L, University of the New South Whales, University of the Sunshine Coast.

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References

1. Wolf, E.J., et al., *Assessment of transfemoral amputees using C-Leg and Power Knee for ascending and descending inclines and steps.* J Rehabil Res Dev, 2012. **49**(6): p. 831-42.
2. McMenemy, L., et al., *Direct Skeletal Fixation in bilateral above knee amputees following blast: 2 year follow up results from the initial cohort of UK service personnel.* Injury, 2020.
3. Overmann, A., et al., *Orthopaedic Osseointegration: Implantology and Future Directions.* Journal of Orthopaedic Research, 2019. **n/a**(n/a).
4. Blough, D.K., et al., *Prosthetic cost projections for servicemembers with major limb loss from Vietnam and OIF/OEF.* J Rehabil Res Dev, 2010. **47**(4): p. 387-402.

5. Potter, B.K., *From Bench to Bedside: We Can (Still) Do Better-Moving Towards More Thoughtful, "Constructive" Amputations.* Clin Orthop Relat Res, 2019. **477**(8): p. 1793-1795.
6. Wood, P., C. Small, and P. Mahoney, *Perioperative and early rehabilitation outcomes following osseointegration in UK military amputees.* Journal of the Royal Army Medical Corps, 2019: p. jramc-2019-001185.
7. Cancio, J.M., et al., *Upper Extremity Amputation and Prosthetics Care Across the Active Duty Military and Veteran Populations.* Physical Medicine and Rehabilitation Clinics of North America, 2018.
8. Grimm, P.D., et al., *Is Lower Extremity Transplantation a Superior Alternative to Prostheses? No—At Least Not Yet.* Current Transplantation Reports, 2018.
9. Kendrew, J., et al., *Direct Skeletal Fixation - a new treatment paradigm in combat amputees?* JTO Subspecialty Section, 2018. **06**(02).
10. Sinha, R. and W.J.A. Van Den Heuvel, *A systematic literature review of quality of life in lower limb amputees.* Disability and Rehabilitation, 2011. **33**(11): p. 883-899.
11. Van De Ven, C., *Leisure for the amputee.* International Rehabilitation Medicine, 1986. **8**(3): p. 128-128.
12. Christensen, J., et al., *Physical and social factors determining quality of life for veterans with lower-limb amputation(s): a systematic review.* Disabil Rehabil, 2016. **38**(24): p. 2345-53.
13. Christensen, J., et al., *Ambivalence in rehabilitation: thematic analysis of the experiences of lower limb amputated veterans.* Disabil Rehabil, 2017: p. 1-8.
14. Aman, M., et al., *Bionic reconstruction : Restoration of extremity function with osseointegrated and mind-controlled prostheses.* Wien Klin Wochenschr, 2019. **131**(23-24): p. 599-607.
15. Aszmann, O.C., et al., *Elective amputation and bionic substitution restore functional hand use after critical soft tissue injuries.* Scientific Reports, 2016. **6**(1): p. 34960.
16. Bumbaširević, M., et al., *The current state of bionic limbs from the surgeon's viewpoint.* EFORT Open Reviews, 2020. **5**(2): p. 65-72.
17. Farina, D. and S. Amsuss, *Reflections on the present and future of upper limb prostheses.* Expert Rev Med Devices, 2016. **13**(4): p. 321-4.
18. Farina, D., et al., *Toward higher-performance bionic limbs for wider clinical use.* Nature Biomedical Engineering, 2021.
19. Gerzina, C., et al., *The future of the amputees with osseointegration: A systematic review of literature.* J Clin Orthop Trauma, 2020. **11**(Suppl 1): p. S142-s148.
20. Keszler, M.S., et al., *Advances in Prosthetics and Rehabilitation of Individuals with Limb Loss.* Phys Med Rehabil Clin N Am, 2019. **30**(2): p. 423-437.
21. Zaid, M.B., et al., *Orthopaedic Osseointegration: State of the Art.* J Am Acad Orthop Surg, 2019. **27**(22): p. e977-e985.
22. Potter, B.K., *From Bench to Bedside: A Perfect Fit? Osseointegration Can Improve Function for Patients with Amputations.* Clin Orthop Relat Res, 2016. **474**(1): p. 35-7.
23. Cooke, D.M., M. Ames, and S. Geffen, *Life without limbs: Technology to the rescue.* Prosthet Orthot Int, 2016. **40**(4): p. 517-21.

24. Pitkin, M., *Design features of implants for direct skeletal attachment of limb prostheses.* J Biomed Mater Res A, 2013. **101**(11): p. 3339-48.
25. Branemark, R., et al., *Osseointegration in skeletal reconstruction and rehabilitation: a review.* J Rehabil Res Dev, 2001. **38**(2): p. 175-81.
26. van der Linde, H., et al., *A systematic literature review of the effect of different prosthetic components on human functioning with a lower-limb prosthesis.* J Rehabil Res Dev, 2004. **41**(4): p. 555-70.
27. Juhnke, D., et al., *Fifteen years of experience with Integral-Leg-Prosthesis: Cohort study of artificial limb attachment system.* Journal of Rehabilitation Research and Development, 2015. **52**(4): p. 407-420.
28. Branemark, R., et al., *A novel osseointegrated percutaneous prosthetic system for the treatment of patients with transfemoral amputation: A prospective study of 51 patients.* Bone Joint J, 2014. **96**(1): p. 106-113.
29. Aschoff, H.H., et al., *Transcutaneous, distal femoral, intramedullary attachment for above-the-knee prostheses: an endo-exo device.* J Bone Joint Surg Am, 2010. **92 Suppl 2**(Supplement 2): p. 180-6.
30. Pitkin, M., *One lesson from arthroplasty to osseointegrationin search for better fixation of in-bone implanted prosthesis.* Journal of Rehabilitation Research & Development, 2008. **45**(4): p. 6-14.
31. Berlin, Ö., et al., *Osseointegration in transfemoral amputees: the gothenburg experience*, in *Journal of Bone and Joint Surgery, British Volume*. 2012. p. 55.
32. Hagberg, K., et al., *Osseointegrated trans-femoral amputation prostheses: Prospective results of general and condition-specific quality of life in 18 patients at 2-year follow-up.* Prosthetics and Orthotics International, 2008. **32**(1): p. 29-41.
33. Khemka, A., et al., *Osseointegrated total knee replacement connected to a lower limb prosthesis: 4 cases.* Acta Orthop, 2015: p. 1-5.
34. Vertriest, S., et al., *Rehabilitation programs after the implantation of transfemoral osseointegrated fixations for bone-anchored prostheses: a scoping review protocol.* JBI Database of Systematic Reviews and Implementation Reports, 2017. **15**(2): p. 1-13.
35. Vertriest, S., et al., *Static load bearing exercises of individuals with transfemoral amputation fitted with an osseointegrated implant: Loading compliance.* Prosthet Orthot Int, 2017. **41**(4): p. 393-401.
36. Vertriest, S., et al., *Static load bearing exercises of individuals with transfemoral amputation fitted with an osseointegrated implant: reliability of kinetic data.* IEEE Trans Neural Syst Rehabil Eng, 2015. **23**(3): p. 423-30.
37. Frossard, L., et al., *Apparatus for monitoring load bearing rehabilitation exercises of a transfemoral amputee fitted with an osseointegrated fixation: a proof-of-concept study.* Gait & posture, 2010. **31**(2): p. 223-8.
38. Frossard, L., et al., *Load-relief of walking aids on osseointegrated fixation: instrument for evidence-based practice.* IEEE Trans Neural Syst Rehabil Eng, 2009. **17**(1): p. 9-14.
39. Atallah, R., et al., *Complications of bone-anchored prostheses for*

individuals with an extremity amputation: A systematic review. PLoS One, 2018. **13**(8): p. e0201821.
40. Hebert, J.S., M. Rehani, and R. Stiegelmar, *Osseointegration for Lower-Limb Amputation: A Systematic Review of Clinical Outcomes.* JBJS Rev, 2017. **5**(10): p. e10.
41. Leijendekkers, R.A., et al., *Comparison of bone-anchored prostheses and socket prostheses for patients with a lower extremity amputation: a systematic review.* Disabil Rehabil, 2017. **39**(11): p. 1045-1058.
42. Meulenbelt, H.E., et al., *Skin problems in lower limb amputees: a systematic review.* Disabil Rehabil, 2006. **28**(10): p. 603-608.
43. van Eck, C.F. and R.L. McGough, *Clinical outcome of osseointegrated prostheses for lower extremity amputations: a systematic review of the literature.* Current Orthopaedic Practice, 2015. **26**(4): p. 349-357.
44. Bui, K.M., et al., *Skin problems in individuals with lower-limb loss: literature review and proposed classification system.* J Rehabil Res Dev, 2009. **46**(9): p. 1085-90.
45. Frossard, L., *Bionic solutions: too good to pass or too bad to grab?* Amplified Magazine, 2021. **2021**(1): p. 22-23.
46. Frossard, L., et al., *Cost-Effectiveness of Transtibial Bone-Anchored Prostheses Using Osseointegrated Fixation: From Challenges to Preliminary Data.* JPO Journal of Prosthetics and Orthotics, 2021. **33**(3): p. 184-195.
47. Frossard, L., et al., *Cost-effectiveness of bone-anchored prostheses using osseointegrated fixation: myth or reality?* Prosthet Orthot Int, 2018. **42**(3): p. 318-327.
48. Frossard, L., et al., *Cost comparison of socket-suspended and bone-anchored transfemoral prostheses.* JPO Journal of Prosthetics and Orthotics, 2017. **29**(4): p. 150-160.
49. Frossard, L. *Osseointegration, Bionic Solutions, and Clinical Outcomes-Part 4: Key Issues for Osseointegration Patients*. 2021 [cited 2021 10/01/2021]; Available from: https://eprints.qut.edu.au/207023/1/2020_B4E_Dialogue_Bionic_solution_Part_4_ePrint.pdf.
50. Frossard, L. *Osseointegration, Bionic Solutions, and Clinical Outcomes-Part 3: Eight Ways to Improve Osseointegration*. 2021 [cited 2021 10/01/2021]; Available from: https://eprints.qut.edu.au/207022/1/2020_B4E_Dialogue_Bionic_solution_Part_3_ePrint.pdf.
51. Frossard, L. *Osseointegration, Bionic Solutions, and Clinical Outcomes-Part 2: Disadvantages of Osseointegration*. 2021 [cited 2021 10/01/2021]; Available from: https://eprints.qut.edu.au/207020/1/2020_B4E_Dialogue_Bionic_solution_Part_2_ePrint.pdf.
52. Frossard, L. *Osseointegration, Bionic Solutions, and Clinical Outcomes-Part 1: Advantages of Osseointegration*. 2021 [cited 2021 10/01/2021]; Available from: https://eprints.qut.edu.au/207019/1/2020_B4E_Dialogue_Bionic_solution_Part_1_ePrint.pdf.
53. Frossard, L., et al., *Role of the prosthetist in provision of bone-anchored prostheses: governmental and practitioner perspectives.* The AOPA Review, 2018. **3**(1): p. 26-27.
54. Frossard, L. and D. Llyod, *The future of bionic limbs.* Research Features, 2021. **134**: p. 54-57.

55. Hagberg, K., et al., *A 15-year follow-up of transfemoral amputees with bone-anchored transcutaneous prostheses.* Bone Joint J, 2020. **102-B**(1): p. 55-63.
56. Leijendekkers, R.A., et al., *Functional performance and safety of bone-anchored prostheses in persons with a transfemoral or transtibial amputation: a prospective one-year follow-up cohort study.* Clin Rehabil, 2018: p. 269215518815215.
57. Matthews, D.J., et al., *UK trial of the Osseointegrated Prosthesis for the Rehabilitation for Amputees: 1995-2018.* Prosthet Orthot Int, 2019. **43**(1): p. 112-122.
58. Wang, W. and J.P. Lynch. *Identification of bone fracture in osseointegrated prostheses using Rayleigh wave methods*. in *SPIE Smart Structures and Materials + Nondestructive Evaluation and Health Monitoring*. 2018. SPIE.
59. Tillander, J., et al., *Osteomyelitis Risk in Patients With Transfemoral Amputations Treated With Osseointegration Prostheses.* Clin Orthop Relat Res, 2017. **475**(12): p. 3100-3108.
60. Atallah, R., et al., *Osseointegrated Transtibial Implants in Patients with Peripheral Vascular Disease: A Multicenter Case Series of 5 Patients with 1-Year Follow-up.* J Bone Joint Surg Am, 2017. **99**(18): p. 1516-1523.
61. Uglow, M. and K.F. Fitzpatrick, *The Osseointegration Group of Australia Accelerated Protocol (OGAAP-1) for two-stage osseointegrated reconstruction of amputated limbs - Editorial.* Bone Joint J, 2016. **98-B**(7).
62. Lenneras, M., et al., *The clinical, radiological, microbiological and molecular profile of the skin-penetration site of transfemoral amputees treated with bone-anchored prostheses.* J Biomed Mater Res A, 2016: p. n/a-n/a.
63. Haket, L.M., et al., *Periprosthetic cortical bone remodeling in patients with an osseointegrated leg prosthesis.* J Orthop Res, 2017. **35**(6): p. 1237-1241.
64. Mollaret, E. and M. Bertrand Marchand, *Osseointegration of the lower limb: Reduction of mechanical strain on the abutment.* Annals of Physical and Rehabilitation Medicine, 2015. **58, Supplement 1**: p. e18.
65. Xu, W. and K. Robinson, *X-ray image review of the bone remodeling around an osseointegrated trans-femoral implant and a finite element simulation case study.* Ann Biomed Eng, 2008. **36**(3): p. 435-43.
66. Tsikandylakis, G., O. Berlin, and R. Branemark, *Implant survival, adverse events, and bone remodeling of osseointegrated percutaneous implants for transhumeral amputees.* Clin Orthop Relat Res, 2014. **472**(10): p. 2947-56.
67. Palmquist, A., et al., *Retrieved bone-anchored percutaneous amputation prosthesis showing maintained osseointegration after 11 years-a case report.* Acta Orthop, 2014. **85**(4): p. 442-5.
68. Tranberg, R., R. Zugner, and J. Karrholm, *Improvements in hip- and pelvic motion for patients with osseointegrated trans-femoral prostheses.* Gait Posture, 2011. **33**(2): p. 165-8.
69. Jacobs, R., et al., *Evaluation of the psychophysical detection threshold level for vibrotactile and pressure stimulation of prosthetic limbs using bone anchorage or soft tissue support.* Prosthetics and Orthotics

International, 2000. **24**(2): p. 133-142.
70. Hagberg, K. and R. Branemark, *One hundred patients treated with osseointegrated transfemoral amputation prostheses: rehabilitation perspective.* J Rehabil Res Dev, 2009. **46**(3): p. 331-44.
71. Hagberg, K., et al., *Socket versus bone-anchored trans-femoral prostheses: hip range of motion and sitting comfort.* Prosthet Orthot Int, 2005. **29**(2): p. 153-163.
72. Frossard, L., et al., *Functional Outcome of Transfemoral Amputees Fitted With an Osseointegrated Fixation: Temporal Gait Characteristics.* JPO Journal of Prosthetics and Orthotics, 2010. **22**(1): p. 11-20.
73. Frossard, L., *Load on osseointegrated fixation of a transfemoral amputee during a fall: Determination of the time and duration of descent.* Prosthet Orthot Int, 2010. **34**(4): p. 472-87.
74. Frossard, L., et al., *Load on osseointegrated fixation of a transfemoral amputee during a fall: loading, descent, impact and recovery analysis.* Prosthet Orthot Int, 2010. **34**(1): p. 85-97.
75. Frossard, L., et al., *Fall of a transfemoral amputee fitted with osseointegrated fixation: loading impact on residuum.* Gait & posture, 2009. **30**(Supplement 2): p. S151-S152.
76. Harris, I., *Surgery as Placebo: A Surgeon Cuts Through the Evidence*, ed. N. Publishing. 2016. 224.
77. Pitkin, M. and L. Frossard, *Loading Effect of Prosthetic Feet's Anthropomorphicity on Transtibial Osseointegrated Implant.* Military Medicine, 2021. **186**(Supplement 1): p. 681-687.
78. Frossard, L., B. Leech, and M. Pitkin, *Loading applied on osseointegrated implant by transtibial bone-anchored prostheses during daily activities: Preliminary characterization of prosthetic feet.* J Prosthet Orthot, 2020. **32**(4): p. 258-271.
79. Frossard, L., *Inter-participant variability of loading characteristics applied on osseointegrated implant by transfemoral bone-anchored prostheses fitted with basic components during daily activities*. 2019: Mendeley data.
80. Frossard, L., *Loading characteristics data applied on osseointegrated implant by transfemoral bone-anchored prostheses fitted with basic components during daily activities.* Data in Brief, 2019. **26**: p. 104492.
81. Frossard, L., B. Leech, and M. Pitkin, *Inter-participant variability data in loading applied on osseointegrated implant by transtibial bone-anchored prostheses during daily activities.* Data in Brief, 2019. **26**: p. 104510.
82. Frossard, L., B. Leech, and M. Pitkin, *Inter-participant variability data in characterization of anthropomorphicity of prosthetic feet fitted to bone-anchored transtibial prosthesis.* Data in Brief, 2019. **25**: p. 104195.
83. Frossard, L., et al., *Load applied on osseointegrated implant by transfemoral bone-anchored prostheses fitted with state-of-the-art prosthetic components.* Clinical Biomechanics, 2021. **In press**.
84. Frossard, L., B. Leech, and M. Pitkin, *Automated characterization of anthropomorphicity of prosthetic feet fitted to bone-anchored transtibial prosthesis.* IEEE Trans Biomed Eng, 2019. **66**(12): p. 3402-3410.
85. Frossard, L., et al., *Load applied on a bone-anchored transfemoral*

prosthesis: characterisation of prosthetic components – A case study Journal of Rehabilitation Research & Development, 2013. **50**(5): p. 619–634.
86. Pather, S., et al., *Load characteristics following transfemoral amputation in individuals fitted with bone-anchored prostheses: a scoping review protocol.* JBI Database of Systematic Reviews and Implementation Reports, 2018. **16**(6): p. 1286-1310.
87. Neumann, E., et al., *Prosthesis: Load Cell Applicability to Outcome Measurement - Chapter 6*, in *Advances in Medicine and Biology*, L.V. Berhardt, Editor. 2017, Nova Science Publishers: New York. p. 133-172.
88. Lee, W.C., et al., *Magnitude and variability of loading on the osseointegrated implant of transfemoral amputees during walking.* Med Eng Phys, 2008. **30**(7): p. 825-33.
89. Lee, W., et al., *Kinetics Analysis of Transfemoral Amputees fitted with Osseointegrated Fixation Performing Common Activities of Daily Living.* Clinical Biomechanics, 2007. **22**(6): p. 665-673.
90. Frossard, L., et al., *Monitoring of the load regime applied on the osseointegrated fixation of a trans-femoral amputee: a tool for evidence-based practice.* Prosthet Orthot Int, 2008. **32**(1): p. 68-78.
91. Frossard, L., et al., *Categorization of activities of daily living of lower limb amputees during short-term use of a portable kinetic recording system: A preliminary study.* JPO Journal of Prosthetics and Orthotics, 2011. **23**(1): p. 2-11.
92. Berg, D. and L. Frossard, *Health service delivery and economic evaluation of limb lower bone-anchored prostheses: A summary of the Queensland artificial limb service's experience.* Canadian Prosthetics & Orthotics Journal, 2021. **In press**.
93. Frossard, L., *Data supporting the 2019 Queensland Artificial Limb Service's science report about innovations of health services and economic evaluation of limb lower bone-anchored prostheses*. 2020: Mendeley data.
94. Frossard, L., *Innovations of health services and economic evaluation of bone-anchored prosthesis using osseointegration: the Queensland Artificial Limb Service's experience - 2019 Scienctific Report*, ed. L. Frossard. 2020, Brisbane, Australia: YourResearchProject. 19.
95. Frossard, L., L. Ferrada, and D. Berg, *Survey data on the quality of life of consumers fitted with osseointegrated fixation and bone-anchored limb prostheses provided by government organization.* Data in Brief, 2019. **26**: p. 104536.
96. Frossard, L., L. Ferrada, and D. Berg, *Survey on the quality of life of consumers fitted with osseointegrated fixation and bone-anchored limb prostheses provided by government organization*. 2019: Mendeley data.
97. Frossard, L., et al., *Development of a government continuous quality improvement procedure for assessing the provision of bone anchored limb prosthesis: A process re-design descriptive study.* Canadian Prosthetics & Orthotics Journal, 2018. **1**(2): p. 1-14.
98. Frossard, L., *Innovations of health services and economic evaluation of bone-anchored prosthesis using osseointegration: the Queensland Artificial Limb Service's experience - 2017 Scienctific Report*, ed. L.

Frossard. 2018, Brisbane, Australia: YourResearchProject. 19.
99. Frossard, L., et al., *Development of a procedure for the government provision of bone-anchored prosthesis using osseointegration in Australia.* PharmacoEconomics - Open, 2017. **1**(4): p. 301-314.