Loading Effect of Prosthetic Feet's Anthropomorphicity on Transtibial Osseointegrated Implant

Loading effect of prosthetic feet's anthropomorphicity on transtibial osseointegrated implant

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Purpose of the study

Osseointegrated implants for direct skeletal attachment of transtibial prosthesis carry risks that are yet to be fully resolved: early loosening, mechanical failure of percutaneous and medullar parts of implant, periprosthetic issues, and infections.[1-11] Underloading could lead to early loosening and infection.[12-17] Overloading might compromise the bone–implant interface.[18-21] Therefore, Goldilocks loading regimen applied by transtibial bone-anchored prostheses is critical for safe and efficient development of osseointegration around the implant during rehabilitation and beyond.[22-37]

Study hypothesis

We hypothesized that Goldilocks loading can be achieved when using a so-called anthropomorphic prosthetic ankle showing moment-angle relationship that resembles to a sound ankle.[38-44] In the long-term, we believe that properly attuned stiffness of an anthropomorphic prosthetic ankle could significantly mitigate the risks of commonly experienced adverse events, particularly loosening, periprosthetic issues and, possibly, infections.[27, 45-58]

Study design

The hypothesis was tested in gait trials with three below-knee amputees with an osseointegrated fixation.[10, 59] The subjects' own prostheses were RUSH foot (RUSH), Trias 1C30 foot and Triton - Vertical shock 1C6 foot (both by Otto Bock), respectively.[15, 17-21, 60-69]

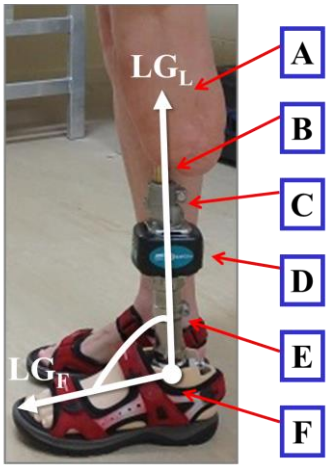


Figure 1. Example of long axes of the leg (LGL) and foot (LGF) used to determine ankle angle of dorsiflexion of the instrumented transtibial bone-anchored prosthesis attached to residuum (A) and percutaneous part of osseointegration fixation (B) including connector (C), transducer (D), pylon (E) and multi-axial rolling Free-Flow Foot (Ohio Willow Wood) (F).
Adapted from Frossard et al (2019).[60, 61]

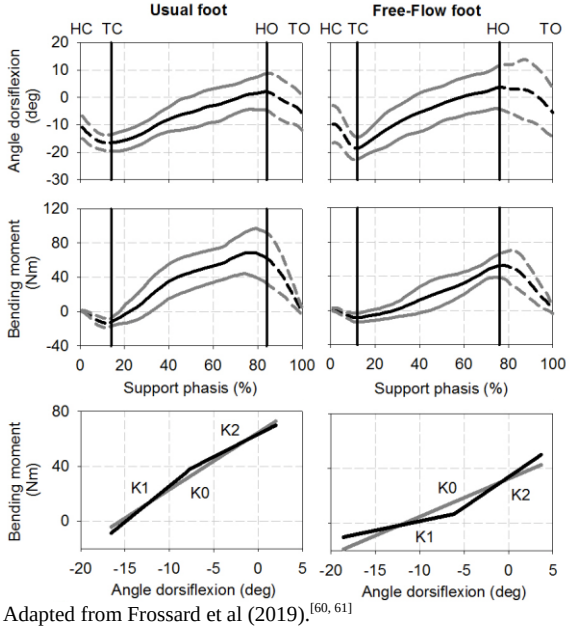
Dorsiflexion angle and bending moment data were collected using video

camera and portable kinetic system (Figure 1).[60, 61] Subjects were recorded when walking with their own foot, and then with the Free-Flow Foot (Ohio Willow Wood).[17, 60, 61] The Free Flow Foot was selected due to its stiffness curve's concavity, which is also observed in the ankle in the norm.[44, 60, 61] The ankle stiffness and index of anthropomorphicity (IA) were computed concurrently with the loads on the fixation.[61]

Results

The three usual feet used by the subjects were classified as non-anthropomorphic as their individual moment-angle curves were convex, with a negative index of anthropomorphicity (IA). Alternatively, the Free-Flow Foot was classified to be anthropomorphic with its concave individual moment-angle curves and positive IA.

Figure 2. Mean and standard deviation of grouped angle of dorsiflexion and bending moment as well as shape and regression lines for macro (K0) and meso (K1, K2) analyses of overall moment-angle curves of usual (N=14) and Free-Flow (N=14) feet fitted to transtibial bone-anchored prostheses. HC: Heel contact, TC: Toe contact, HO: Heel off, TO: Toe off



Adapted from Frossard et al (2019).[60, 61]

Data analysis demonstrated that anthropomorphic foot prosthesis reduced maximal bending moment applied to the implant by 25%, compared to three non-anthropomorphic feet worn by the subjects (Figure 2).[17]

Conclusion

The results suggest that providing patients with prostheses meeting the criterion of anthropomorphicity decreases maximal loads. This could potentially increase the longevity of the bone-implant interface while reducing rate of revisions without modifying existing technology of osseointegration. This work was an initial effort toward laying out characterization principles for stiffness analysis and providing benchmark of stiffness data in feet with and without anthropomorphic designs.

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