A synthesis of the range of loads applied on the residuum of individuals with transfemoral amputation fitted with bone-anchored prostheses

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Background

Bone anchored prostheses have recently been implemented in the field of limb replacement, as it alleviates many of the issues surrounding the conventional socket interfaces.[1-35] However, due to the direct skeletal attachment, serious injury and damage can occur through excessive loading events such as a fall.[36-38] For this reason, it is essential to understand the range of loads experienced within bone anchored prostheses to: optimize the design of componentry; provide safety solutions; and tailor rehabilitation programs accordingly.[8, 10, 11, 14, 15, 36-61]

Aim

The aim of this study was to review the current literature targeting direct measurement of the forces and moments within bone anchored prostheses, to provide a synthesis of the range of loads observed.

Method

A literature search was conducted to identify all articles related to the loading of bone anchored prostheses during: rehabilitation exercises; a variety of everyday activities; and adverse events (e.g., a fall). Studies were screened by examining whether direct measurement techniques (e.g., load transducers) were used to assess the three-dimensional forces and moments occurring within the bone anchored fixation of individuals with a transfemoral amputation.[8, 10, 11, 14, 15, 36-40, 42, 44, 46-48] The three axes were defined as: Anterior Posterior (AP), Medial Lateral (ML), and Axial or Long (LG). The loading data were presented in raw units (Newtons) and a percentage of bodyweight (% BW) where possible.[43] The data was mapped graphically to display the forces and moments for each activity analyzed across all studies.

Results

Table 1. Combined average value and standard deviation (in brackets) for the forces and moments applied on each axes of the bone anchored prostheses during everyday activities.

Axis	Force (N)	Moment (Nm)
AP	127 (41)	17 (20)
ML	100 (35)	21 (16)
LG	793 (102)	5 (3)

This study included 11 articles published between 1990 and 2016. Frossard et al. (2010) presented data from a subject falling, reporting the largest recorded loading values, where a maximum force of 1145 N, and moment of 153 Nm, occurred along the long axis and

medial-lateral axis of the prostheses respectively, which corresponds to 126 % BW and 16.8 % BWm.[38] For everyday activities, the combined average of the maximum values and corresponding standard deviations for each axes are shown in Table 1, which displays a small portion of the results.

Discussion and Conclusion

The range of loads presented in this study has implications for a variety of areas in the utilisation of bone anchored prostheses. For example, the mean and maximum loading values for everyday activities can be used in the design and optimisation of system components, and limits can be established for safety devices. Additionally, rehabilitation programs can be tailored to accommodate these verified loads which regularly occur through daily living. This study highlighted the limited loading information available, and the requirement for further research into the loads experienced by bone anchored prostheses.

Overall, this study has demonstrated the large range of loads that occur within bone anchored prostheses, and provides a starting point for the optimisation of this technology.

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