Where to Amputate based on Probabilities the Prosthetic Components will Fit

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INTRODUCTION

Traditionally, surgeons performing amputation surgery intend to leave the residuum as long as possible but this practice may inhibit prosthetic componentry options. As prosthetists become more involved in the healthcare team, he/she's advice may be sought by surgeons performing amputation about desirable residual limb lengths.

The amount of space needed for prosthetic components (component clearance) will be dependent on more than prosthetic foot build height. There will need to be additional allowances for the socket thickness, distal attachment plate, alignable components, and suspension design. The plethora of available prosthetic technology makes for a near infinite number of possible component selection combinations and this makes a straight calculation impractical. However, advanced mathematical modeling based on predictive variability can calculate the probabilities a successful combination could be fit.

The purpose was to calculate the probability a successful combination of prosthetic components could be achieved at a given component clearance using a random Monte Carlo simulation. These results will be a first step to better inform surgeons.

METHOD

A random Monte Carlo simulation was used to assign a probabilistic distribution to model parameters (e.g. data will be normally distributed with a mean and standard deviation) and reiterated 10,000 times (π times the minimum iterations). Each iteration pseudo-randomly uses a value consistent with the defined probabilistic distribution function, calculates an output, and builds a database of possible outcomes.

The model used here calculated component clearance based on male and female anthropometric variability (NASA, 1978), gender probability, residuum length probabilities (Childers et al., 2014), component build height variability, and probability a foot within an L-code would be chosen (Levinson, 2011).

Component build heights were acquired for fifty prosthetic feet with L5972, L5980, L5981, and L5987 associated L-codes, suspension components (shuttle locks, vacuum pumps, etc.), lamination thickness (direct measurement of twenty sockets), attachment plate thicknesses, and pyramid receiver heights.

The probability a random combination of components would fit anyone was calculated by subtracting predicted residual limb length and total component build height from the total shank/foot length. The percentage of outputs with positive values indicated the likelihood of success.

Component clearance was calculated by isolating the build height data organized by foot Lcode.

RESULTS

There was a 74.3% chance a random component combination would fit anyone with an amputation, regardless of the prosthetic foot being used. There were 89.8, 81.6, 56.6, and 56.6% chance a random component selection with a L5972, L5981, L5980, & L5987 code foot (respectfully) would result in enough clearance. The probability a selected component combination would fit increased with component clearance (Figure1).

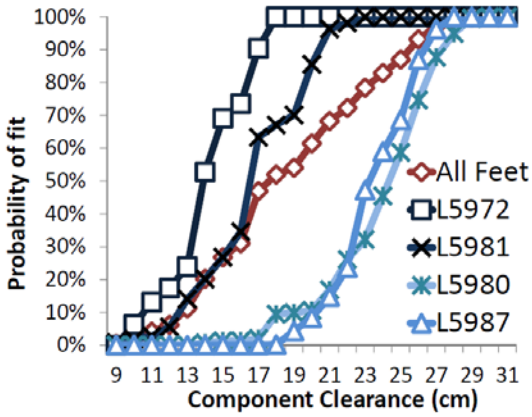

Figure 1. Probability of fit based on component clearance. For example, an amputation 27 cm from the bottom of the heel would yield a 95% chance any component combination with a L5987 foot would fit.

DISCUSSION

Residual limb length optimization will be the tradeoff between biomechanical advantages of a longer length and potential functional advantages of prosthetic components that require higher build heights. This work demonstrated the relationship between component clearance and the probability those components will fit. Future work can model the relationship between residual limb length and biomechanical advantage and then calculate an optimal amputation length.

CONCLUSION AND CLINICAL APPLICATION

A transtibial amputation that leaves at least 27 cm of component clearance will ensure a high likelihood the person will not be limited by component build heights.

REFERENCES

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