Elan

Elan is the first of its kind, taking the microprocessor-control technology more commonly seen in prosthetic knees, and applying it to the Echelon, an articulating prosthetic foot-ankle device with hydraulic damping. As such, it retains the benefits achieved by Echelon, in fact enhancing performance with the ability to control how much resistance is applied and at what time. As such the device can be tuned to the individual, providing a more natural, efficient gait pattern.

The addition of this control is especially beneficial during slope ambulation where it reduces energy expenditure of the user and improves stability and safety, particularly during descent. The control also enhances stability whilst standing, where resistances can be increased, thus decreasing the amount of energy required by the user to balance.

Improvements in Clinical Outcomes using Elan compared to ESR feet

Improvement in **SAFETY**

- Reduced risk of tripping and falls
  - Increased minimum toe clearance during swing phase[1,2]
- Improved knee stability on the prosthetic side during slope descent
  - Increased mid-stance external prosthetic knee extensor moment[3]
- Improving standing balance on a slope
  - 24-25% reduction in mean inter-limb centre-of-pressure root mean square (COP RMS)[4]

Improvement in **ENERGY CONSUMPTION**

- Reduced energy expenditure during walking
  - Mean 11.8% reduction in energy use on level ground, across all walking speeds[5]
  - Mean 20.2% reduction in energy use on slopes, across all gradients[5]
  - Mean 8.3% faster walking speed for the same amount of effort[5]

Improvement in **MOBILITY**

- Improved gait performance
  - Faster self-selected walking speed[2,6-9]
- Improved ground compliance when walking on slopes
  - Increased plantarflexion peak during level walking, fast level walking and cambered walking[10]
  - Increased dorsiflexion peak during level walking, fast level walking and cambered walking[10]
- Less of a prosthetic “dead spot” during gait
  - Reduced aggregate negative COP displacement[7]
  - Centre-of-pressure passes anterior to the shank statistically significantly earlier in stance[7]
  - Increased minimum instantaneous COM velocity during prosthetic-limb single support phase[7]

- Reduced peak negative COP velocity[9]
- Reduced COP posterior travel distance[9]

- Improved ground compliance when walking on slopes
  - Increased plantarflexion range during slope descent[3]
  - Increased dorsiflexion range during slope ascent[3]
- Less effort on residual hip for trans-femoral amputees on varied terrains
  - Reduced the mean hip extension and flexion moments[11]
- Effects consistent over time
  - Same gait variable changes in two gait lab sessions one year apart[6]
  - Magnitude of changes comparable between sessions[6]
- Brake mode during slope descent to control momentum build up
  - Reduced mean prosthetic shank angular velocity in single support[12]
  - Increased Unified Deformable Segment (prosthetic 'ankle') negative work[12]
- Less gait compensation movements during slope descent
  - Reduced residual knee flexion at loading response[12]

Improvement in **RESIDUAL LIMB HEALTH**

- Helps protect vulnerable residual limb tissue, reducing likelihood of damage
  - Reduced peak stresses on residual limb[13]
  - Reduced stress RMS on residual limb[13]
  - Reduced loading rates on residual limb[13]

Improvement in **LOADING SYMMETRY**

- Greater contribution of prosthetic limb to support during walking
  - Increased residual knee peak extension moment[6]
  - Decreased residual knee peak flexion moment[6]
  - Increased residual knee negative work[8]
- Reduced reliance on sound limb for support during walking
  - Reduced intact limb peak hip flexion moment[8]
  - Reduced intact limb peak dorsiflexion moment[8]
  - Reduced intact ankle negative work and total work[8]
  - Reduced intact limb total joint work[8]
- Better symmetry of loading between prosthetic and sound limbs during standing on a slope
  - Degree of asymmetry closer to zero for 5/5 amputees[4]
- Reduced residual and sound joint moments during standing of a slope
  - Significant reductions in both prosthetic and sound support moments[14]
- Reduced residual joint moments during standing of a slope for bilateral amputees
  - Significant reductions in prosthetic support moment[14]
  - Permitted 'natural' ground reaction vector sagittal plane position, relative to knee joint centres[14]
- Less pressure on the sole of the contralateral foot
  - Peak plantar-pressure[15]
- Improved gait symmetry
  - Reduced stance phase timing asymmetry[16]

Improvement in **USER SATISFACTION**

- Patient reported outcome measures indicate improvements
  - Mean improvement across all Prosthesis Evaluation Questionnaire domains[17]
  - Bilateral patients showed highest mean improvement in satisfaction[17]
- Subjective user preference for hydraulic ankle
  - 13/13 participants preferred hydraulic ankle[15]

Improvements in Clinical Outcomes using Elan compared to non-microprocessor-control hydraulic ankle-feet

Improvement in **SAFETY**

- Improved knee stability on the prosthetic side during slope descent
  - Increased mid-stance external prosthetic knee extensor moment[3]

Improvement in **MOBILITY**

- Improved ground compliance when walking down slopes
  - Reduced time to foot flat[12]
- Brake mode during slope descent increases resistance to dorsiflexion to control momentum build up
  - Reduced dorsiflexion range during slope descent[3]
  - Reduced mean prosthetic shank angular velocity in single support[12]
  - Increased Unified Deformable Segment (prosthetic 'ankle') negative work[12]
  - Transition from dorsiflexion to plantarflexion moment occurs earlier in stance phase[18]
  - Increase in mean prosthetic 'ankle' plantarflexion moment integral[18]
- Assist mode during slope ascent decreases resistance to dorsiflexion to allow easier progression
  - Transition from dorsiflexion to plantarflexion moment occurs later in stance phase[18]
  - Decrease in mean prosthetic 'ankle' plantarflexion moment integral[18]
- Less gait compensation movements during slope descent
  - Reduced residual knee flexion at loading response[12]

Improvement in **LOADING SYMMETRY**

- Greater reliance on prosthetic side for bodyweight support during slope descent
  - Increased support moment integral[18]
- Less reliance on sound side for bodyweight support during slope descent
  - Decreased support moment integral[18]
- Less reliance on sound side for bodyweight support during slope ascent
  - Decreased support moment integral[18]
- Reduced sound joint moments during standing of a slope
  - Significant reductions in sound support moment[14]
- Reduced residual joint moments during standing of a slope for bilateral amputees
  - Significant reductions in prosthetic support moment[14]

– Permitted 'natural' ground reaction vector sagittal plane position, relative to knee joint centres[14]

References

1. Riveras M, Ravera E, Ewins D, Shaheen AF, Catalfamo-Formento P. Minimum toe clearance and tripping probability in people with unilateral transtibial amputation walking on ramps with different prosthetic designs. Gait & Posture. 2020 Sep 1;81:41-8.

2. Johnson L, De Asha AR, Munjal R, et al. Toe clearance when walking in people with unilateral transtibial amputation: effects of passive hydraulic ankle. J Rehabil Res Dev 2014; 51: 429.

3. Bai X, Ewins D, Crocombe AD, et al. A biomechanical assessment of hydraulic ankle-foot devices with and without micro-processor control during slope ambulation in trans-femoral amputees. PLOS ONE 2018; 13: e0205093.

4. McGrath M, Laszczak P, Zahedi S, et al. Microprocessor knees with "standing support" and articulating, hydraulic ankles improve balance control and inter-limb loading during quiet standing. J Rehabil Assist Technol Eng 2018; 5: 2055668318795396.

5. Askew GN, McFarlane LA, Minetti AE, et al. Energy cost of ambulation in trans-tibial amputees using a dynamic-response foot with hydraulic versus rigid 'ankle': insights from body centre of mass dynamics. J NeuroEngineering Rehabil 2019; 16: 39.

6. De Asha AR, Barnett CT, Struchkov V, et al. Which Prosthetic Foot to Prescribe?: Biomechanical Differences Found during a Single-Session Comparison of Different Foot Types Hold True 1 Year Later. JPO J Prosthet Orthot 2017; 29: 39–43.

7. De Asha AR, Munjal R, Kulkarni J, et al. Impact on the biomechanics of overground gait of using an 'Echelon'hydraulic ankle–foot device in unilateral trans-tibial and trans-femoral amputees. Clin Biomech 2014; 29: 728–734.

8. De Asha AR, Munjal R, Kulkarni J, et al. Walking speed related joint kinetic alterations in trans-tibial amputees: impact of hydraulic'ankle'damping. J Neuroengineering Rehabil 2013; 10: 1.

9. De Asha AR, Johnson L, Munjal R, et al. Attenuation of centre-of-pressure trajectory fluctuations under the prosthetic foot when using an articulating hydraulic ankle attachment compared to fixed attachment. Clin Biomech 2013; 28: 218–224.

10. Bai X, Ewins D, Crocombe AD, et al. Kinematic and biomimetic assessment of a hydraulic ankle/foot in level ground and camber walking. PLOS ONE 2017; 12: e0180836.

11. Alexander N, Strutzenberger G, Kroell J, et al. Joint Moments During Downhill and Uphill Walking of a Person with Transfemoral Amputation with a Hydraulic Articulating and a Rigid Prosthetic Ankle—A Case Study. JPO J Prosthet Orthot 2018; 30: 46–54.

12. Struchkov V, Buckley JG. Biomechanics of ramp descent in unilateral trans-tibial amputees: Comparison of a microprocessor controlled foot with conventional ankle–

foot mechanisms. Clin Biomech 2016; 32: 164–170.

13. Portnoy S, Kristal A, Gefen A, et al. Outdoor dynamic subject-specific evaluation of internal stresses in the residual limb: hydraulic energy-stored prosthetic foot compared to conventional energy-stored prosthetic feet. Gait Posture 2012; 35: 121–125.

14. McGrath M, Davies KC, Laszczak P, et al. The influence of hydraulic ankles and microprocessor-control on the biomechanics of trans-tibial amputees during quiet standing on a 5° slope. Can Prosthet Orthot J; 2.

15. Moore R. Effect of a Prosthetic Foot with a Hydraulic Ankle Unit on the Contralateral Foot Peak Plantar Pressures in Individuals with Unilateral Amputation. JPO J Prosthet Orthot 2018; 30: 165–70.

16. Moore R. Effect on Stance Phase Timing Asymmetry in Individuals with Amputation Using Hydraulic Ankle Units. JPO J Prosthet Orthot 2016; 28: 44–48.

17. Sedki I, Moore R. Patient evaluation of the Echelon foot using the Seattle Prosthesis Evaluation Questionnaire. Prosthet Orthot Int 2013; 37: 250–254.

18. McGrath M, Laszczak P, Zahedi S, et al. The influence of a microprocessor-controlled hydraulic ankle on the kinetic symmetry of trans-tibial amputees during ramp walking: a case series. J Rehabil Assist Technol Eng 2018; 5: 2055668318790650.