

Figure 1: Attachment zones for leg exoskeleton (<https://www.researchgate.net/publication/326905472> *Comfort-Centered Design of a Lightweight and Backdrivable Knee Exoskeleton*)

## Ergonomics in Lower Limb Exoskeleton

**Goal:** Limit pressure and added weight on limbs while increasing comfortability and ease of use

**Notes:**

- Configuration changes the amount of force present on the user seen in the middle diagram of figure 1
- The amount of force at the contact points decreases when the distance between the points of the same body section increases
  - o Ex. If attachment 3 and 4 are further apart that decreases the pressure at points 3 and 4
- 4 attachment layout means the system is consistent
- With less than four attachments it is likely there could be too much pressure on the knee joint or elsewhere in the body

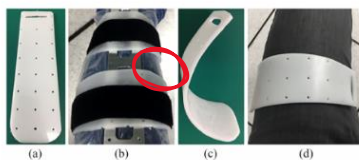


Fig. 7. Procedure of customizable braces as the mechanical interface attachment. (a) The unprocessed thermoplastic is machined to form raw part of universal shape. (b) Raw part is heated and applied on user's leg with the mechanical frame. (c) Raw part cools down and forms customized brace. (d) Precise fit with the user's limb.

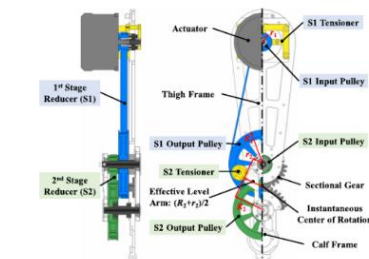


Fig. 9. Two-stage timing belt transmission system. This compact and simple system can amplify the torque of the electric motor to meet the assistive requirement. Moreover, through power transmission, the electric motor can be installed at the proximal end of thigh frame. The inertia of the exoskeleton can be significantly reduced by this configuration.

the input pulley of 2<sup>nd</sup> stage reducer (S2) are concentric with the thigh roller center; the output pulley of S2 aligns with calf

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### Avoiding Misalignment of The Knee Joint

- Completely avoided if the attachment between the thigh frame and the calf frame is not rigid
- Popular approach is to use add mechanism which can ensure alignment with unactuated DOFs
- Approx. human knee with 1 DOF to reduce the misalignment
  - o Rolling knee joint mechanism works well

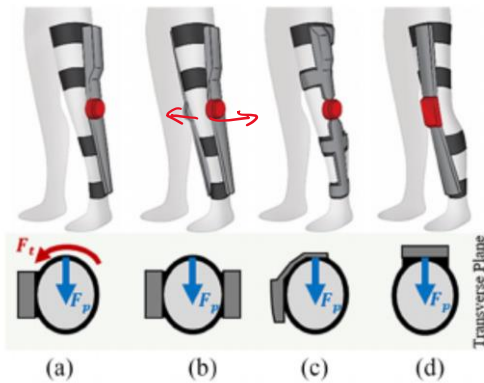


Fig. 3. Illustration of different knee exoskeleton layouts to demonstrate the advantages of the improved lateral-support design. (a) Lateral-support layout is most commonly used in multi-joint exoskeletons. The mechanical frame extends along the lateral side of the leg and transmits torque through soft attachment component (black) as  $F_p$ . The undesired twisting force  $F_t$  is also generated as side-effect. (b) Two-side-support has an additional mechanical frame on medial side of leg, balancing the force transmission and avoiding undesired  $F_t$ . However, extra components on medial side causes interference during adduction movement. (c) Our improved lateral-support design has rigid attachment component extending from the frame to either anterior or posterior side of the leg. It avoids  $F_t$  without introducing mechanical interference. (d) Anterior-support layout has the entire mechanical frame on the anterior side of leg. It generates the least undesired force compared to other layouts, but the implementation is limited by the complexity.

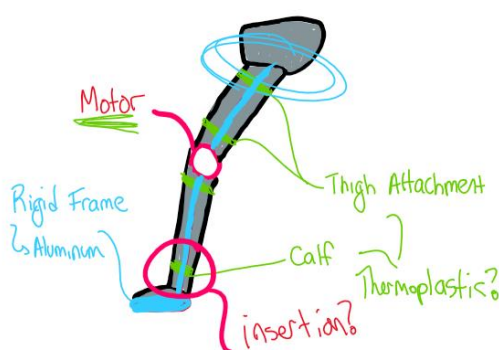
### Avoiding Misalignment in Frontal Plane

- Concern for Valgus and Varus movements if not mitigated properly
- Potential solutions include:
  - o Double hinge mechanisms can add 2 unactuated DOF reducing the degrees of vagus and varus

### Customized Thermoplastic Brace

- Rigid brace should fit the limb as closely as possible
- Any gaps create a backlash problem
  - o This can be mitigated by using a thermoplastic material for attachment
  - o Can be heated to fit to the user's leg correctly

### Preliminary Design Ideas



Notes:  
 ↳ it will be heavy (20 lbs?) but want to keep it not cozy heavy  
 ↳ Do we even want to touch ankle?  
 ↳ How do we attach?  
 ↳ How much weight do we want to "take off"

