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Research Article

Affordance-based Design Methods during Reconstruction of a Torn Anterior Cruciate Ligament

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Abstract

The affordance-based design has been best illustrated for artifacts that having biomechanical offerings, how to avoid the ligament impingement during ACL reconstruction, focused on the search for placing optimal tibial tunnel. This study shows that whereas the current rationale for tibial tunnel placement identifies a range in which the roof impingement is not allowed to avoid the negative affordance, in reality, all this can be done to constrain the target bounds with respect to the positive affordance that is desired.

Keywords: *Knee-Tensegrity-Structure; Affordance-Based-Design; Gibson's Theory of Affordance; ACL Impingement; The Perceptual System of Knee*

Introduction

Since the term „affordance" was coined by the psychologist James Gibson almost 40 years ago, the idea has been applied in a variety of fields, including childhood psychology, the design of graphical user interfaces, mobile robots, control room interfaces, and as a bedrock concept for the field of ecological psychology, which Gibson pioneered in the 1960s and '70s. The application of the concept of affordance to engineering design is a relatively late development. The use of the theory of affordances to engineering design has been advocated by Maier and Fadel in a recent series of works Maier [1-4]. According to them, the impetus for any design project can be understood in terms of creating and changing affordances: The design process can be viewed simply as the specification of an artifact that possesses specific desired affordances and does not possess certain undesired affordances. An artifact with more (higher quality) positive affordances is considered better, while an artifact with more negative (or lower quality) affordances is considered worse.

Meanwhile, considering all these precepts, at the categories in biomechanical offerings, we can now observe that some offerings of the things are beneficial and some are injurious. These are slippery terms that should only be used with great care, but if we pin down their meanings to the level of practical biomechanical application in this study, we can minimize the danger of confusion. We drew on a surgical technique as an example of how the theory of affordances may be utilized to a high-level affordance-based design, customizing the placements of the tunnel during the anterior cruciate ligament (ACL) reconstruction.

Aim of the Study

The aim of this study is, therefore, to identify the measurable invariant as a new basis for placement of the tunnel during the ACL reconstruction for the positive affordance-based design.

Materials and Methods

Artifact-user affordances (AUA) and artifact-artifact affordances (AAA)

The affordances of a product are what it provides, offers, or furnishes to a user or another product. Gibson's "system theory" of perceiving corresponds to an open system, which is quite different from the view of the isolated artifacts [4]. Whereas the concept of affordance was initially introduced in the field of perceptual psychology [5], in the context of engineering design, an affordance was defined as a relationship between two subsystems in which a potential behavior can occur that would not be possible with either subsystem in isolation [1,2]. Their previous works discussed several theoretical aspects of affordance-based design that could be used to construct prescriptive methods. These affordances, between artifacts and the people that use them, which are called artifact-user affordances (AUA).

The perceptual systems of knee

Uniform motion transmission between two axes (each of thigh and shank, respectively) is affordable only if their line of action pass through the knee screw axis (KSA ($) as shown in the figure 1), postulating the positive affordances of the knee perceptual organ, maintaining the ligaments to remain in isometric condition or continuous tension, otherwise ligaments become slack or in taut.

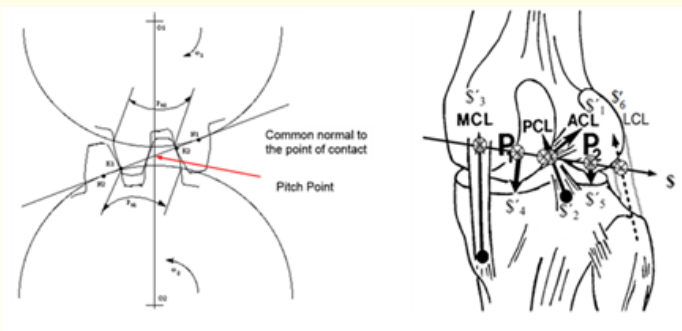

Figure 1

Recently the perceptual system of knee proposed by authors was validated experimentally. The study [6] has experimentally reported the invariant of the knee perceptual system by measuring whether all lines of action intersect the KSA ($) along the natural motion, resulting in that the mean distances between each constraint line of action and the KSA are staying below 3.4 mm and 4.5 mm for *in vitro* and *in vivo* respectively (Figure 2).

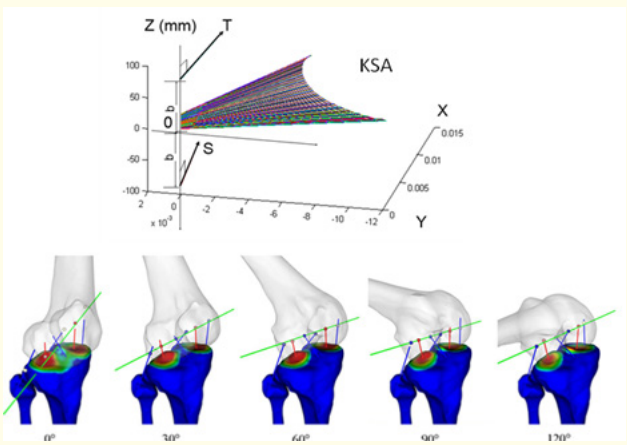

Figure 2

Positive and negative affordances

Recall that physical properties of the tibial tunnel and the roof of the intercondylar notch, are not affordances in and of themselves, but they do determine what affordances exist with reference to patients' anatomic cues. Therefore, the characteristics that affect a positive AAA are the same characteristics that affect negative AAAs. The artifact, in other words, only has one set of characteristics that is a customization of the tunnel placement, and that is all the designers (or surgeons) have control over. Once again, the first step in designing against this affordance is defining and understanding the affordance. As a consequence of the property of complementarity, the affordance does not exist with only one system (i.e. either the tunnel or the roof); in other words, two artifacts conflict each other when the graft becomes slack or in taut, i.e. the loss of extension in the graft at the full extension, the graft being trapped in the notch, indicated as the negative affordance or injuries.

Therefore, when a designer identifies a range in which a character is not allowed to fall to avoid a negative affordance, in reality, all this does is to constrain the target bounds for that same character with respect to the positive affordances that are desired. These ideas are best illustrated by the result section.

Results

Two lines were projected respectively to the sagittal plane so that the path of graft could be aligned to any transversal intersecting the KSA ($): the central line of knee tensegrity system (KTS) that is the invariant line, also called the screw axis of the knee (Figure 3) [7]. The lines were generated at the full extension. Notice that if the graft line may be not precisely aligned with the member line within the KTS, due to position errors, for example, the velocity difference on the graft line would not be zero, but still be small. If the path of an ACL graft is so selected that it cuts the KSA of the KTS, then the line becomes a member of the KTS, which ensures the isokinetic graft placement related to trans-tibial-femoral tunneling. If the knee model were set swing and then photographed, giving it a time-exposure over a few swings, a screw $ placed along the KSA would remain sharp in an otherwise blurred picture (Figure 3).

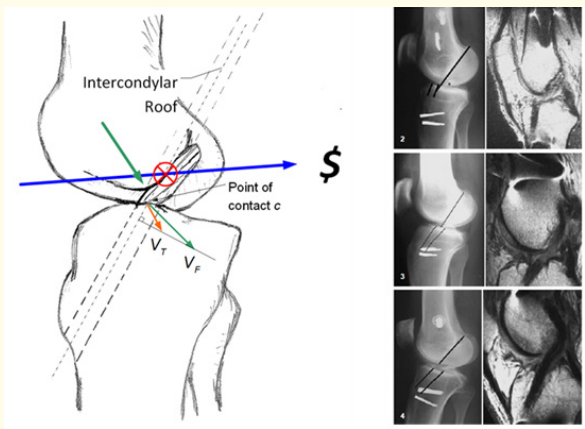

Figure 3

Discussion and Conclusions

The central question for the theory of affordances is not whether they exist and are real but whether the information is available in the invariant structure of systems for perceiving them. Accordingly, the related program of the tibial tunnel placement is positioned so that the ACL line intersects the KSA ($). The knee perceptual system must concurrently register persistence and change in the flux of the KTS to each organ is sensitive, which may facilitate information to be more available to the perceivers.

Clinicians or designers define the structure of a system, and thus its affordances, and therefore how not only the artifact will behave (via AAA) but also how the user will behave with the artifact (via AUA). This suggests an affordance-based definition of design. We conclude from the results of Gibson's argument that he did not set out to pre specific action, but instead he set out to characterize its potential and make it available for further study.

Acknowledgements

The original values of quantities, as well as the anatomical sketch (Figure 2b) that was originally published by Conconi., *et al*. [6], are used by permission of professor Michele Conconi.

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