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Ligament tensioning devices in total knee prostheses: evolution and classification

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Abstract. Prosthetic knee arthroplasty is a major issue of orthopedics. The success of total knee prostheses demonstrated by longevity is guaranteed by a diminished degree of wear. Current knowledge indicates that wear is dependent on the stability of the prosthesis. Most of the primary prosthesis implantation involves carrying out non anatomical sections followed by regulating of the ligament tension or ligament balancing. The importance of this act led to the invention of specific surgical instruments, called tensors. This paper aims to show their evolution, highlighting the features that define them. Using databases as PubMed, Science Direct, Springer and brochures we did a review of ligament tensioning devices. Classification allows for understanding the efforts made to improve prosthetic balance, the proper use and future development paths of these devices.
Key words: *knee, tensor, evolution, classification.*

Introduction

Ligament tensioning devices used in total knee arthroplasty aimed at achieving joint stability by ensuring proper capsulo-ligamental tension level. This avoids the creation of postoperative residual laxity.

Currently it is considered necessary to have a balance/equality between the medial/ lateral ligament tensions. So ligament tensioning devices (tensors) seek to apply a distraction force and obtain equal medio-lateral ligament tension in both flexion and in extension, in order to achieve joint stability. As technology does not allow quantification "in vivo" of ligament tension, this can be done through the femoral-tibial pressures. So tensors aim at obtaining equal femoral-tibial pressures.

Evolution balancing devices/tensors is closely related to the knee prosthesis. Their modern history begins in 1970: Freeman (1971) designed and implanted the first contrained cemented functional prosthesis. He recommended the use of flat right-angle bone cuts using intramedullary guides for both femoral and tibial cuts, spacers to check gaps remaining after making bone cuts and tensor device for ligament balancing (1).

More than his friend, Insall (1974) imposed the prosthetic knee by the success of its model: Total Condylar Knee, which he improved continuously turning it to Insall-Burstein, NexGen Legacy Posterior-Stabilised (LPS), Mobile Bearing Knee (MBK) and LPS-Flex Mobile. Adopting the tensor instrumentation of Freeman in 1974, Insall coined the terms flexion gap and extension gap. Being receptive to new ideas, he developed instrument systems for improvement in the surgical technique. Realizing that the tensors are precise, but difficult to use Insall focused on the use of intramedullary instruments since 1986 (1, 2). This will lead to a delay in the evolution of tensors. Certainly the idea to tension the ligaments launched by Freeman continued to subsist in the instrumentation of various types of prosthetic knees that were followed later. Different devices have been created to separate tibia and femur, but they were bulky and unreliable. In addition they did not exceed operator subjectivity.

Only the mid-1990s the idea of a specific instrument for ligament balancing in a controlled way is materialized. Since 1993 a study group in the UK (Balancer Study Group) has designed and developed a device that is able to apply a femoral-tibial distraction force, distributed to collateral ligaments and is able to quantify joint space and the femural-tibial angle (3,4). Their project is materialized into the Monogram (1990) which later became X-celerate (5) (fig. 1).

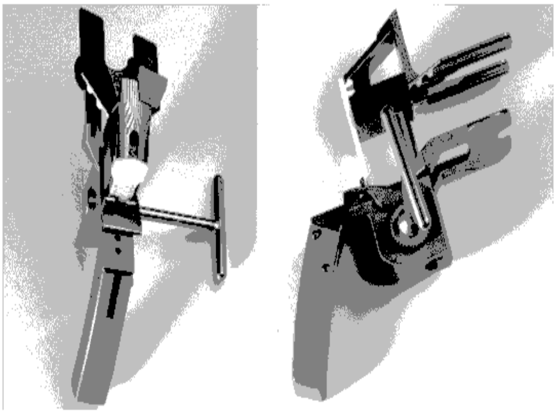

Figure 1. X-celerate (4)

The same group outlined the future development: in 1994 they experienced electronic measuring the distance of separation and femoral-tibial angle (6). Attaching a torquemetru in 1998, Asano and Wilton quantified the force applied (7), and in 2007 Viskontas measured in vitro the contact pressure (8). The same trends within other devices: V-State (Zimmer) 1996 (9), (10), Balansys (Mathys) 1998 (11,12). Although two decades efforts have managed to improve tensors, these tools could be used only with patellar dislocation, which cause errors (13,14).

Since 2003 the 3rd generation devices appear or physiological (15).

The most representative example is Offset Repo-tensor (Zimmer) (fig. 2), similar to X-Celerate (Stryker), but with a adapted design, which not only allows its use with reduced patella, but also at any angle of flexion knee (16).

In the same class may fall another two ligament tensioning devices from companies DePuy (2003) (17), (18) and Smith Nephew used in navigation systems (Ci and PiGalileo).

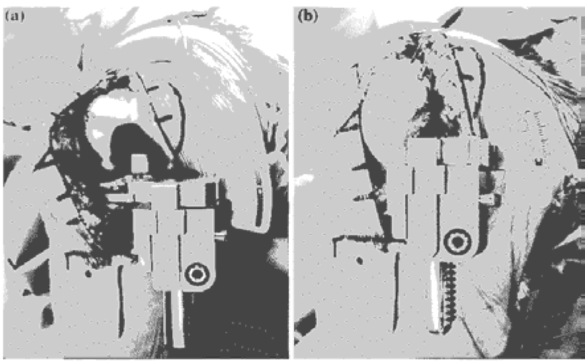

Figure 2. Offset Repo-Tensor
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Figure 3. E-Libra
(*www.synvasive.com*)

Further development of tensors ligament is influenced by prosthetic joint acquisition of pressure sensors and data transmission through wireless systems. In 1993 starts a project aimed at measuring in vivo knee forces. In 1994 Kaufman demonstrates the use of pressure sensors in the knee (19). The success was complemented by the use of telemetry in 2000, so eKnee (first electronic prosthesis) became a reality in 2004 (20).

So in parallel with the 3rd generation (physiological) a new generation of devices arises, digital tensors, integrating pressure sensors: Nanospacer (2003) Praxim (21, 22) and E-libra (2008) Synvasive (23) (fig.3).

Classification

compartment. Forces can be applied independently or asynchronously.
On the contrary Ligament tensioning devices can be classified as follows:
1. traditional - measures the joint space (24, 25) ;
2. parametric - quantifies the tensioning force and the femurotibial angle (3-5, 9-12, 26, 27);
3. physiological - applicable to any degree of flexion of the knee and with patella reduced (16-18);
4. digital - able to quantify the femurotibial contact pressure by sensors (21- 23).
Tensors aimed at equalizing the two forces. They must do this with minimal errors. Therefore it is important how the force is applied and measured. Although there are many devices designed only 3 types of forces were used: pure mechanical (screw gear), elastic (spring) and hydraulic (liquid column). This force can be linear if the springs, screws or nonlinear, when blocks of predetermined thickness are applied. Force may be under operator control (controllable) as to the mechanisms or uncontrollable (some resorts). Quantification of force guarantees reduces errors, and this can be analog or digital.
Finally there is a synchronicity interest or feedback between external and internal, there may be a correlation as a guarantee of accuracy. This can be achieved in analog mode, using a symmetric / asymmetric pivot point, which provides an equal/unequal tension force distribution. Also synchronization can be achieved digitally by the interposition of pressure sensors and a computer so leading to the CAGE technique (computer-assist-gap-equilibration) of the CAS (computer assisted surgery) (8, 21, 22).
Ligament tensioning devices aimed at balancing the endo prosthetic knee and therefore they should simulate the postoperative conditions of the prosthesis. They should work both in flexion and in extension, and the patella in the physiologic position. From this perspective, ligament tensioning devices can be classified into physiological and non physiological, and the latter depending on the position that can be applied (flexion/extension). By combining these criteria arises a global classification useful in understanding the efforts made to improve the Prosthetic balance and future development paths of these devices (tab I).

		FORCE					POSITION			
	DEVICE	type	linear	adjustable	quantifiable	syncronous	patella	flexion	extension	FIRM
I	LCS instrum.	m	-	-	-	+ (A)	-	+	-	De Puy
I	HLS instrum.	m	+	+	-	+ (A)	-	-	+	Tornier
I	LBS II	m	+	+	-	+ (A)	-	+	-	Exatech
I	Sigma	m	+	+	-	+ (A)	-	+	-	De Puy
I	Equiflex	m	+	+	-	+ (A)	-	+	+	Biomet
I	Femuro-tibial distractor	m	+	+	-	-	-	+	+	Aesculap
I	KeyTensor	m	+	+	-	+ (A)	-	+	+	Istittuti Ortopedici Rizzoli
II	X-Celerate	m	+	+	+/- (A)	+ (A)	-	+	+	Stryker
II	V-Stat	m	+	+	+/- (A)	-	-	+	+	Zimmer
II	BalanSys	e	+	+	+ (A)	-	-	+	+	Mathys
II	Laminar Spreader	e	+	+	+ (A)	-	-	+	+	Plus orthopedics
II	BalAnswer	e	+	+	+ (A)	-	-	+	+	De Puy
III	CAS Ligament Tensor	e	+	+	-	-	+	+	+	De Puy
III	Offset Repo Tensor	m	+	+	+/- (A)	+/-(A)	+	+	+	Zimmer
IV	E-Libra	m	+/-	+/-	+ (D)	+ (A)	+	+	+	Synvasive/ Zimmer
IV	Nanospacer	h	+	+	+ (D)	+ (D)	+	+	+	Praxim/ Orthopedics Synergy

Table I. Tensors Classification
(m=mechanical; e=elastic; h=hydraulic; A=analogical; D=digital)

Conclusions

The evolution of ligament tensioning devices is far from over. Although a history of nearly 40 years, their improvement is only just beginning: they are at the beginning of the digital age and also before them is a big challenge: a patellar femoral compartment completely unexplored.

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