Collagen fibres and mechanoreceptors in regenerated menisci of rabbits

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Summary. *Total medial meniscectomy was carried out on 30 mature rabbits; subsequent regeneration of the meniscus and degenerative joint changes were observed. Out of 30 knees, 22 had regenerated menisci and 10 of these had not developed gross degenerative changes after 6 months. Collagen fibres were arranged irregularly in the regenerated menisci, although in some areas they occurred in parallel. Every type of mechanoreceptor was found in the outer third of the normal menisci, and in the middle and outer third of the regenerated menisci with no statistical difference in numbers. Mechanical-receptors can regenerate in regenerated menisci and may protect the joint from degeneration.*

Résumé. *Une ménisectomie interne totale fut pratiquée sur 30 lapins adultes. De ces 30 genoux, dans 22 on observa une régénération méniscale et de ceux-là 10 ne montraient pas de lésions dégénératives articulaires après 6 mois. Les fibres de collagène étaient irrégulièrement réparties dans les ménisques régénérés, bien que dans certaines zones elles adoptaient une disposition parallèle. Tous les types de mécanorécepteurs étaient présents dans la périphérie des ménisques normaux et dans la zone moyenne et périphérique des ménisques régénérés sans différence statistique en nombre. Les récepteurs mécaniques peuvent se régénérer dans les ménisques régénérés et protéger l'articulation d'un processus dégénératif.*

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Introduction

Mechanoreceptors are found in the peripheral and middle thirds of menisci, particularly in the anterior and posterior horns [19], suggesting that this structure provides stability, not only by its mechanical shape, but by protective muscle reflexes.

The regenerated meniscus which grows after total meniscectomy differs from normal, both structurally and histologically. Instability and degenerative changes have been reported in the joint [12], but some patients develop neither symptoms nor radiographic signs of these changes after meniscectomy [2], even though the normal fibrocartilaginous meniscus has a proprioceptive function.

Morphological and histological evidence of regeneration of a meniscus have been reported after meniscectomy [9, 10, 11], but there are few accounts of the arrangement of collagen fibres or the occurrence of mechanoreceptors in the regenerated meniscus [1, 5, 8, 19]. This study was planned to investigate the presence of these structures in regenerated menisci.

Materials and methods

Thirty mature New Zealand white rabbits, weighing 2 to 3 kg, were used. After anaesthesia with ketamine, the medial meniscus was removed completely from the right knees through a anteromedial approach.

Six months after meniscectomy, the rabbits were killed and their knees opened. The state of the regenerated meniscus and the presence of gross degenerative changes in the articular cartilage were observed.

Out of the 30 rabbits, the 10 with regenerated menisci that did not develop gross articular changes were selected for further study, the medial meniscus in the opposite knee being used as a control.

Table 1. The total numbers and types of mechanoreceptors in each location of the normal and regenerated menisci

		Anterior horn		Body		Posterior horn	
		Normal	Regenerated	Normal	Regenerated	Normal	Regenerated
Type 1	Out.	2.43 ± 0.54	2.43 ± 1.32*	2.14 ± 0.69	1.57 ± 0.97	3.14 ± 0.90	1.86* ± 1.22
	Mid.	0	0.71 ± 0.95	0	0.86* ± 0.90	0	0.71 ± 1.95
Type 2	Out.	2.00 ± 0.81	2.58 ± 1.13	1.43 ± 0.54	2.00 ± 1.53*	1.43 ± 0.54	2.86* ± 1.34*
	Mid.	0	0.57 ± 0.79	0	0.86* ± 0.90	0	0.57* ± 0.54
Type 3	Out.	2.29 ± 0.76	2.14 ± 0.90	1.00 ± 0.58	0.86 ± 0.69	1.57 ± 0.53	2.71 ± 1.25*
	Mid.	0.14 ± 0.38	0.27 ± 0.49	0	0.43 ± 0.54	0	0.71 ± 0.49

Values are expressed as mean ± standard deviation

Out: outer 1/3 of meniscus

Mid: middle 1/3 of meniscus

*: Significantly different ($P < 0.05$) in mean value

#: Significantly different ($P < 0.05$) in standard deviation value

Three regenerated menisci and 3 normal menisci were cut in 5 µm thick sections and stained with Masson trichrome stain; the arrangement of the collagen fibres was noted.

The other menisci were stained with modified gold chloride stain to show mechanoreceptors [18]. After freezing, the regenerated and control menisci were cut by a microtome at 60 µm thickness. Each meniscus was divided into the anterior horn, the body and the posterior horn; each part was then subdivided into inner, middle and outer thirds. The types and numbers of mechanoreceptors were recorded at each site.

Results

There were regenerated menisci in 22 of the 30 knees; 20 of these did not have gross articular degenerative changes. The regenerated menisci were wedge-shaped, but half the normal size. The surface was glistening, pearly white and relatively firm (Fig. 1).

In the normal menisci, most of the collagen fibres were arranged circumferentially, and a few were arranged radially (Fig. 2). In regenerated menisci, the collagen fibres were poorly developed and arranged irregularly, although in some areas the fibres were parallel to each other (Fig. 3).

Ruffini corpuscles (type 1), Pacinian corpuscles (type 2), Golgi tendon organs (type 3), and free nerve endings were found in the outer third of the normal meniscus, and in the middle third in one anterior horn (Fig. 4), and the numbers were the same for each ($P < 0.0$) (Table 1).

These mechanoreceptors were also found in the regenerated menisci, but they also occurred in the middle third (Fig. 5). The numbers of receptors in normal and regenerated menisci were not significantly different ($P > 0.05$). There were exceptional areas, such as type 1 mechanoreceptors in the middle third of the posterior horn, and type 2 also in the outer third of the posterior horn. All types were also found in the middle third, but

statistical significance was not present ($P > 0.05$), except for type 2 in the body and type 2 in the body and posterior horn. Variance of distribution in the regenerated menisci was greater than in normal menisci, especially type 1 in the anterior horn, type 2 in the body and posterior horn and type 3 in the posterior horn ($P < 0.05$).

Discussion

Fairbank described degenerative changes in the knee after meniscectomy [4], which have also been seen after animal experiments [9, 12, 15]. Moon et al. demonstrated that these changes occurred in inverse proportion to the size of the regenerated meniscus [11]. Burr and Radin reported a 10 year follow up of 22 human knees which all had regenerated menisci with a radius of at least one third of normal, and none had symptoms at follow-up; 20 of the 22 had no arthroscopic evidence of medial compartment damage [2]. This suggests that even the regenerated meniscal rim may protect the joint from osteoarthritis. Wigren et al. reported that a fibrocartilaginous meniscus appeared 4 years after a total knee replacement in 4 patients [16]. Moon et al. observed that regeneration of menisci was present in 83.7% of immature rabbits' knees and in 76.5% of mature rabbits with fibrocartilaginous cells in localised areas, but they did not discuss the distribution of collagen fibres or the distribution of mechanoreceptors [10].

Clark and Ogden found that most collagen fibres in regenerated menisci run circumferentially, and a few radially [3]. Gosh and Taylor showed that compression of the wedge-shaped meniscus during loading is translated into circumferential stress, and the collagen fibres are well adapted for this mechanical role [7]. Gosh et al. reported that

there were marked differences in fibre size and orientation between normal and regenerated menisci after 6 months in dogs [6].

The mechanoreceptors transfer the changes due to physical stress into special nerve impulses, so acting as the first line of defence. The free nerve endings act as pain receptors, and vasomotor control is not by the mechanoreceptors. These receptors were known to be present in the capsule, collateral and cruciate ligaments, but it was thought there were no mechanoreceptors in the menisci, except for free nerve endings [8, 14, 17]. Recent studies have shown that nerves penetrate the outer and middle thirds of the body and horns of normal menisci from the perimeniscal tissues with the greatest concentration in the meniscal horns [19].

We have demonstrated the three types of receptor in the outer third of normal menisci, and in the outer and middle thirds of regenerated menisci. There was no statistical difference in the numbers of receptors, regardless of type, between normal and regenerated menisci, but the numbers of regenerated receptors varies from meniscus to meniscus.

Our findings also indicate that regenerated menisci have some of the functions of normal menisci and play a protective role. Although the collagen fibrils are arranged irregularly, there is some evidence of parallelism at 6 months, but further follow up is needed to see if the normal parallel arrangement develops further with time.

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