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COMPARATIVE STUDY ON TROCHLEAR SULCOPLASTY AND CHONDROPLASTY WITH REFERENCE TO THE ANATOMY OF STIFLE JOINT IN GOATS

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ABSTRACT : The present study was carried out to determine the sequllae of trochlear sulcoplasty and chondroplasty as two techniques for correction of patellar luxation as well as to evaluate the anatomy of the stifle joint in goat. The surgical study was carried out on 6 healthy goats, one used for sham operation and the other five for application of the two techniques while the anatomical study was carried out on 10 specimens of hind limb of goats .

In addition to the topographical anatomy of stifle, the anatomical results revealed that the femoropatellar joint has a single patellar ligament and two medial and lateral retinaculae.The surgical and histopathological results proved that trochlear chondroplasty had better results leaving a nearly normal trochlear groove covered with a normal hayaline cartilage than trochlear sulcoplasty technique.

INTRODUCTION

Patellar luxations have been reported to occur in cats, dogs, foals, calves, goats, llamas, and human beings(**Baron 1987; Kaneps et al .,1989; Baird et al., 1993; Van Hoogmoed et al., 1998).**

The causes of patellar luxations have been identified as congenital, developmental, or traumatic in origin **(Leith and Kotlikoff 1980; Engelbert et al., 1993; Vasseur 1993;** and **Van Hoogmoed et al., 1998)**. There are species variations in the development of this disorder. In small dogs, medial patellar luxation is thought to be primarily caused by congenital or developmental factors **(Vasseur 1993)** or may be a result of abnormal ligamentous pull that causes a disparity between growth of the medial and lateral aspects of the distal femoral physis, resulting in various secondary muscular abnormalities **(Chen and Ramanathan 1984,** and **Dandy** and **Griffiths 1989**). Congenital Patellar luxations in foals or ponies tend to develop secondary to hypoplasia of trochlear ridges, whereas patellar luxations in calves are thought to develop as a result of excessive muscular pull on the lateral aspect of the stifle **(Baron 1987)**.

Various surgical techniques have been described for treatment of patellar luxation. The treatment plan is directed mainly at reducing anatomic defects that require the realignment of the extensor mechanism and stabilization of the patella in the femoral trochlea **(Vasseur 1993 and Piermattei and Flo 1997)**. Trochlear sulcoplasty (curettage technique) and trochlear chondroplasty (cartilage flap technique) are used if patellar instability results from hypoplasia of the trochlear groove or if insufficient stability is achieved with imbrication of the joint capsule **(Kobluk 1993)**. These two techniques are used for deepening the trochlear groove **(Vasseur 1993)** that should be deep enough to allow half of the patella to ride within it, and wide enough to accommodate the entire patellar surface **(Arnoczky 1983)**.

Therefore, the purposes of this work are to evaluate the sequellae of trochlear chondroplasty (cartilage flap technique) and trochlear sulcoplasty (curettage technique) as two techniques for treating patellar luxation and to study the anatomy of the stifle joint in goat.

MATERIAL AND METHODS

Anatomical study:

The present study was carried out on ten pelvic limbs from medium to large sized Egyptian goats. They were fixed and preserved in 10% formalin. Manual dissection was conducted in five specimens to the stifle joint as well as its relationship with the surrounding structures. In the other five specimens, the soft tissues around the joint were removed completely and all the ligamentous structures were preserved to study its anatomical features.

Experimental study:

This study was carried out on six clinically healthy goats of both sex aging from 4-6 months. The animals were kept under good hygienic conditions. The surgical interference was performed in five goats on both hind limbs. Trochlear chondroplasty was performed in one limb and trochlear sulcoplasty in the other with two weeks interval in between. One goat was operated with sham surgery as control animal.

Before surgery, the operated animal was fasted for 12 hours while water was permitted up to 4 hours preoperatively. A combination of ketamine hydrochloride (Ketallar, Park Davis) in a dose of 2.45 mg/kg and xylazine (Rompun, Bayer) in a dose of 0.045 mg/kg body weight was given intramuscularly for anesthesia and the region of stifle joint was prepared for aseptic surgery.

Surgical procedure:

With the animal in lateral recumbency and the limb to be operated uppermost, a 12-cm curvilinear skin incision was made on the craniolateral aspect of the stifle joint starting at the junction between the middle and distal thirds of the the femur and continuing to approximately 2 cm distal to the tibial tuberosity. Arthrotomy was performed and the patella was luxated medially to clear the femoral trochlea.

For trochlear sulcoplasty, the articular surface is removed with 1-2 mm of the subchondral bone and the surface was smoothed with a bone rasp (Fig.9). For trochlear chondroplasty, two incisions were made along the trochlear ridges and the cartilage surface is elevated from the underlying subchondral bone using a chisel, leaving a proximal attachment. Two to three mm of the subchodral bone was then removed using a high-speed bur and the cartilage flap was then replaced in its position (Fig.10).

The joint cavity was flushed thoroughly with sterile saline solution and gentamycine sulphate (Gentamycin 5%, Adwia). The patella was then returned to its normal position. The joint capsule was sutured with chromic catgut No.0 followed by the lateral retinaculum, the fashia lata and subcutaneous tissue using simple interrupted sutures. Skin was sutured with silk No.1 using horizontal mattress sutures. In the control animal, the same steps were performed without the interference on the trochlear groove.

A systemic course of antibiotic was given to the operated animal together with a prophylactic dose of antitetanic serum. A soft padded dressing is applied to the limb for 5-6 days and the animal was confined for one week after which leach exercise for 15 min. twice a day was permitted.

Histopathological examination:

The operated animals were divided into two groups. In Group 1 (2 animals) the specimens were taken two months post-operatively while in group 2 (3 animals and sham operated one), specimens were taken 4 months postoperatively.

The animals were anesthetized, arthrotomy was performed, patella was luxated manually and a transverse wedge-shape osteochondral section was taken from the middle of all femoral trochleas including the trochlear groove. The joint was then closed as usual. Specimens were preserved in neutral buffered formalin, decalcified with 20% formic acid and processed for histopathological examination.

RESULTS

Anatomical results:

The goat stifle joint was a complex joint involving four separating articulations; femoropatellar, femorotibial, femorofibular and tibiofibular. Clinically, the most important articulations were; the femoropatellar and femorotibial (Fig.1).

The femoropatellar joint (Articulatio femoropatellaris) was formed between the femoral trochlea and patella. The femoral trochlea was formed of two slightly oblique ridges, nearly at the same level separated by a shallow groove. The patella resembled a triangle with its base lying proximal. Its cranial surface was tuberous with presence of a groove laterally. The articular surface of the patella subdivided by a ridge into small lateral area and a large medial one. The apex of the patella was thin, pointed and rounded (Fig.2).

The ligament of the femoropatellar joint was the patellar ligament which was a single ligament in the form of a strong fibrous band, extending from the cranial surface of the patella to the tibial tuberosity and tibial crest. This ligament arised from the further course of quadriceps femoris muscle insertion on the tibial tuberosity and the patella was involved as a sesamoid bone in this insertion (Fig.3). The more superficial layer of the patellar ligament was formed by a fibers of conjoined tendon of insertion of muscle rectus femoris, vastus medialis and vastus lateralis forming a cap covering both the patella and the patellar ligament (Fig.4).

Due to the absence of medial and lateral patellar ligament, there were a strong fibrous sheath termed medial and lateral retinaculum ligaments. Each one was formed from superficial and deep layers. The superficial medial one was formed from the aponeorosis of Mm. Sartorius and gracilis together with that of M. vastus medialis (Fig.5). The superficial lateral one was formed from the aponeorosis of the cranial portion of m. gluteobiceps as well as M. vastus lateralis (Fig.6). The deep layer of both retinaculae formed the medial and lateral femoropatellar ligaments which were closely adherent to the joint capsule.

The femorotibial joint (Articulatio femorotibialis) was formed by the femoral condyles and the tibial plateau (Fig.1). The tibial plateau was the widest part of the bone. It consisted of two condyles; the medial was larger than the lateral one. The medial and lateral intercondylar eminences were similar in size with a prominent tibial crest that lacked a distinct depression for the insertion of patellar tendon with a clear extensor fossa for the insertion of M. extensor digitorum longus. There were crescent-shaped fibrocartilage pads (menisci) interposed between the two articular surfaces (Fig.7). The medial meniscus was closely adherent to the inner surface of the medial collateral ligament, the lateral one does not come in contact with the lateral collateral ligament.

The ligaments of the femorotibial articulation were the collateral ligaments, the cruciate ligaments and the ligaments of menisci. The collateral ligaments; the lateral collateral ligament originated from the femoral condyle and inserted on the remnant of fibular head, the tendon of M. popliteus passed between this ligament and the lateral meniscus. The medial collateral ligament originated from a roughened area on the medial epicondyle of femur and inserted on the medial tibial metaphysis.

The cruciate ligaments; the cranial one was made up of two bundles; craniomedial and caudolateral. They were originated from the intercondylar surface of the lateral femoral condyle and inserting cranial and caudal to the intermeniscal ligament. The caudal one originated from the medial femoral condyle and inserted on the caudal surface of tibial plateau (Fig.8). The menisci were attached to the tibia, femur and to each other cranially by intermeniscal ligament. The meniscofemoral ligament was a single ligament originating from the caudal part of lateral meniscus and inserting on medial intercondylar fossa caudal to the caudal cruciate ligament. The medial and lateral menisci were attached to the tibia by two short meniscotibial ligaments (Figs.7&8).

Surgical results:

Surgically operated stifle joints of some goats were slightly inflamed up to one week postoperatively with high intense of inflammation in sulcoplasty treated joints. However, no goats were lame by the second week after surgery; and post surgical crepitus, joint effusion, and signs of pain were not observed three weeks postoperatively.

On arthrotomy of the operated stifles, the gross picture revealed deep irregular trochlear groove with a glisinning vascular surface in sulcoplasty operated joints with presence of few deep crevices (Fig 11A). Joints operated with chondroplasty showed a deep trochlear groove with a nearly normal hyaline cartilage except for presence of shallow crypts on both sides of the trochlear groove and against its distal end (Fig.12A).

The histopathological results at the 8th postoperative week revealed that the sulcoplasty operated joints had a beginning of formation of young cartilaginous matrix from the trochlear ridge inward with reduction in thickness toward the center. The articular surface was lined by a continuous layer of large cells. Collagen fibers were arranged in bundles and many cells were present in between. Clear vascularization of the subchondral bone was seen with prensence of red blood cells on the surface of the trochlear groove (Fig.11B).

Chondroplasty operated joints showed that the cartilage flap healed without any complications. The borders of the flap showed healing by mature fibrous tissue containing cartilage specules at the junction between the cartilage flap and the trochlear ridge where red blood cells were present at this area. The hyaline cartilage of the flap showed no adverse reaction (Fig.12B).

On the 16th postoperative week, the gross picture of the trochlear groove of sulcoplasty operated joints showed smooth less vascular articular surface with absence of crypts (Fig.13A). Histopathologically, remodeling of the young cartilage to form cartilaginous specules with differentiation of lacunae had been observed. Round cells surrounded by distinct lacunae were arranged in clusters or rows, specially in the deepest areas, and collagenous fibers in some areas were less obvious. Blood vessels appeared less numerous(Fig.13B).

In chondroplasty operated joints, the trochlear groove appeared deep and nearly normal with absence of the shallow crypts on both sides (Fig.14A). Histopathologically, no adverse reaction was seen either in the cartilage or subchondral bone with smooth connections between the trochlear ridges and grafted cartilage (Fig.14B).The cartilage peripheral to the replacement tissue always ended abruptly at the replacement tissue-cartilage junction and never overlapped it. Also, this cartilage showed an increased cellularity followed by an increase in the eosinophilic matrical staining (Fig.11B, 12B &14B). The flow of matrix and chodrocytes from the trochlear ridges toward the the defect in the trochlear groove was not observed neither in sulcoplasty nor in trochleoplasty allover the whole period of the experiment.

The sham operated joints (control animal) showed neither gross nor histopathological changes through out the whole period of the experiment.

DISCUSSION

The anatomy of goat stifle joint was similar to that described for sheep (**May 1977** and **Allen et al., 1998**), dog (**Getty 1975** and **Evans 1993**), goat (**Gad 1985**), rabbit (**Gad et al., 1991**), llamas (**Van Hoogmoed et al., 1998**) and dromedary camel (**Smuts** and **Bezuidenhout ,1987**). Stability of the patella in the trochlear groove was maintained by the patellar ligament, the medial and lateral patellar retinaculae, tendineous insertion on the patella and the shape of the groove itself. Any disruption of these structures could lead to patellar luxation.

The dissection had revealed that the genual articulation of goat was provided by a single patellar ligament as in dog (**Evans, 1993**), Cat (**McClure et al., 1973**), Pig, small ruminants and man (**Nickle et al., 1986**) that was considered as the common tendon of insertion of M. quadriceps femoris. In contrast, our findings confirmed the observation of **Gad (1985)** in goat and **Gad et al., (1991)** in rabbit that only the superficial layer of the patellar ligament appeared to be derived from the common tendon of insertion of Ms. rectus femoris, vastus medialis and vastus lateralis.

The medial and lateral patellar retinaculum included the patellar and femoropatellar ligaments of its own side. Both were formed from superficial and deep layers. These results are in agreement with **Gad (1985)** in goat, **Gad et al., (1991)** in rabbit and **Van Hoogmoed et al., (1998)** in llamas. The presence of these retinaculae provided an ease approach for arthrotomy of the stifle joint from either the medial or lateral aspects. Also, the congenital looseness or shortening in these retinaculae could aid in the incidence of patellar luxation and need their imbrication or release procedures as mentioned by **Vasseur (1993)** and **Ferguson (1997)**.

Concerning the surgical techniques, in trochlear chondroplasty (cartilage flap technique), a cartilage flap is elevated from the groove and the subchondral bone removed from beneath it. This results in a deepened trochlea with maintenance of articular cartilage in the sulcus. While in trochlear sulcoplasty (curretage technique), the articular cartilage is removed to the level of subchondral bone to create a sulcus deep enough to prevent patellar luxation. In the two techniques, the lesion was extended to the subchondral bone and the blood oozing from the bone was used as a guide to judge whether enough tissue had been removed from the trochlear groove. Most authors agree the subchondral bone have a role in the healing prosses as the mesenchymal cells originated from it can contribute to healing as can the underlying blood supply, peripheral synovial membrane or even the synovial fluid (**Zarnett and Salter 1986** and **Kim et al.,1991**).

The surgical results revealed that no signs of lameness were present on the second post operative week in the operated animals. This observation may prove that the operation for deepening the trochlear groove had no effect on the bearing ability of the animal providing that the signs of inflammation is absent and the infection of the joint was avoided.

Leach exercise was permitted on the second postoperative week for the operated animals. **Salter et al., (1980)** mentioned that passive movement from the 4th day after operation has proved to produce a consistant neocartilage similar histologically to normal articular cartilage. However, continuous passive motion is difficult to accomplish routinely after veterinary surgery but we believe that the post operative exercises have a role in stabilizing the cartilage flap and enhancing its healing to the subchondral bone. This together with the pressure exerted by the patella as mentioned (**Vasseur 1993** and **Ferguson 1997**). In full thickness , as in case of sulcoplasty, the healing allowed by normal exercise, rather than continuous passive motion, heal by fibrocartilage (**Hulse et al., 1986**).

The healing of the trochlear grooves observed in this study in sulcoplasty treated joints was generally corresponded with other descriptions of repair in full thickness cartilage defects recorded by **Meachim (1963)** and **Depalma et al., (1966), Salter et al., (1980)** and **Mahmoud (2000).** However the flow of matrix and chondrocytes attributable to joint motion and weight bearing was not seen in this study and the cartilage always ended abruptly at the replacement tissue-cartilage junction and never overlapped it. This may be attributed to that the contact between the patella and the deepened trochlear groove was decreased leading to alteration in articular pressure and weight bearing.

The remaining cartilage peripheral to the replacement tissue showed an increased cellularity and eosinophilic fibrillar matrical staining that indicated that the original articular hyaline cartilage was being replaced by fibrocartilage at this area. **Dingle et al., (1979)** owed the cartilage matrix breakdown to mediators such as catabolin released from the synovial membrane in response to cartilage injury, so paving the way for good connection between this area and the replacement tissue.

The presence of large cells seen at the articular surface in this study has been described previously by **Boone et al., (1983)** as resembling a synovial layer and appeared to extend from the synovial lining of the joint capsule as a result of decreased intra-articular pressure of the femoropatellar joint.

In chondroplasty treated joints, healing of the cartilage flap was observed on the 8th postoperative week without any complications. So, in this technique, the cartilage flap is preserved that means preserving the normal hyaline cartilage except for two small shallow crypts on either sides of the flap that healed with fibrocartilage as in sulcoplasty. Fibrocartilage as reported by **Zaslow (1972)** and **Boone et al., (1983)** can provide a smooth surface for articulation with the patella but may not withstand compression and abrasion as well as hyaline cartilage. dThe only exception in this technique is that the cartilage flap cannot be easily separated in adult animals (**Vasseur 1993** and **Ferguson 1997**).

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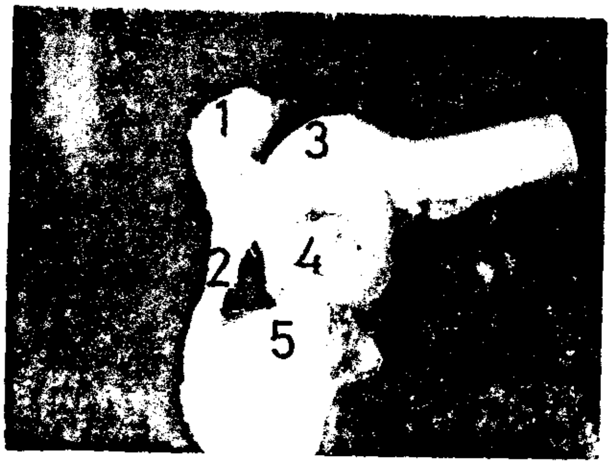

Fig.1: Medial view of goat stifle showing patella (1), Patellar ligament (2), medial trochlear ridge (3), medial femoral condyle (4), medial aspect of the tibial plateau (5), and medial meniscus (6).
(Right pelvic limb)

Fig.(2): Cranial aspect of stifle joint showing the trochlea of the femur (1), patella (2), Patellar ligament (3), tendon of extensor digitorum longus m.(4), lateral meniscus (5), lateral collateral ligament (arrow), tendon of muscle popliteus (double arrow), cranial cruciate ligament (c), medial meniscus (m), and intermeniscal ligament (i).
(Left pelvic limb)

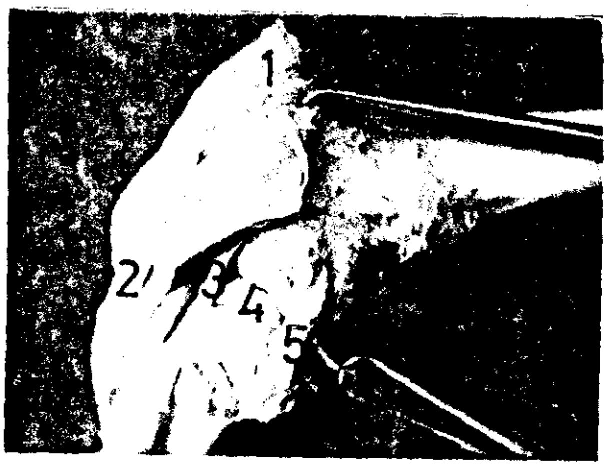

Fig.3: lateral view of stifle joint showing m. quadriceps femoris (1), patellar ligament (2), tendon of insertion of M. extensor digitorum longus (3), tendon of muscle popliteus (arrow), lateral meniscus (4), and lateral collateral ligament (5).
(Left pelvic limb)

Fig.4: Medial view of stifle joint showing the superficial layer of the patellar ligament (P), M.rectus femoris (R), M. vastus medialis (V), and M. sartorius (S)
(Right pelvic limb)

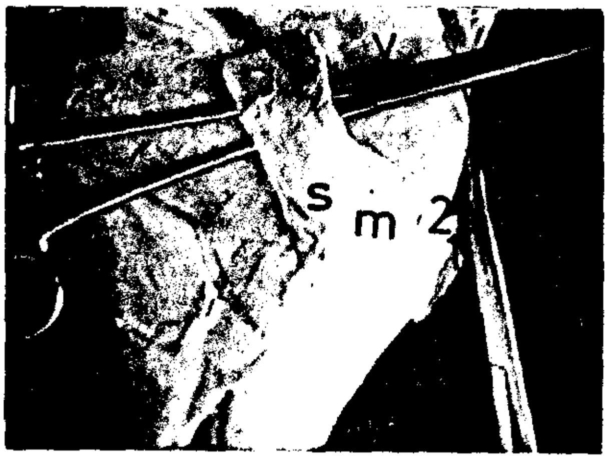

Fig.5: Medial aspect of the dissected stifle joint of goat showing the medial retinaculum ligament (m), the aponeorosis of M. sartorius(s),M. vastus medialis(v), superficial layer of the patellar ligament(1), and the patellar ligament (2).
(Left pelvic limb)

Fig.6: lateral aspect of the stifle joint showing the patellar ligament (arrow), lateral retinaculum ligament (L), the aponeorosis of M. gluteobiceps (1), the aponeorosis of M. vastus lateralis(2), the presence of fibular nerve (N).
(Right pelvic limb)

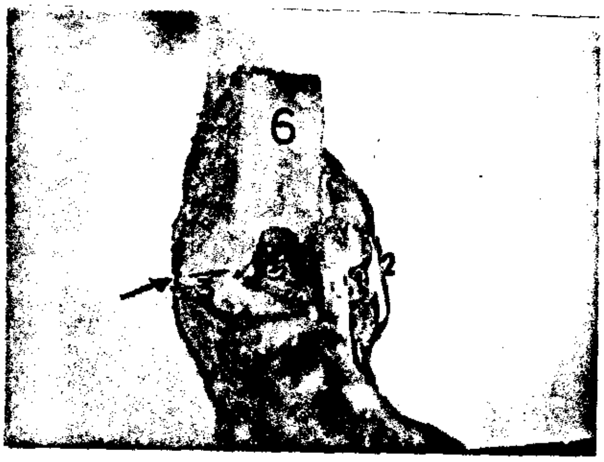

Fig.7: Cranial view of the opened stifle joint showing the lateral meniscus (1), lateral collateral ligament (2), medial meniscus (3), medial collateral ligament(arrow), intermeniscal ligament (4), cranial cruciat ligament (5), trochlea of the femur (6).
(Left pelvic limb)

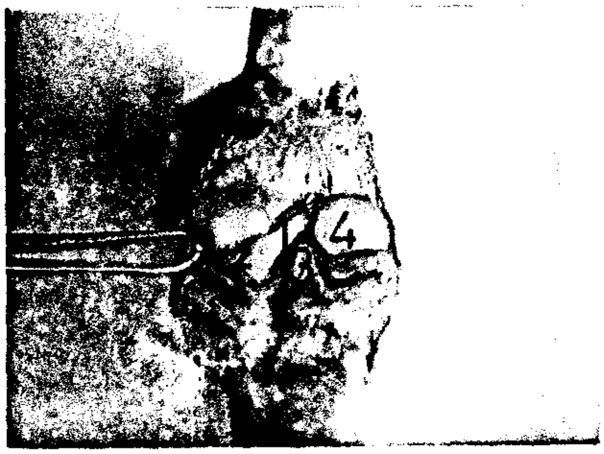

Fig.8: The caudal aspect of the stifle joint showing the meniscofemoral ligament(1), lateral meniscus(2), caudal cruciat ligament(3), and medial femoral condyle(4).
(Left pelvic limb)

A B

Fig.9: Trochlear sulcoplasty technique : The articular cartilage was removed with 1-2 cm of the subchondral bone (A), and the surface was smoothed using a bone rasp (B).

A B C

Fig.10: Trochlear chondroplasty technique: Two incisions were made along the trochlear ridges and the cartilage is elevated using a bone chisel leaving a proximal attachment (A). A high speed bur was used to remove 2-3 mm of the subchondral bone (B), then the cartilage flap was replaced (C).

Fig.11A: Gross picture of a sulcoplasty operated joint 8 weeks postoperatively. The troclear groove was deep and irrigular with a glisining vascular surface and presence of few deep crevices (arrows).

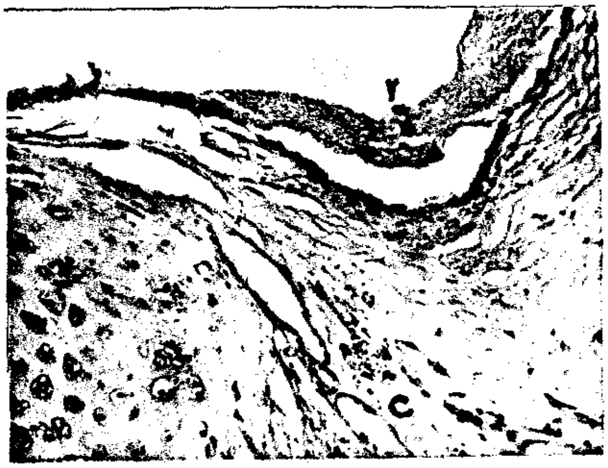

Fig 11B: Photomicrograph of a sulcoplasty treated trochlear groove 8 weeks postoperatively showing a beginning of formation of young cartilaginous matrix (arrow) with clear vascularization (c) and presence of red blood cells on the surface (r) (H&E stain X 100)

Fig.12A: Gross picture of chondroplasty treated joint 8 weeks postoperatively. A deep trochlear groove with a nearly normal hyaline cartilage except for presence of shallow crypts on both sides (

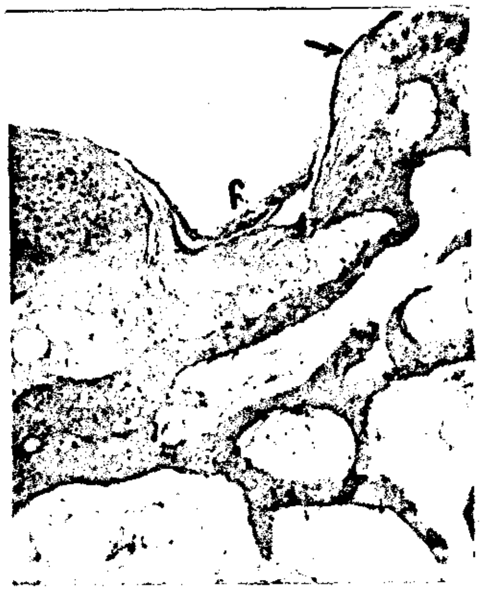

Fig.12B: Photomicrograph of chondroplasty treated joint 8 weeks postoperatively showing the cartilage flap healed without any complications (arrow) and its border has a sulcus that begin to heal by fibrocartilage with presence of red blood cells on its surface (f). (H&E stain X40)

Fig.13A: Sulcoplasty trated joint 16 weeks postoperatively showing smooth less vascular trochlear groove with absence of crypts.

Fig.13B: Photomicrogaph of a sulcoplasty treated joint 16 weeks postoperatively showing remodeling of the new fibrocartilage to form cartilaginous specules with differentiation of lacunae (arrows).(H&E stain X200)

Fig.14A: Chondroplasty treated joint 16 weeks postoperatively showing nearly normal trochlear groove with absence of crypts on both sides.

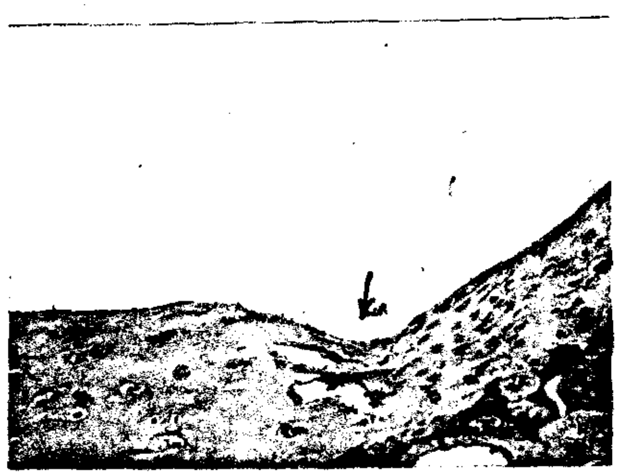

Fig.14B: Photomicrogaph of a chondroplasty treated joint 16 weeks postoperatively showing smooth connection between the trochlear ridge and the grafted cartilage (arrow).(H&E stain X200)