Patellar Development After Patella Instability And Early Reduction In Growing Rabbits

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Abstract

Background: Patella-shaped disorder has been considered as a predisposing factor for patellar instability. But the influence of early patella reduction for patellar development remains unclear. This study aimed to evaluate whether early operation in patella instability could improve patella morphology in growing rabbits.

Methods: Fifty rabbits (1-month-old) were were included in the study. The control group underwent no surgical procedures. The two experimental groups (reduction group and non-reduced group), underwent medial soft tissue restraint release. The reduction group, rabbits underwent the medial soft tissue sutura surgery in order to stabilize the patella 2 months postoperative. The non-reduced group, rabbits did not undergo suture surgery. Computed Tomography (CT) scans analysis in two experimental endpoints (2, 5 months postoperatively) were selected to evaluate the transverse diameter, thickness, Wiberg index, and Wiberg angle of patella. Gross observation was conducted to assess morphological changes of the patella.

Results: CT scans showed significant difference in the mean transverse diameter and Wiberg angle of patella between the two groups after 2 months surgery. 5 months after surgery, the four indices were found no statistically difference in the reduction group versus the control group. However, the transverse diameter, Wiberg angle in the non-reduced group were significantly differences than that in the reduction group ($P < 0.05$). Gross observation showed a flattened articular surface of the patella in the non-reduced group.

Conclusions: The results indicated that patella instability may lead to patella-shaped disorder, showing a flattened morphology. Early patella reduction can improve the patella morphology in growing rabbits.

Introduction

The biomechanics of the patellofemoral joint is a involved subject, which is contained by the articulation between the patella and the trochlear groove. Wibeeg et al. [1, 2] reported that the patella had a medial and a lateral facet like an upside-down triangle, and revealed the shape based classification. The patella plays an important role in the function of the knee joint. It increases the biomechanical lever arm and improves the effective extension capacity of the knee. Patellar dislocation is a common disease especially in adolescents [3, 4]. Many researchers believe that the shape of the trochlear groove is significant in maintaining the stabilization of the patella [5–7]. On the other hand, Panni AS et al. [8] demonstrated that a correlation between patella tilt and patella shape. Servien et al. [9] showed that in patients with patellar dislocation often exist a short patellarapex and a hypoplastic medial border. Previous studies have investigated that patellar dislocation not only results in trochlear dysplasia but also affect the development of the patella by rabbit models. Li [10] and Huri [11] found that early patellar dislocation could occur trochlear dysplasia in growing rabbits. Niu et al. [12] recently reported that patella dysplasia can be caused by patella instability in rabbits. Wang et al. [13] showed that early relocation of the patella can prevent the development of trochlear dysplasia in growing rabbits.

However, up to now, few studies have described the role of patella reduction on the development of patella. The aim of the study was to determine whether early patella reduction could improve the patella morphology in growing rabbits. We hypothesize that early patellar patella instability may lead to patella-shaped disorder, and early patella reduction can improve the patella morphology.

Materials And Methods

Study Design

The experimental protocol was approved by the local Animal Care and Use Committee.

Fifty 1-month-old female New Zealand healthy white rabbits, weighing between 320 and 420 g (provided by the local Animal Center) were included in the study. The control group consisted of 50 right knees, which underwent no surgical procedures. The two experimental groups comprised 50 left knees, which were performed patella instability surgery (medial soft tissue restraint release). In order to stabilize the patella, the reduction group (N = 25 knees) underwent medial soft tissue sutura 2 months postoperative. The non-reduced group (N = 25 knees) underwent no suture surgery. All procedures executed involving animals were under the Western University's Animal Care and Use Guidelines (London, Ontario, Canada) [14].

Surgical Procedures

The surgical protocol for making patella instability models of growing rabbits have been proved by previous studies [12, 13]. First, the rabbits were intravenous anesthetized with ketamine (20 mg/kg) and xylazine (5 mg/kg) through the ear vein. The knee was shaved and prepped in a sterile following standard procedure pre-operation. Next, a 4-cm longitudinal incision was preferred on the knee joint in the two experimental group, the soft tissue of medial retinaculum and the joint capsule were dissected and exposed. Then, a 2.5-cm longitudinal incision was made along the medial border of the patella to incise the medial retinaculum and joint capsule. The state of patella instability was found intraoperatively (Fig. 1). The patella was in dislocated state when the knee was flexed, and the patella returned to the relatively normal location when the knee was straighted. Finally, the incision was irrigated and sutured without reconstruction of medial retinaculum. 2 months after medial soft tissue restraint release surgery, the reduction group underwent patellar reduction via the original longitudinal incision. The skin and soft tissue were dissected and the medial patellar retinaculum were exposed. Then, the medial patellar retinaculum was sutured, keeping patella in the normal trochlear groove. Finally, the incision was irrigated and sutured in layers. Prudence was performed to avoid damage the articular cartilage. All rabbits were raised under the same conditions (food, water and individual steel cage (310 × 550 × 320 mm)) and allowed free activity in cages. Skeletal maturation of rabbits is complete at 6 months of age [15], so all the rabbits were euthanized (by intravenous injection of pentobarbital, 100 mg/kg) at 5 months after soft tissue release surgery.

Ct Measurements

CT scans of the rabbits were performed immediately after the release operation, 2 and 5 months post-operatively using a 16-slice CT scanner (SOMATOM Sensation 16; Siemens Medical Solutions, Erlangen, Germany). All CT images were captured on the axial plane, which is the optimal position to observe and measure the patellofemoral joint. The measurements were performed by RadiAnt-DICOM software (Medixant Ltd, Poznan, Poland) which has a 0.1°and 0.01mm measuring accuracy (Fig. 2). The CT slice image with the widest diameter of the patella was acquired for the indice measurements in the transverse plane. The transverse diameter (AB) of the patella was described by Stäubli [16], which was defined as the length between the most medial edge (A) and the most lateral edge (B) of the patella. The posterior patellar edge farthest from the baseline (AB) was defined as point D. The thickness of the patella was measured between the most anterior point (C) of the patella and the most posterior point (D) of the patellar edge, and line CD vertical to the baseline (AB). The insertion between line AB and line CD was defined as point E. The Wiberg index was defined as the ratio of the length of BE to the length of AB. For the Wiberg angle (∠D) measurement, as described by Fucentese [17], which was defined as between the slopes of the medial patella and the lateral patella. All measurements were taken blindly by two independent researchers. To determine the intra-observer variation, one researcher repeated the observations at 7 days after the first measurement.

Cross Observation

CT scans were performed 5 months post-surgery. Subsequently, the rabbits were euthanized, The skin and soft tissue were carefully removed and the patella was dissected. Morphological differences were taken to observed and recorded.

Statistical analysis

SPSS statistical software (version 22.0; SPSS, IL, USA) was performed for data analyse. The data were compared with Student’s t test between the control and experimental groups immediately after release operation. Dunnett’s multiple-comparisons was used to evaluate the transvers diameter, thickness, Wiberg index, and Wiberg angle of patella among the three groups at each time point. $P < 0.05$ were defined as the threshold for statistical significance. The results values were expressed by Mean ± SD. The inter-and intraobserver reliabilities were then determined by calculating intra-class correlation coefficients (ICC).

Results

Ct Measurement

In the study, the transverse diameter, thickness, Wiberg index and Wiberg angle were measured immediately after release surgery, and the values were not significantly different among the three groups (Table 1). However, 2 months after release surgery, the mean transverse diameter in the control group was 5.50 ± 0.38 mm, the mean transverse diameter in the experimental groups was 7.02 ± 0.34 mm. The mean Wiberg angle showed the greater difference: 128.6 ± 5.3°in the control group versus 136.5 ± 6.9°in the experimental groups. The experimental groups had longer transverse diameter and larger Wiberg angle than the control group (Fig. 3). Furthermore, 5 months after surgery, the mean transverse diameter in non-reduced group was 7.86 ± 0.64 mm, while that in reduction group was 6.35 ± 0.46 mm; the difference between the two groups was statistically signifcant ($P < 0.05$) (Table 2). 2 and 5 months after surgery, the mean thickness of the patella was not significantly different among the three groups (Table 3). Changes in Wiberg index (Table 4) showed the same pattern as thickness. However, 5 months after surgery, the mean Wiberg angle in non-reduced group was 138.5 ± 6.4°, while that in reduction group was 129.8 ± 4.5°; the difference between the two groups was statistically signifcant ($P < 0.05$) (Table 5). On the other hand, the four indices between the reduction group and the control group were not statistically different 5 months after surgery. As a result, the reduction group had a normal patella morphology. The inter-and intraobserver correlation coefficients were showed in Table 6.

Table 1
Measurements immediately after release operation (X ± SD)

Indexes control group experimental group p-value
Mean AB(mm) 3.81 ± 0.24 3.79 ± 0.26 0.309
Mean CD(mm) 2.82 ± 0.37 2.86 ± 0.33 0.114 Wiberg index 0.53 ± 0.03 0. 52 ± 0.04 0.446 Mean Wiberg angle(°) 130.8 ± 6.6 131.5 ± 6.4 0.157
AB, transverse diameter of the patella; CD, thickness of the patella

Table 2
The measurements of transverse diameter (mm) in the three groups (X ± SD)

non-reduced group reduction group control group
Two months 7.02 ± 0.34* 7.02 ± 0.34* 5.50 ± 0.38
Five months 7.86 ± 0.64*& 6.35 ± 0.46 6.27 ± 0.39
* Significant difference compared with the control group (p < 0.05)
& Significant difference compared with the reduction group group (p < 0.05)

Table 3
The measurements of thickness (mm) in the three groups (X ± SD)

non-reduced group reduction group control group
Two months 3.82 ± 0.26 3.82 ± 0.26 3.85 ± 0.32
Five months 4.23 ± 0.44 4.18 ± 0.36 4.11 ± 0.32

Table 4
The measurements of Wiberg index in the three groups (X ± SD)

non-reduced group reduction group control group
Two months 0.49 ± 0.05 0.49 ± 0.05 0.48 ± 0.06
Five months 0.51 ± 0.04 0.50 ± 0.05 0.50 ± 0.03

Table 5
The measurements of Wiberg angle (°) in the three groups (X ± SD)

non-reduced group reduction group control group
Two months 136.5 ± 6.9* 136.5 ± 6.9* 128.6 ± 5.3
Five months 138.5 ± 6.4*& 129.8 ± 4.5 129.2 ± 5.0
* Significant difference compared with the control group (p < 0.05)
& Significant difference compared with the reduction group group (p < 0.05)

Table 6
Intra-observer and inter-observer agreement of geometric measurements with 95% confidence intervals(CI)

Measurement	Intraobserver		Interobserver	
SSG-AB	ICC	95% CI	ICC	95% CI
SSG-CD	0.776	0.726 to 0.857	0.741	0.699 to 0.822
SSG-WI	0.813	0.725 to 0.865	0.768	0.635 to 0.858
SSG-WA	0.873	0.780 to 0.904	0.863	0.801 to 0.932
PSG-AB	0.736	0.690 to 0.852	0.728	0.653 to 0.835
PSG-CD	0.764	0.731 to 0.880	0.745	0.702 to 0.873
PSG-WI	0.863	0.798 to 0.937	0.856	0.808 to 0.936
PSG-WA	0.830	0.784 to 0.920	0.828	0.757 to 0.916
CG-AB	0.736	0.681 to 0.805	0.732	0.631 to 0.803
CG-CD	0.872	0.756 to 0.906	0.855	0.808 to 0.920
CG-WI	0.833	0.774 to 0.912	0.820	0.714 to 0.916
CG-WA	0.766	0.701 to 0.845	0.739	0.705 to 0.858
	0.828	0.752 to 0.889	0.810	0.730 to 0.869

ICC, intra-class correlation coefficient; RG,reduction group; AB, transverse diameter of the patella; CD, thickness of the patella; WI, Wiberg index; WA, Wiberg angle; NRG, non-reduced group; CG, control group.

Gross Observation

5 months post surgery, the non-reduced group had wider and more flattened patella than the other groups. In the reduction group, the patella morphology appeared no morphological changes compared with the control group (Fig. 4).

Discussion

The key findings in the study were that patella instability may lead to patella-shaped disorder in growing rabbits, and early patella reduction could improve patella morphology. Studies the mechanism elucidation and pathological changes during trochlear dysplasia have continued to be published. Li [10] and Wang [13] had confirmed that after patella dislocation or subluxation, the trochlear groove results in an reduced groove height and increased groove angle. Fu et al. [18] recently found that the morphology of the femoral trochlea may improve after surgical correction of patellar instability in children. In recent studies, it had been demonstrated that patients with trochlear dysplasia also present with patella dysplasia [19, 20]. Fucentese et al. [21] found that patients with trochlear dysplasia had a smaller medial facet and a higher prevalence of type II and type III patella compared to controls. Li et al. [22] found that patients with trochlear dysplasia usually had a smaller and more flattened patella.Yılmaz et al. [23] also reported that a significant difference in the mean length and width of the patella in children with patellofemoral dislocation compared to the controls. Niu et al. [12] demonstrated an association between patellar shape (more flattened) and patella dislocation in an animal study.

The potential influence of patella reduction have not been described in growing rabbits. On the basis of the previously animal studies, we modified the model of patella dislocation, and used a model of patella instability similar to that of humans. The patella was in dislocated state and the trochlear groove was seen when the knee was flexed, and the patella returned to the relatively normal location when the knee was straighted. We believe that the animal model can better reflect the patellar morphology changes in human knee that are related to patella instability.

In this study, 2 months after surgery, the mean transverse diameter in the control group was 5.50 ± 0.38 mm, and the mean transverse diameter in the experimental groups was 7.02 ± 0.34 mm. The mean Wiberg angle showed the greater difference: 128.6 ± 5.3°in the control group versus 136.5 ± 6.9°in the experimental groups.

There were significant difference between the experimental groups and control group at 2 months after surgery, while the thickness and Wiberg index showed no signifcant diference between the experimental groups and control group, which is consistent with the results of Niu [12]. 5 months after surgery, the mean transverse diameter and Wiberg angle of the patella in non-reduced group were significantly longer and larger than that in the reduction group. However, no significant differences were seen in the four indices between the reduction group and control group. Although the cause of patellar dysplasia is not clear, the two possible reasons should be attention: absence of patellar mechanical stress and the tension of medial patellofemoral ligament. Grelsamer RP et al. [24] indicated that mechanical stress is a important factor affecting bone growing development, which can stimulates the growth and remodelling of the patella and femoral trochlea during functional movement [25]. Thus, the patella morphology could be remodeled, when early medial soft tissue restraint tension returns to normal and the patella reduction. The findings of the animal studies indicate that morphological changes of patella during childhood should be remedied as early as possible to avoid patella dysplasia in patellofemoral joints.

This study has several limitations. First, rabbit models rather than human bodily specimens were used in the study. The anatomy and growing period of animals do not always match the clinical situation in human. Second, the number of immature rabbits was narrow, even though it showed statistical differences. More animals would have been required to more accurately assess for the study. Also, changes in cartilage, subchondral bone and molecular level should be researched in the future.

Conclusions

In conclusion, the study demonstrated that patella instability in growing rabbits can result in patella-shaped disorder, and early patella reduction can improve the patella morphology. Based on these results of the study, it was concluded that patella instability should be treated as early as possible in childhood to prevent patella dysplasia that may be encountered in the future.

Abbreviations

CT: Computed Tomography; ICC: intra-class correlation coefficient; RG: reduction group; AB: transverse diameter of the patella; CD: thickness of the patella; WI: Wiberg index; WA: Wiberg angle; NRG: non-reduced group; CG: control group

Declarations

Ethics approval and consent to participate

The experimental protocol was approved by the local Animal Care and Use Committee (Baoding No 1 Central Hospital Research Ethics Committee [2019]-N21). All procedures executed involving animals were under the Western University's Animal Care and Use Guidelines (London, Ontario, Canada). The study was carried out in compliance with the ARRIVE guidelines.

Consent for publication

Not applicable.

Availability of data and materials

The detailed data and materials of this study were available from the

corresponding author through emails on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

WFL and SYW designed the study. WFL performed the experimental work. HYW processed the statistical analysis. WFL and QW draw the manuscript and made the figures and tables. All authors read and approved the final manuscript.

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Figures

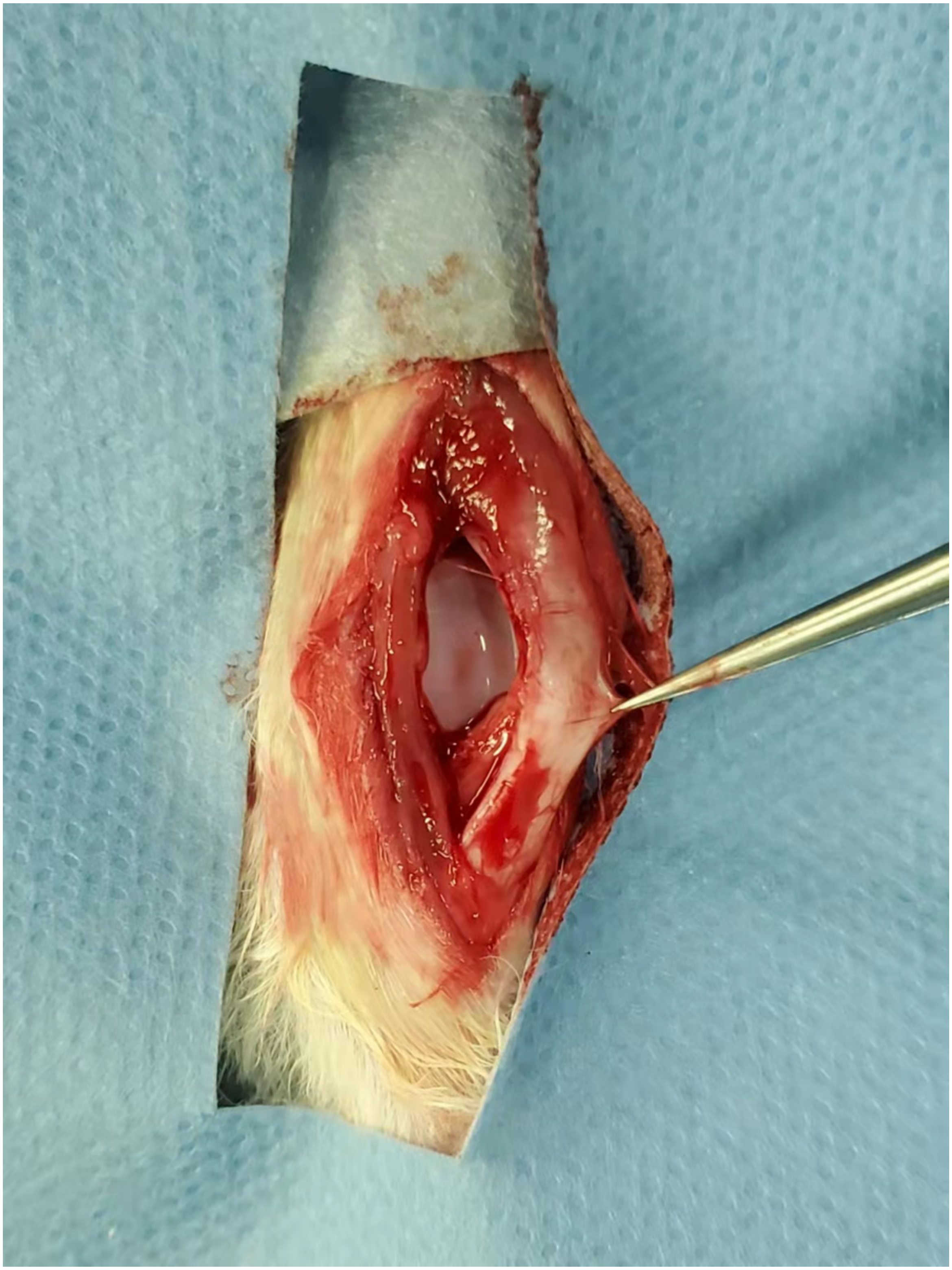

Figure 1

The picture during operative. The medial soft tissue restraint was released. Patella was moved laterally and femoral trochlear could be noticed.

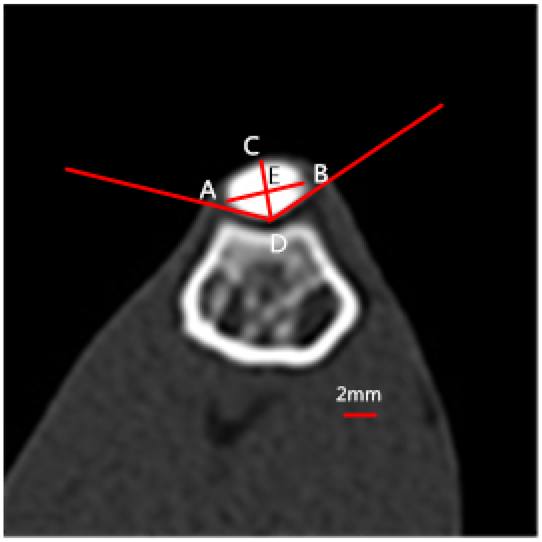

Figure 2

AB is defined as transverse diameter; CD is defined as thickness; length of BE/length of AB is defined as Wiberg index; angle ∠D is defined as Wiberg angle.

Figure 3

Three-dimensional reconstructed CT of the patella 2 months after surgery.

Figure 4

Gross anatomy of the patella: 5 months after surgery of the non-reduced group (left), 5 months after surgery of the control group (middle), 5 months after surgery of the reduction group (right).