Assessment of the relationship between patellar volume and chondromalacia patellae using knee magnetic resonance imaging

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Abstract

Objective: In this study, we evaluated the relationship between patellar volume and chondromalacia patellae.

Methods: A total of 162 patients who underwent knee magnetic resonance imaging (MR) due to knee pain at our department between January 2017 and May 2017 were included in this study. Of the cases, 111 were chondromalacia patellae, and 51 were healthy individuals. The patella volumes of all cases were analyzed using semi-automated software. Staging in cases with chondromalacia was graded according to the Outerbridge classification (stages 1–4). The relationship between patellar volume, presence of chondromalacia, cartilage thickness, age, and sex was analyzed statistically.

Results: Of the 162 cases, 67 (41.4%) were male, and 95 (58.6%) were female. The median age of the cases was 44. Patellar volume was a minimum of 12.24, a maximum of 39.44, and a median 21.4 cm³, and it was higher in cases with chondromalacia (p=0.026). In patients with chondromalacia patellae, the thickness of cartilage in the medial facet was lower. There was a statistically significant weak positive correlation between chondromalacia grade and patellar volume (p=0.031, r=0.204).

Conclusion: This study showed that chondromalacia patellae, one of the important causes of chronic frontal knee pain, has a statistically significant relationship with patellar volume. The medial facial cartilage of the patella was thinner than in cases with chondromalacia patellae. Although the mean age of the cases with chondromalacia was higher than the cases without chondromalacia, there was no significant difference between male and female individuals.

Keywords: Chondromalacia; patellar volume; knee pain.

type of force, patellar height, the shape of the patellar and
trochlear groove, patellar tilt, and the distance between
 Tibial tuberosity and the trochlear groove [6–10] have
an effect on the complex structure of the patellofemoral
joint. However, the relationship between patellar volume
and development of chondromalacia patellae has not yet
been clarified. This study investigated the correlation be-
tween patellar volume and chondromalacia patellae.

MATERIALS AND METHODS
Our research was approved by the local ethics commit-
tee. A total of 162 patients that underwent knee magnetic
resonance (MR) due to knee pain at our clinic between
January 1, 2017, and May 31, 2017, were included in this
study. According to the MR examination, 111 patients had
chondromalacia patellae, and 51 individuals had normal
findings. The MR images were obtained using the 1.5T
 system (Philips, Achieva, the Netherlands). The patellar
volume of all cases was analyzed using the PD SPAIR
sequence [Repetition Time (TR) 3034 ms, Echo Time
(TE) 30 ms, slice thickness 3.5 mm, and Gap 0.3 mm)
using semi-automated software on the workstation (Fig.
1). The cases of chondromalacia were graded according
to the Outerbridge classification from stage 1 to stage 4.

Statistical Analysis
In the statistical analysis, the categorical values of the
cases were expressed in numbers and percentages.
Numerical data without normal distribution were ob-
tained as minimum, maximum and median values. The
distribution of numerical data was evaluated using the
Shapiro Wilk test. Pearson’s Chi-square test was used to
compare categorical data and the Mann-Whitney U test
was used to compare numerical data between the two
groups. Spearman’s correlation analysis was undertaken
to analyze the correlation of the stage of chondromalacia
with patellar volume and cartilage thickness. SPSS 21.0
software (IBM Corp. New York, USA) was used for sta-
tistical analysis. The relationship between patellar vol-
ume and chondromalacia presence and grade, cartilage
thickness, age, and sex was statistically analyzed.

RESULTS
A total of 162 cases were included in this study, of which
67 (41.4%) were male, and 95 (58.6%) were female.
Chondromalacia patella was found in 111 (68.5%) cases.
Of the chondromalacia patellae cases, 23 (20.7%) were
grade I, 52 (46.8%) were grade II, 32 (28.8%) were grade
III, and 4 (3.6%) were grade IV. None of the numerical
data showed the normal distribution in the Shapiro Wilk
test; thus, nonparametric tests were used in the statisti-
cal analysis. The minimum, maximum and median ages
of the 162 cases were 18, 74, and 44, respectively. Patel-
lar volume was measured as a minimum of 12.24 cm$^3$,
a maximum of 39.44 cm$^3$, and a median 21.4 cm$^3$. The
thickness of cartilage measured from the medial facet was
a minimum of 1.6 mm, a maximum of 5.9 mm and a me-
dian 3.2 mm. The thickness of cartilage measured from
the lateral facet was a minimum of 1.6 mm, a maximum of
5.9 mm and a median 3.2 mm. Chondromalacia patellae
was present in 45 (67.16%) male cases (67.16%) and 66
(69.47%) female cases (n=95) with no statistically signif-
ificant difference according to sex in Pearson’s Chi-square
test (p=0.755). Age also did not differ significantly be-
tween men and women. Patellar volume and medial and
lateral facet cartilage thickness were statistically higher in
males than in females (Table 1). The age of the patients
with chondromalacia was statistically significantly higher
than that of individuals without this condition. Further-
more, in cases with chondromalacia, patellar volume was
higher, the thickness of the cartilage in the medial fascia
was lower, and the difference was statistically significant
for both. There was no statistically significant differ-
ence in the cartilage thickness measured from the lateral
facet. In chondromalacia patients, a statistically signifi-
cant, weak, and positive correlation was found between
chondromalacia grade and patellar volume (p=0.031,
However, there was no statistically significant correlation between chondromalacia grade and the medial and lateral facet cartilage thickness (p=0.446, r=-0.073 and p=0.444, r=-0.073, respectively) (Table 2).

**DISCUSSION**

Patellar cartilage damage may develop acutely as a result of direct trauma, but may also occur chronically due to microtraumas. There is limited research investigating whether micro-traumas may cause chondromalacia patellae in predisposed cases, and some studies have been undertaken on tibiofemoral and patellofemoral joints; however, they mostly focused on the patellofemoral joint, which has a more complex structure. The effects of alignment disorders related to patellar height, patellar and trochlear groove, patellar tilt, and the distance between tibial tuberosity and trochlear groove have been investigated [7–10]. However, to our knowledge, no assessment has been performed on patellar volume, a structural characteristic of individuals. Patellar cartilage defects are closely related to the geometry of the patellofemoral joint. Patellar height, patellar lateral facet width, patellar lateral facet ratio, sulcus depth, lateral patellar displacement, patellar epicondylar congruence angle, and abnormal length of the lateral condyle have been associated with chondromalacia patellae [6, 10, 11]. It has been reported that frequent recurrent dislocations, subluxations, and especially severe patellar femoral cartilage defects in the presence of patella alta also increase the presence of chondromalacia patellae [6, 12–17]. A flat and shallow femoral trochlea with less sulcus depth that arises from an increased sulcus angle defined by the angle between the lateral condyle and the medial condyle on the transverse plane used in the identification of the trochlear morphology may result in disproportionate load distribution across the patellofemoral joint during knee movement, increasing the pressure on this joint and leading to the development of chondromalacia [8, 10, 18, 19]. Stabilization of the patellofemoral joint by bone and cartilage is weakened in the presence of trochlear dysplasia, which leads to patellofemoral disorder, instability, dislocation, and, ultimately an increased risk of cartilage damage [10, 20]. Damage or weakness of ligament and joint capsules plays an important role in joint stability, which is also known to cause joint degeneration. Joint subluxations due to the disruption of the ligament and capsule functions cause instability, resulting in incongruence in the surfaces of joints, e.g., trochlear disorder, preventing the normal distribution of weight and stress and increasing the risk of joint cartilage injury. In all important studies, it has been shown that a high body weight and body mass index (BMI) have detrimental effects on patellar cartilage. It has been found that increased fat thickness of subcutaneous knee circumference, which is an indicator of obesity in middle-aged adults, especially women, is positively correlated with the presence and severity of patellar cartilage defects in MR imaging [21, 22].

In this study, patellar volume was higher in patients with chondromalacia patellae. The mean patellar medial facet cartilage thickness was lower in the patients with chondromalacia. As expected, the risk of chondromalacia increased with age. Although it was slightly higher in females, no significant difference was found between men and women with chondromalacia patellae in our study. Furthermore, there was a significant but weak relationship between patellar volume and chondromalacia grade.

### Table 1. Numerical data on age, patellar volume and cartilage thickness by sex*

<table>
<thead>
<tr>
<th></th>
<th>Male Median</th>
<th>Female Median</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>41</td>
<td>46</td>
<td>0.292</td>
</tr>
<tr>
<td>Patellar volume (cm³)</td>
<td>23.41</td>
<td>20.12</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Cartilage thickness at the medial facet (mm)</td>
<td>3.3</td>
<td>2.9</td>
<td>0.017</td>
</tr>
<tr>
<td>Cartilage thickness at the lateral facet (mm)</td>
<td>3.5</td>
<td>3.1</td>
<td>0.006</td>
</tr>
</tbody>
</table>

*Mann-Whitney-U test.

### Table 2. Numerical data on age, patellar volume, and cartilage thickness according to the presence of chondromalacia patellae*

<table>
<thead>
<tr>
<th></th>
<th>Chondromalacia patellae present Median</th>
<th>Chondromalacia patellae absent Median</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>49</td>
<td>32</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Patellar volume (cm³)</td>
<td>21.84</td>
<td>19.73</td>
<td>0.026</td>
</tr>
<tr>
<td>Cartilage thickness at the medial facet (mm)</td>
<td>3</td>
<td>3.5</td>
<td>0.001</td>
</tr>
<tr>
<td>Cartilage thickness at the lateral facet (mm)</td>
<td>3.3</td>
<td>3.1</td>
<td>0.353</td>
</tr>
</tbody>
</table>

*Mann-Whitney-U test
The limitations of this study include the lack of an assessment of the relationship between patellar volume and BMI of cases and data loss that arises from the routine MR section thickness, both due to the retrospective design. Further studies can be planned with thin-section MR imaging to evaluate chondromalacia cases according to BMI and calculate the optimal patellar volume. In this study, the difference of age was statistically significant between the study and control group, which may cause bias due to possible effects of age on other parameters. Besides, a statistically significant difference in patellar volume between males and females may cause bias, as well. Thus, further studies with a more homogeneous population in study and control groups are needed.

In conclusion, our study demonstrated a significant correlation between chondromalacia patellae and patellar volume, in which as the patellar volume increased, the chondromalacia risk increased and cartilage thickness at the medial facet of the patella decreased at a further level compared to the lateral measurement. There was also a significant but weak relationship between patellar volume and grade of chondromalacia patellae. The mean age was higher in the cases with chondromalacia than the cases without chondromalacia, but chondromalacia frequency did not significantly differ between men and women.

**REFERENCES**


