Is the Clock Face an Accurate, Precise, and Reliable Measuring Tool for Anterior Cruciate Ligament Reconstruction?

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**Purpose:** (1) To assess the use and practice of the clock face among surgeons who routinely perform anterior cruciate ligament (ACL) reconstructions, and (2) to assess the accuracy, precision, and reliability of 3 commonly used clock-face schemes in ACL reconstruction. **Methods:** First, 9 surgeons completed a questionnaire assessing the use and definition of the clock-face technique. Next, to assess the accuracy, precision, and reliability of the clock face, each surgeon estimated the “time” of 8 artificial femur models with a black dot located on the posterior aspect of the lateral condylar wall. The estimates were performed using 3 different clock-face schemes and were repeated 10 months later. Solutions for each specimen were obtained by use of a computer graphical interface. **Results:** More than half of the respondents (55%) use the clock face in ACL reconstructions, with the reported mean ideal “time” for a femoral tunnel in a right knee of 10:05 (SD, 31 minutes). When we accounted for the different clock definitions, this ideal position was found along the entire lateral condylar wall. In the assessment of the performance of the clock face, the mean error was 32 to 40 minutes (which translates to 3 to 4 mm) among the 3 clock schemes. The maximum error was 4 hours 0 minutes, and the range of responses was 1 hour 0 minutes to 4 hours 0 minutes depending on the specimen and clock scheme. Regardless of the clock scheme used, the intrarater and inter-rater reliabilities were similar—measuring, on average, 0.78 and 0.68, respectively. **Conclusions:** The clock face continues to be commonly used in ACL reconstruction. Different clock-face definitions affect the position for the same “time.” When the clock-face parameters were strictly defined, there was good reliability with borderline accuracy and poor precision. **Clinical Relevance:** Considering the borderline performance of the clock face in accuracy and poor precision, we recommend against using the clock face in ACL reconstruction.

Since the inception of arthroscopic anterior cruciate ligament (ACL) reconstruction in the 1980s, the clock face (or interface) has become a widely used technique to describe and select the femoral tunnel position.1-5 The premise of this technique is to visualize an analog clock face within the intercondylar notch and use the “time” to measure the position of the ACL femoral footprint along the lateral condylar wall. This concept became well accepted because it appeared to simplify femoral tunnel placement.

However, recently, the clock face has caused dissemination. The idea that a 2-dimensional structure is being used to measure a 3-dimensional space is fundamentally flawed.6 Clock orientation, knee flexion, and depth are all parameters that can affect the measurement.6,7 Clock times are often specified with no mention of these parameters, and when described, different definitions exist in the literature. Although 12 o’clock is defined as the top of the notch, the 3-o’clock to 9-o’clock axis has been referenced from the center of the notch,2,4,8,9 the epicondylar axis,3 the articular margin at the base of the notch,10,11 or the joint line.5,12,13 The position of the center of the clock is different in all these cases. Furthermore, although the epicondylar axis is perpendicular to the axis of the center of the intercondylar notch (Whiteside’s line),14,15 it is externally rotated 3° to 6° from the posterior condyles,6,16-18 which the joint line and articular margin references disregard. These differences will likely account for a different position for the same “time.”

Despite these limitations, the clock face continues to be widely used. Given the importance of anatomic tunnel placement10,19,20 and given that malpositioning is the leading cause of graft failure,21-23 a thorough...
evaluation of the clock face is of paramount importance. The purposes of this study were (1) to assess the use and practice of the clock face among surgeons who routinely perform ACL reconstructions and (2) to assess the accuracy, precision, and reliability of 3 commonly used clock-face schemes. Our hypotheses were as follows: (1) the clock face is commonly used in ACL reconstruction; (2) surgeons use different clock-face schemes or parameters in their measurements; (3) the same “clock time” provides for a different position depending on the clock scheme; and (4) even if the clock-face parameters are explicitly defined, the clock face still would not provide for an accurate, precise, or reliable measuring tool in ACL reconstruction.

**Methods**

Nine orthopaedic sports medicine surgeons who routinely perform ACL reconstructions (with a reported average of 56 ACL reconstructions per year [SD, 25 ACL reconstructions]) in an academic university-based practice setting were voluntarily enrolled in our study. In the first part of this study, each surgeon completed a questionnaire that assessed (1) whether the surgeon uses the clock face in ACL reconstruction, (2) how the surgeon defines the clock face, and (3) at what “time” the ideal femoral tunnel should be placed. The results of the survey were tabulated to determine the prevalence of clock-face use, examine whether the clock-face parameters were universal among the participants, and determine the actual location of the ideal femoral tunnel based on the participants’ reported “time” and their defined clock parameters. The actual location was determined by converting the time from 1 clock scheme to the other clock schemes, which was then plotted on a femoral condylar graph assuming that the notch correlates to a semicircle with a 2-cm diameter,3,24,25 1 minute is equivalent to 0.5°/C14, and the epicondylar axis is externally rotated from the posterior joint line by 3°. Graphical software, Visio (version 2007; Microsoft, Redmond, WA), was used to convert the “times” among schemes A and B (Fig 1). For example, the location of 10 o’clock using scheme A calculates to 8:14 using scheme B and 8:08 using scheme C.

Next, to assess the accuracy, precision, and reliability of the clock face, 8 right femoral Sawbones (Pacific Research Laboratories, Vashon, WA) were marked with a single dot as shown in Fig 2 for 1 specimen. The dots were placed randomly on the posterior aspect of the lateral femoral condylar wall to cover a wide range of clock positions and footprint locations. The participants were asked to specify the time of each mark on the Sawbones based on 3 commonly used clock-face schemes as illustrated in Fig 3. Scheme A has the center of the clock and the clock’s horizontal axis (axis connecting 3 and 9 o’clock) aligned with the joint line (posterior femoral condyles). Scheme B has the center of the clock at the center of the intercondylar notch and the clock’s horizontal axis aligned with the joint line. Scheme C has the center of the clock at the center of the intercondylar notch and the clock’s horizontal axis aligned with the epicondylar axis. All 3 schemes controlled for knee flexion at 90°, and depth was specified at the mark. The Sawbones were presented in random order. No time limit was enforced, and the surgeons were allowed to hold and manipulate the Sawbones freely to facilitate visualization of the surface anatomy and the black dot. The respondents were...
asked to provide the most accurate estimates with a minimum unit of 1 minute. The survey was performed twice with an intervening 10-month period. Between tests, the Sawbones were randomized and the responses blinded from the surgeons.

The control time (actual “time” of the dotted mark) for all clock schemes, referred to as the “solution,” was obtained using a software graphical interface. Each specimen was placed in a vice, and a digital photograph was taken perpendicular to the long axis of the femur. The photographs were then analyzed by the computer graphical software, where the exact “times” were calculated to the nearest minute as shown in Fig 4 for 1 specimen. Statistical analysis was performed by use of Matlab (Statistics Toolbox, version 7.0; The MathWorks, Natick, MA) and SPSS (version 16.0; IBM, Armonk, NY).

Accuracy was assessed by computing the difference between each surgeon’s estimate and the computer-generated solution, referred to as the “error,” for all trials (9 surgeons × 8 specimens × 2 trials = 144 data points). Precision was evaluated by the range of responses. Intraclass correlation coefficients were generated among the surgeons’ answers to evaluate the intrarater and inter-rater reliability. Lastly, to evaluate whether there was a difference in the magnitude of errors between surgeons who routinely use the clock interface and those who do not, a Student t test was applied with a null hypothesis that the errors were similar.

### Results

The answers to the questionnaire are summarized in Table 1. Of the 9 surgeons enrolled in the study, 5 (55%) routinely use the clock face for their ACL reconstructions. The definitions of the clock face were not universal among the respondents, with variances in the clock center, horizontal axis, and flexion. The mean ideal “time” for a femoral tunnel in a right knee was

<table>
<thead>
<tr>
<th>Surgeon No.</th>
<th>Routine Use of Clock Face</th>
<th>Clock Definition</th>
<th>Control for Knee Flexion</th>
<th>Ideal “Time” for Femoral ACL Tunnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No</td>
<td>Scheme C</td>
<td>90°</td>
<td>9:30</td>
</tr>
<tr>
<td>2</td>
<td>Yes</td>
<td>Scheme C</td>
<td>90°</td>
<td>11:00</td>
</tr>
<tr>
<td>3</td>
<td>Yes</td>
<td>Scheme B</td>
<td>90°</td>
<td>10:30</td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td>Scheme B</td>
<td>90°</td>
<td>10:30</td>
</tr>
<tr>
<td>5</td>
<td>No</td>
<td>Scheme A</td>
<td>90°</td>
<td>10:00</td>
</tr>
<tr>
<td>6</td>
<td>No</td>
<td>Scheme C</td>
<td>90°</td>
<td>9:45</td>
</tr>
<tr>
<td>7</td>
<td>Yes</td>
<td>Scheme A</td>
<td>No</td>
<td>10:15</td>
</tr>
<tr>
<td>8</td>
<td>Yes</td>
<td>Scheme B</td>
<td>90°</td>
<td>9:30</td>
</tr>
<tr>
<td>9</td>
<td>No</td>
<td>Scheme A</td>
<td>90°</td>
<td>9:45</td>
</tr>
</tbody>
</table>

**NOTE.** The “time” is specified for a right knee.
reported by the participants as 10:05 (SD, 31 minutes). When these times were converted according to how the clock face was defined, the mean ideal “time” at which the surgeons would place the femoral tunnel was calculated to be 10:43 (SD, 36 minutes) for scheme A, 9:36 (range, 9:30; SD, 1 hour 8 minutes) for scheme B, and 9:24 (SD, 1 hour 8 minutes) for scheme C. When these times were plotted on a representative femoral condyle, the reported ideal “time” (when we accounted for how the surgeons define the clock-face parameters to measure location) was seen to be scattered along the entire lateral femoral condyle (Fig 5).

The absolute mean standard error of the surgeons’ responses ± standard deviation (accuracy) was 40 ± 43 minutes, 33 ± 47 minutes, and 32 ± 47 minutes for clock-face schemes A, B, and C, respectively. The maximum error was 4 hours 0 minutes for scheme A, 2 hours 51 minutes for scheme B, and 2 hours 49 minutes for scheme C (Table 2).

Regardless of the clock-face scheme used, the intrarater and inter-rater reliabilities were similar—measuring, on average, 0.78 and 0.68, respectively (Table 3). Furthermore, there was no significant correlation between the stated preferred clock interface scheme on the questionnaire and the measured error. In other words, the standard error was not lower when the surgeon used his or her preferred clock scheme. Lastly, there was a significant difference ($P < .01$) between the errors of surgeons who routinely use the clock interface compared with those who do not; counterintuitively, however, the errors were larger in the group that routinely uses the clock interface.

**Discussion**

Despite recent criticisms of the clock face in the literature, the results of the questionnaire in this study show that the clock face is still commonly used among

**Table 2. Range of Responses for All 8 Specimens According to 3 Different Clock Schemes**

<table>
<thead>
<tr>
<th>Specimen No.</th>
<th>Scheme A</th>
<th>Scheme B</th>
<th>Scheme C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10:27</td>
<td>10:52</td>
<td>10:36</td>
</tr>
<tr>
<td>2</td>
<td>10:00</td>
<td>10:00</td>
<td>10:30</td>
</tr>
<tr>
<td>3</td>
<td>9:45</td>
<td>10:00</td>
<td>9:57</td>
</tr>
<tr>
<td>4</td>
<td>9:30</td>
<td>10:36</td>
<td>9:35</td>
</tr>
<tr>
<td>5</td>
<td>9:00</td>
<td>9:28</td>
<td>9:30</td>
</tr>
<tr>
<td>6</td>
<td>9:45</td>
<td>9:57</td>
<td>9:35</td>
</tr>
<tr>
<td>7</td>
<td>10:30</td>
<td>10:00</td>
<td>10:03</td>
</tr>
<tr>
<td>8</td>
<td>11:00</td>
<td>11:00</td>
<td>10:10</td>
</tr>
</tbody>
</table>

Fig 5. Actual position of surgeons’ ideal femoral tunnel position when using clock face and normalizing for differing clock definitions in a right femur. It should be noted that there is some overlap between answers, and there are a total of 9 points.
surgeons performing ACL reconstructions on a routine basis, with over half of the surgeons enrolled in this study stating that they use it regularly. Given that this survey was performed in an academic center, we suspect use of the clock face to be even higher in the general community. Moreover, the lack of a unified definition for the clock face is exemplified by the diverse range of responses with respect to the alignment and centering of the clock. So, although surgeons in this survey mostly agree that 10 o’clock is the ideal “time” for the femoral tunnel, this ideal position is actually scattered along the entire lateral femoral condyle when accounting for the surgeons’ definition of the clock face (Fig 5).

The major criticisms of the clock face are that multiple definitions of the clock face exist in the literature, often without specifying their parameters, and that a 2-dimensional object is used to measure a 3-dimensional space. To further elaborate on why this is problematic, first, it is imperative that there is agreement on how something is measured in order for the measurement to be useful. For example, if one says that an object’s length is 10 but does not disclose whether it is measured in inches, centimeters, or yards, then this measurement will not be very meaningful to another person. Second, it has previously been explained that the clock face is 2-dimensional and does not address depth in the notch or knee flexion; however, each of these factors can change the clock position.34

If these problems were solved, could the clock face be an accurate, precise, and reliable measuring tool in ACL reconstruction? The second part of this study attempted to address this question by controlling for the location of the clock’s center, clock’s rotational alignment, degree of knee flexion, and anteroposterior depth. Although the minimum angle around the intercondylar notch discernible to a surgeon is unknown, a high measurement resolution of 0.5° (1 minute around the clock face) was used in this study to minimize quantization (rounding) errors. All 9 surgeons provided responses in units of 30 or 15 minutes despite having the opportunity to answer in units of 1 minute, confirming that our resolution is sufficient (7.6° to 15°).

Accuracy of the clock face was assessed by comparing the respondents’ answers with a computer-generated solution. The error was between 32 and 42 minutes depending on the clock scheme used. If we assume that the intercondylar notch is a circular structure with a width w, we can use the arc length formula to determine the distance caused by an error of minutes (m), as follows: Error distance = \((m \times \pi \times w)/720\). Therefore, for a typical intercondylar notch width of 2 cm,3,24,25 our error of 32 to 42 minutes results in an error distance of 3 to 4 mm. However, if we add 1 SD to our error, this results in an error between 1 hour 19 minutes and 1 hour 23 minutes, or an error distance of 7 mm for all 3 clock schemes. Furthermore, the maximum error in this study was 4 hours. Studies have shown that a difference of just 1 hour can change the rotational stability and knee kinematics,4,26-29 and Marchant et al.30 previously defined an ACL tunnel to be nonanatomic if greater than 50% of the tunnel was located outside the native ACL attachment site.

In evaluating precision, we looked at the range of responses. For the 8 specimens, the range was between 1 hour 0 minutes and 3 hours 45 minutes for scheme A, 2 hours 30 minutes and 4 hours 0 minutes for scheme B, and 1 hour 30 minutes and 4 hours 0 minutes for scheme C. In terms of descriptive statistics, we would consider this to be poor precision for ACL reconstruction.

The intraclass correlation coefficient was used to evaluate intrarater and inter-rater reliability. All but 1 of these values can be categorized as good when using the following rating scale: poor, less than 0.40; good, 0.40 to 0.75; and excellent, greater than 0.75.31

When we compared the 3 commonly used clock schemes, scheme A had the overall worst performance, with a standard error of 40 minutes. Schemes B and C had similar performance, with standard errors of approximately 33 minutes and 32 minutes, respectively. Contrary to what one would expect, the magnitude of the errors did not improve when the surgeon used his or her preferred clock scheme. Moreover, the surgeons who routinely use a clock-face scheme had significantly worse estimates. We also found that by using this model, differences when referencing from the epicondylar axis, the joint line, or the top of the notch can be considered not significant because 0.5° translates to 1 minute and, therefore, a difference of 1.5 minutes would reflect the typical difference of 3° from the joint line to the epicondylar axis.

To our knowledge, this is the only study that has assessed the accuracy of the clock-face technique, which is of utmost importance to ensure proper tunnel placement.32,33 Azzam et al.33 also recently examined the intrarater and inter-rater reliability of the clock face. A major flaw in that study was that “times” were compared without controlling for differences in clock definitions. If the definitions are not explicitly defined, it is not possible to properly assess the measuring capacity of the clock face. Surprisingly, Azzam et al. found excellent inter-rater reliability for the clock face even

<table>
<thead>
<tr>
<th>Table 3. Intrarater and Inter-Rater Reliability Rating According to 3 Different Clock Schemes</th>
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<tbody>
<tr>
<td><strong>ICC (95% CI)</strong></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Intrarater</td>
</tr>
<tr>
<td>Inter-rater</td>
</tr>
</tbody>
</table>

CI, confidence interval; ICC, intraclass correlation coefficient.
though surgeons were using different measuring techniques, and this may be a result of a lower resolution (30 minutes) and/or bias limiting the number of reasonable answers (because it is often cited that the center of the ACL footprint is approximately at 10 o’clock). However, given the wide range of responses, Azzam et al. concluded that the clock face should not be used in ACL reconstruction.

In our study, in which we explicitly defined the parameters of the clock face, we found reliability to be worse than that in the study by Azzam et al. Although we found “good” reliability, we would argue that this may not be clinically acceptable. Nonetheless, the poor precision and range of errors preclude against using the clock face in ACL reconstruction in which accurate and precise tunnels are necessary for the success of surgery. Alternative options that may be more accurate and precise should be used, such as referencing off bony landmarks, using the radiographic quadrant method, or using computed tomography—based navigation, and possibly using 3-dimensional magnetic resonance imaging to establish the landmarks for the native ACL footprint.

Limitations

Limitations of this study include the use of Sawbones ex vivo in lieu of arthroscopy in real knees. The ability of the surgeons to hold and manipulate the Sawbones freely represents a different perspective than arthroscopy. Subtle variations in portal placement, different viewing portals, or different-degree arthroscopes can provide for a different view, which may affect clock-face measurements. Other variations of the clock-face technique exist and were not tested in this study. All our knee specimens were right sided; however, sidedness would unlikely influence our findings. There were 9 surgeons, all from 1 center, which can represent selection bias. Surgeons also were asked to “read” the time rather than “locate” the time, and this study assumed that the accuracy, precision, and reliability of doing so would be interchangeable. Center points rather than actual tunnels were also used.

Conclusions

The clock face continues to be commonly used in ACL reconstruction. Different clock-face definitions affect the position for the same “time.” When we strictly controlled for the clock-face parameters, there was good reliability with borderline accuracy and poor precision.

Acknowledgment

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References

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