Comparison of Corneal Flap Morphology Using AS-OCT in LASIK With the WaveLight FS200 Femtosecond Laser Versus a Mechanical Microkeratome

Yu Zhang, MD; Yue-guo Chen, MD; Ying-jie Xia, MD

ABSTRACT

PURPOSE: To evaluate and compare the thickness and the morphology of femtosecond and mechanical microkeratome LASIK flaps using anterior segment optical coherence tomography (AS-OCT).

METHODS: Bilateral LASIK was performed in 132 eyes from 61 myopic patients. Flaps were created in 72 eyes using the WaveLight FS200 femtosecond laser (WaveLight GmbH, Erlangen, Germany) and in 50 eyes using the Moria microkeratome (Moria SA, Antony, France). AS-OCT was used 1 week postoperatively to evaluate the thickness of 17 points across each flap, which were 0, 2, and 3.5 mm to the corneal vertex on the horizontal, vertical, 45°, and 135° meridians.

RESULTS: The mean central flap thickness was 105.53 ± 5.86 µm in the WaveLight group and 132.96 ± 13.91 µm in the Moria group (P < .001). The difference between the achieved and the intended flap thickness (accuracy) was 6.17 ± 3.98 and 23.60 ± 12.64 µm, respectively (P < .001). The standard deviation within individual flap (uniformity) was smaller in the WaveLight group. The symmetry and regularity were also better in the WaveLight group. Flap morphology showed a more regular planar shape in the WaveLight group and a meniscus shape in the Moria group.

CONCLUSIONS: AS-OCT showed that the flaps created by the WaveLight femtosecond laser were more accurate, reproducible, and uniform than those created by the Moria microkeratome.

PATIENTS AND METHODS

PATIENTS
Patients who received LASIK surgery for myopia at the Peking University Third Hospital from May to October 2011 participated in the prospective study. Each patient underwent routine preoperative examinations to rule out contraindications for LASIK. Patients were divided into the WaveLight group or the Moria group based on each patient’s preference. All procedures were reviewed and approved by the Ethics Committee of the Peking University Third Hospital. The procedures were explained to each patient, and informed consent was obtained.

SURGICAL PROCEDURES
All surgical procedures were performed by the same surgeon (YC). Femtosecond laser flaps were created by a WaveLight FS200, with the intended flap thickness of 110 μm, flap diameter of 9.0 mm, and side-cut angle of 90°. Every flap was superiorly hinged and had a superior canal to release the air bubbles during the flap creation. Microkeratome flaps were created by a Moria M2 90 single-use microkeratome with superior hinges and intended flap thickness of 110 μm. One microkeratome head was used for each patient. The flap was first created in the right eye. Flaps were lifted immediately after flap creation to perform the ablation. Stromal ablation was performed with the Allegretto Eye-Q excimer laser platform (WaveLight GmbH).

AS-OCT MEASUREMENT
The flap thickness was measured with a noncontact high-speed AS-OCT system (Visante OCT; Carl Zeiss Meditec) at 1 week postoperatively. Measurements were performed by the same experienced technician who was blind to the treatment group. The cornea was scanned within 1 second under the ‘High Res Corneal Quad’ mode at four meridians (45°, 90°, 135°, and 180°). The best frame from three consecutive frames was chosen for flap evaluation. The flap thickness at five points (0, ±2 mm, and ±3.5 mm from the vertex) on each meridian was calculated using the flap tool provided by the software. Each flap was measured at a total of 17 points. The flap thickness of the central point (0) was measured at each meridian (4 times), and the mean value was regarded as the central flap thickness.

STATISTICAL ANALYSIS
Central flap thickness accuracy was calculated as the difference between the achieved and intended flap thickness. Reproducibility was defined as the standard deviation of the central flap thickness among eyes. Uniformity was calculated as the standard deviation in flap thickness of 17 points in each flap. Symmetry (index S) was defined as the sum of the absolute values of the difference between the flap thicknesses of the opposite points from the vertex.9 Regularity (index R) was defined as the standard deviations in the flap thickness of the points at the same eccentricity.9 The independent sample t test was used to compare the data and indices between the two groups. A P value of .05 or less was considered to be statistically significant. Statistical analysis was performed using SPSS 13.0 software (SPSS, Inc., Chicago, IL).

RESULTS
Sixty-one patients participated in the prospective study. The WaveLight group comprised 72 eyes of 36 patients and the Moria group comprised 50 eyes of 25 patients. The age, gender, preoperative spherical equivalent, and central corneal thickness were not significantly different between the two groups (Table 1). No vision-threatening flap complication was found in either group. There was no statistically significant difference between the two groups in terms of postoperative uncorrected distance visual acuity.

### Table 1

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>WaveLight Group (72 Eyes)</th>
<th>Moria Group (50 Eyes)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>30.45 ± 5.23</td>
<td>29.28 ± 4.96</td>
<td>.265</td>
</tr>
<tr>
<td>Gender (M/F)</td>
<td>10/26</td>
<td>8/17</td>
<td>.722</td>
</tr>
<tr>
<td>Spherical equivalent (D)</td>
<td>-6.34 ± 2.06</td>
<td>-6.12 ± 1.86</td>
<td>.318</td>
</tr>
<tr>
<td>Corneal thickness (μm)</td>
<td>536.3 ± 18.6</td>
<td>530.4 ± 20.4</td>
<td>.216</td>
</tr>
<tr>
<td>Mean keratometry (D)</td>
<td>43.20 ± 1.25</td>
<td>43.16 ± 1.33</td>
<td>.513</td>
</tr>
<tr>
<td>Corneal astigmatism (D)</td>
<td>0.56 ± 0.43</td>
<td>0.59 ± 0.40</td>
<td>.427</td>
</tr>
</tbody>
</table>

M = male; F = female; D = diopters

The WaveLight femtosecond laser is manufactured by WaveLight GmbH, Erlangen, Germany, and the Moria microkeratome is manufactured by Moria SA, Antony, France.
WaveLight vs Moria for Corneal Flap Morphology/Zhang et al

and refraction at 3 months (Table 2). There was no loss of best corrected visual acuity in either group at 3 months postoperatively.

The morphology of the flap showed by the AS-OCT was different between the two groups (Figure 1). Figure 2 provided the mean flap thickness in different meridians of the 17 points. The WaveLight flap showed a more regular planar shape, with a side-cut angle closer to 90°. The Moria flap showed a meniscus shape, which was thin in the center and became gradually thicker toward the periphery.

The mean central thickness of the WaveLight flaps (105.53 ± 5.86 μm) was significantly thinner than that of the Moria flaps (132.96 ± 13.91 μm) (P < .001). WaveLight flaps were more accurate than the Moria flaps (P < .001). Reproducibility was also better in the WaveLight flaps (Table 3).

For different eyes in the same patients, the mean central thickness of the WaveLight flaps was 105.75 ± 5.96 μm in the right eyes and 105.30 ± 6.12 μm in the left eyes (P = .532). The mean central thickness of the Moria flaps was 136.68 ± 14.39 μm in the right eyes and 129.24 ± 12.61 μm in the left eyes (P < .001). The mean ratio of right to left central thickness was 1.003 ± 0.057 in the WaveLight flaps and 1.058 ± 0.057 in the Moria flaps (P = .0004).

The mean standard deviation of the 17 points within the individual flap (uniformity) was 4.07 ± 0.94 μm in the WaveLight group and 8.48 ± 2.35 μm in the Moria group (P < .001). The index S of the WaveLight group was significantly smaller than that of the Moria group (P < .001). The index R was significantly higher in the Moria group than in the WaveLight group (P < .001) (Table 3).

In terms of mean flap thickness at each eccentricity, there were significant differences between the two groups at center, 2-mm radius, and 3.5-mm radius (P < .001). There was no significant difference among the three eccentricities in the WaveLight group. The Moria flaps were thicker at the 3.5-mm radius than at the 2-mm radius and at the center (P < .001), and they were also thicker at the 2-mm radius than at the center (P < .001) (Figure 3).

DISCUSSION

The accuracy of the central flap thickness is a key safety consideration for LASIK. In this study, the intended flap thickness was 110 μm with both the WaveLight femtosecond laser and the Moria microkeratome; the mean central flap thicknesses achieved at 1 week postoperatively were 105.53 ± 5.86 and 132.96 ± 13.91 μm, respectively. Therefore, the WaveLight flaps had significantly higher accuracy and reproducibility than the Moria flaps. Similar results were also reported in previous studies of femtosecond laser flaps, such as IntraLase, Femto LDV, and VisuMax. Kezirian and Stonecipher found that the mean flap thickness was 114 ± 14 μm with the IntraLase programmed for 130 and 156 ± 29 μm with the Hansatome microkeratome (Bausch & Lomb, Rochester, NY) using a 180-μm plate. Zhang et al. found that the mean central flap thickness

![Figure 1. Anterior segment optical coherence tomography revealed the profile of the LASIK flap created by (A) the WaveLight femtosecond laser (WaveLight GmbH, Erlangen, Germany) or (B) the Moria M2 90 microkeratome (Moria SA, Antony, France). A thinner flap and a side-cut angle closer to 90° was showed in (A).](image)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>WaveLight Group (72 Eyes)</th>
<th>Moria Group (50 Eyes)</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>UDVA (logMAR)</td>
<td>-0.06 ± 0.12</td>
<td>-0.03 ± 0.15</td>
<td>.825</td>
</tr>
<tr>
<td>SE (D)</td>
<td>0.05 ± 0.42</td>
<td>0.02 ± 0.51</td>
<td>.652</td>
</tr>
<tr>
<td>Sphere (D)</td>
<td>0.16 ± 0.56</td>
<td>0.20 ± 0.75</td>
<td>.687</td>
</tr>
<tr>
<td>Cylinder (D)</td>
<td>-0.23 ± 0.36</td>
<td>-0.29 ± 0.41</td>
<td>.326</td>
</tr>
</tbody>
</table>

UDVA = uncorrected distance visual acuity; SE = spherical equivalent refraction; D = diopters

*Independent sample t test.

The WaveLight femtosecond laser is manufactured by WaveLight GmbH, Erlangen, Germany, and the Moria microkeratome is manufactured by Moria SA, Antony, France.
was 107.43 ± 4.7 μm with the Ziemer LDV intended for 110 and 125.90 ± 17.50 μm with the Hansatome microkeratome using a 160-μm plate. Yao et al.9 found that the mean flap thickness at 1 week postoperatively was 114.2 ± 6.93 μm with VisuMax intended for 100 and 127.9 ± 7.57 μm using the Moria microkeratome with an intended thickness of 110 μm. In terms of the accuracy and reproducibility of the central flap thickness, the results of the WaveLight flaps observed in this study were consistent with an in vitro porcine study14 (mean flap thickness: 96.3 ± 7.45 μm; intended thickness: 100 μm). In this study, no significant difference in central flap thickness was found between the right and left eyes in the WaveLight group, but the right eye flaps were significantly thicker than the left eye flaps in the Moria group. The central flap thickness of the

![Figure 2](image)

**Figure 2.** Comparison of flap thickness in the (A) 180°, (B) 45°, (C) 90°, and (D) 135° meridian between the WaveLight group (WaveLight GmbH, Erlangen, Germany) and the Moria group (Moria SA, Antony, France).

### TABLE 3

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>WaveLight Group (72 Eyes)</th>
<th>Moria Group (50 Eyes)</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central thickness (μm)</td>
<td>105.53 ± 5.86</td>
<td>132.96 ± 13.91</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Accuracy (μm)</td>
<td>6.17 ± 3.98</td>
<td>23.60 ± 12.64</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Reproducibility (μm)</td>
<td>5.86</td>
<td>13.91</td>
<td></td>
</tr>
<tr>
<td>Uniformity (μm)</td>
<td>4.07 ± 0.94</td>
<td>8.48 ± 2.35</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Symmetry (μm)</td>
<td>33.81 ± 11.28</td>
<td>68.46 ± 26.66</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Regularity (μm)</td>
<td>8.08 ± 1.91</td>
<td>14.28 ± 4.10</td>
<td>&lt; .001</td>
</tr>
</tbody>
</table>

*Independent sample t test.

The WaveLight femtosecond laser is manufactured by WaveLight GmbH, Erlangen, Germany, and the Moria microkeratome is manufactured by Moria SA, Antony, France.

![Figure 3](image)

**Figure 3.** Comparison of flap thickness at each eccentricity between the WaveLight group (WaveLight GmbH, Erlangen, Germany) and the Moria group (Moria SA, Antony, France). For the Moria flaps: P < .01 for 2 versus 0 mm, 3.5 versus 0 mm, and 2 versus 3.5 mm. For the WaveLight flaps: no statistically significant differences between different eccentricities.
Moria flaps was affected by the first use or the second use of the blade, which increased the uncertainty in the flap thickness.

The uniformity of the WaveLight flaps was evaluated in several ways in this study and showed exciting evidence of flap-dimension regularity. The small standard deviation of the 17 measured points in the individual flap indicated a general uniformity. Index S and index R evaluated the symmetry and regularity of the flaps. The WaveLight flaps also showed better results of index S and index R than the Moria flaps. The poorer uniformity results of the Moria flaps were probably due to the rotary mechanical blade causing different velocities at different radii. Our previous study was performed with the in vivo measurement of LASIK with a femtosecond laser and MEL 80 excimer laser platforms. The WaveLight flaps also showed better results of index S and index R than the Moria flaps. The WaveLight FS200 platform can release the air bubbles quickly through a canal during flap creation and complete the entire flap creation within 6 seconds. Therefore, it might have the potential to create more uniform flaps. Further comparison with other commercially available femtosecond lasers is warranted.

This study demonstrated that the WaveLight femtosecond laser-created corneal flaps with higher accuracy, reproducibility, and uniformity than the Moria microkeratome and comparable to or better than reported data from other femtosecond lasers. Further studies on clinical outcomes of the WaveLight femtosecond laser, such as contrast sensitivity and wavefront aberration, are warranted to fully evaluate this system.

AUTHOR CONTRIBUTIONS
Study concept and design (YC, YZ); data collection (YX, YZ); analysis and interpretation of data (YC); drafting of the manuscript (YZ); critical revision of the manuscript (YC, YX); statistical expertise (YX, YZ); administrative, technical, or material support (YC); supervision (YC)

REFERENCES