Analysis and improvement of surgeons' posture during ophthalmic microsurgery (part 2): Development of a chair with backrest for forward-inclined posture

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Abstract. A chair for ophthalmic surgeons was developed for the reduction of postural stress and improvement of surgical performance. The backrest consisted of rolls with different diameters that were designed for supporting the pelvis, sacrum, and lumbar spine; stabilizing forward-inclined posture in response to sustained small upper body movements; and inducing a postural reflex when the upper body touched the backrest slightly. The effects of the backrest on the pelvic tilt angle, pressure distribution, and contact ratio between the backrest and back of surgeon during microsurgery were evaluated. The results showed that the pelvic angle was almost in the correct sitting position, the maximum pressure on the backrest was a low pressure, and the contact ratio was above 80 %, which might contribute to the postural stability and the reduction of postural stress.

Keywords: ophthalmic microsurgery, forward-inclined posture, chair backrest

1. Background and objectives

The use of microscopes is common in ophthalmic surgery. On the basis of previous literatures, Noro et al. (2012) attributed an increased risk for musculoskeletal disorders in surgeons involved in microsurgery to the following characteristics: 1) sustained foot elevation while operating surgical equipment, 2) improper seat pans, which have an impact on a surgeon's thighs, 3) inadequate hand support during surgery, 4) an inability to recline or sustain pelvic support, 5) sustained neck flexion while using microscopes, and 6) a constrained posture over a long term. Such restrictive postural demands contribute to the development of musculoskeletal disorders.

On the basis of observations made in an operating room, Noro et al. (2012) reported that a surgeon's seat provides considerably less support to the buttocks than that commonly provided by a conventional seat. These seats cause surgeons to assume a perched posture, with their legs extended. They also lacks hand support while operating. Similar observations by Kondo et al. (2016) also confirmed a constrained posture over a long term and high pressure on the seat pan. In addition, it was confirmed that the use of a chair backrest is rare. This led to increased physical fatigue among surgeons, as confirmed through a questionnaire survey. A chair for ophthalmic surgeons was developed in an effort to help solve these problems. This paper focuses on the functions of a chair backrest and the results of ergonomic evaluation in an operating room.

2. Development of a chair backrest

2.1 Developmental policy

It is considered that factor of rare usage of backrest is the use of microscope. During the use of a microscope, the upper body is in an upright or forward-inclined posture and thus is not rested on the backrest. The need for a backrest may be low because a neutral position can be maintained in the upright or forward-inclined posture from the viewpoint of spinal alignment. However, the use of a backrest will be necessary considering long-term operation and reduction of postural stress. In addition, there is a possibility that a reflexive postural balance (posture reflex) may be induced when the upper body slightly touches the backrest. Backrest were developed to support the pelvis, sacrum, and lumbar spine and to help adapt to a forward-inclined posture. An adaptation for heads-up surgeries involving the use of a 3D display (Eckardt and Paulo 2016) was also considered.

2.2 Functions and Materials

A backrest composed of two rolls was developed (Figure 1). The lower roll supports the pelvis and sacrum, and the upper roll supports the lumbar spine. In collaboration with the orthopedic surgeons, radiography was performed to check the alignment between the surgeons' lumbar spine and pelvis and the backrest and determine the appropriate shape. The new feature of these backrests is that the diameter of each roll is different and they can be adjusted such that they can be positioned upside down (Figure 2). This was intended to adapt to the forward-inclined posture; for this purpose, the upper roll was large and the lower roll was small. This mechanism was intended to facilitate functionality for both conventional microscopic surgery and heads-up surgery. The adjustability of the height and depth of the backrest were intended to adapt to different human body size and shallow sitting.
The use of a conventional polyurethane foam with a large hysteresis loss became problematic. Thus, straw-type plastic with a low intending load and high impact resilience was used as the padding material in combination with a silicon cotton in both rolls. This was expected to induce a postural reflex when the upper body rested against the backrest slightly.

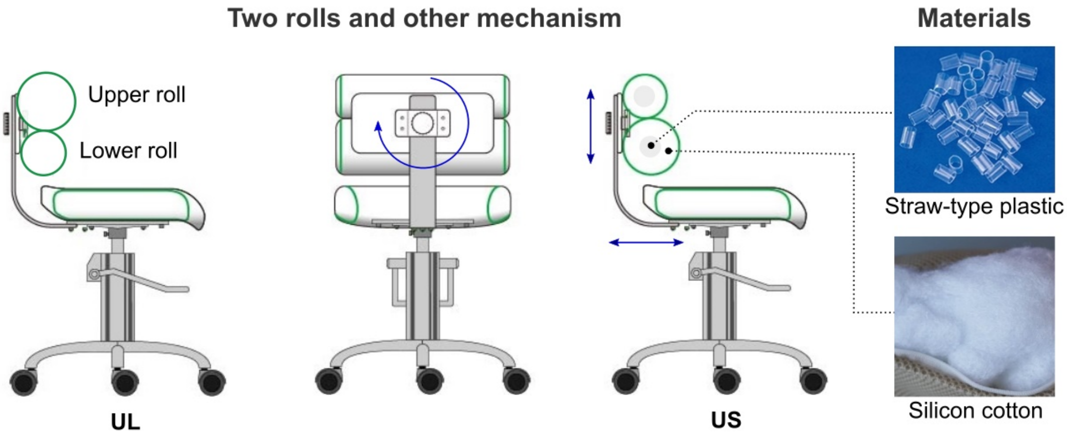

Figure 1. *Functions and materials of a backrest on chair for ophthalmic surgeons. UL: Combination of large upper roll and small lower roll. US: Combination of small upper roll and large lower roll.*

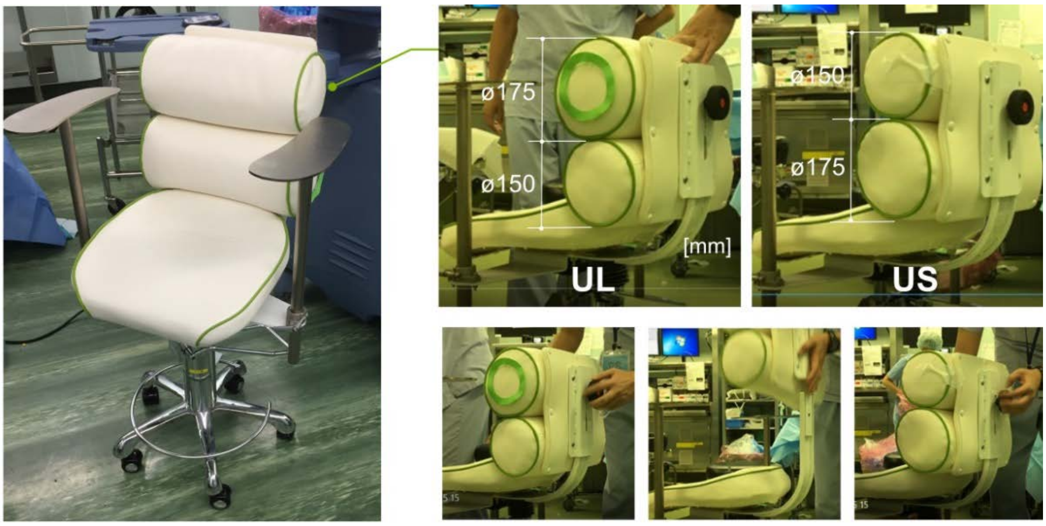

Figure 2.: *Upside down adjustment mechanism of two rolls*

3. Ergonomics evaluation

3.1 Methods

Evaluation of the backrest was conducted on five ophthalmic surgeons during a vitreous surgery in an operating room at the University of Environmental and Occupational Health, Japan. The surgery time was about 30-120 minutes. It was carried out with the approval of the ethics committee of the university.

Measurement items were pelvic tilt angle, pressure distributions, backrest-human contact conditions, and survey on the surgeons' opinions. Figure 3 shows each measurement device used during microsurgery. The pelvic tilt angle was measured by a gyroscope sensor that measured pelvic rotation with pitch and roll. The sensor was mounted on the iliac crest on the body surface under the surgical gowns. The relative value of the pelvic angle was calculated in a standing posture. In this paper, pitch angles relevant to forward pelvic tilt are assumed to take positive values. In the pressure distribution, maximum pressure, mean pressure, and contact area were measured using a pressure-sensing device (X-sensor, XSENSOR Co.). The backrest-human contact conditions were recorded using an electrical contact confirmation device (Dog's eye). The device was newly developed, as it was difficult to acquire valid data from a conventional pressure distribution sensing device because of the ultra-low pressure, and provided chronological records on the backrest-human body contact conditions. Thin aluminum tapes were attached to the backrest (A1: upper roll, A2: lower roll) and the human body (B1: lumbar spine, B2: behind the buttocks); then the contact states (A1-B1, A2-B2) were electrically detected as on/off and recorded in the PC via an A/D converter. The contact ratio was calculated by dividing the contact time to the operation time. The sampling frequency of each measurement item was 1 Hz and start times were synchronized.

The measurements were conducted under two backrest conditions, one with a large upper roll and small lower roll (UL) and the other with a small upper roll and large lower roll (US).

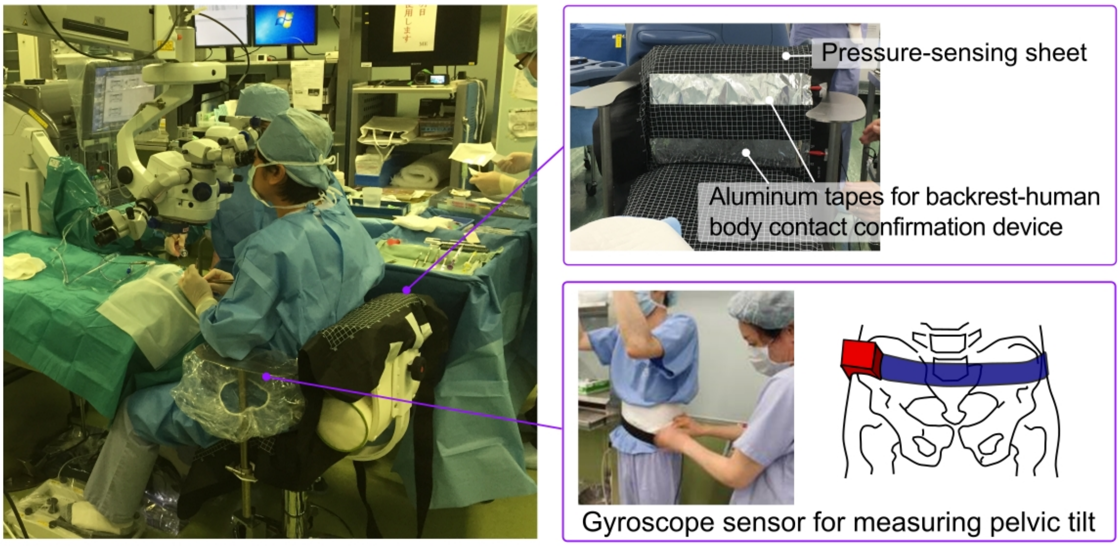

Figure 3. *Measurement of pelvic tilt, pressure distribution, and backrest-human contact conditions*

3.2 Results

Figure 4 shows the change in pelvic angle, maximum pressure on the backrest, and contact frequency between backrest and back of surgeon. Figures 5 shows the results of each measurement item for three surgeons under both conditions. The pelvic angle was -15.8±3.0° under the UL and -15.3±6.1° under the US condition. The maximum pressure on the backrest was 19.7±23.0 mmHg under the UL and 18.3±5.3 mmHg under the US condition. The contact ratio of the upper roll was 87.5±19.4% under the UL and 84.1±16.4 % under the US condition. The contact ratio of the lower roll was 75.1±23.7 % under the UL and 99.4±0.7 % under the US condition.

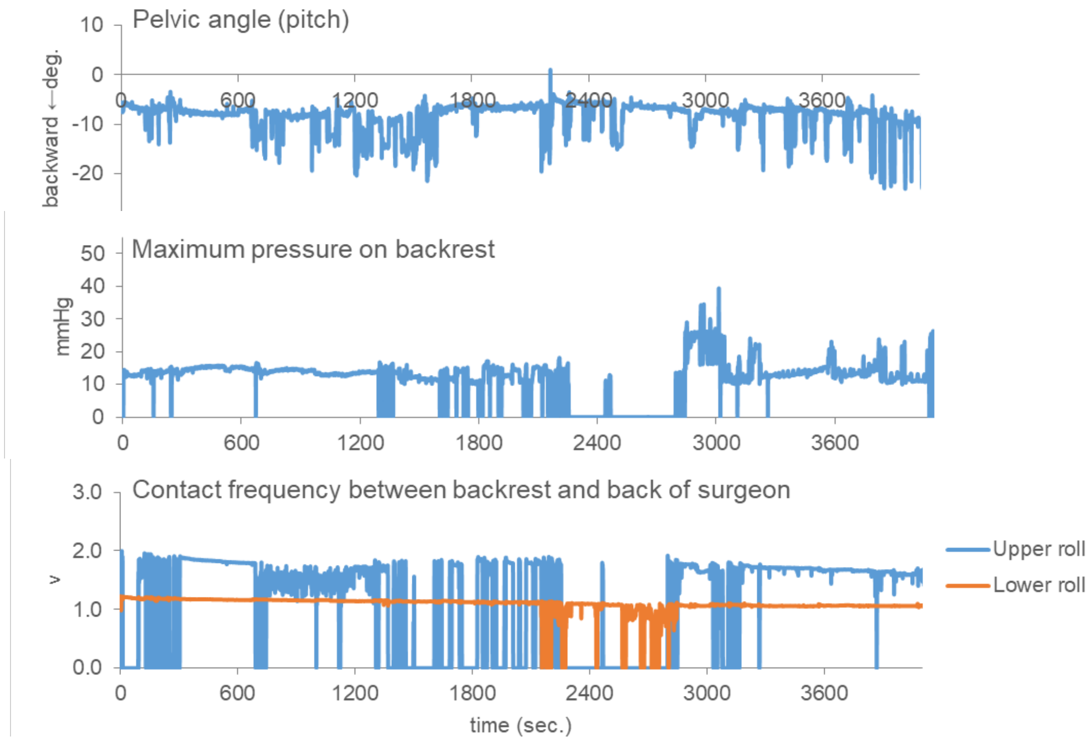

Figure 4. *An example of changed pelvic angle, maximum pressure on the backrest, and contact frequency between backrest and back of surgeon during ophthalmic microsurgery*

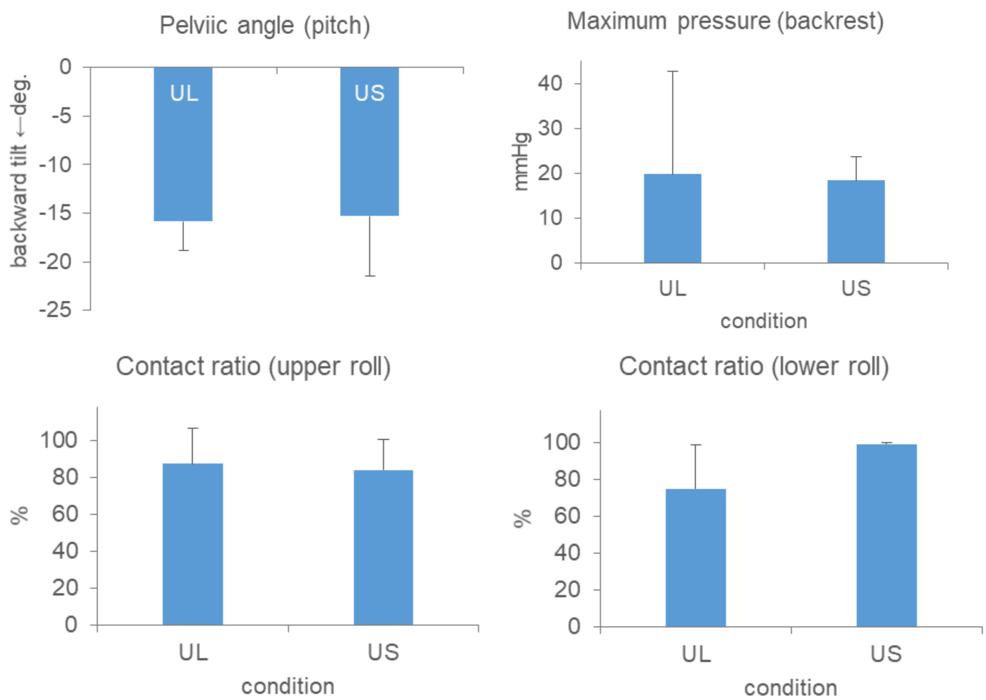

Figure 5. *The mean value ± SD of pelvic angle, maximum pressure on the backrest and contact ratio on the upper roll and the lower roll under two conditions*

3.3 Discussion

On the basis of the contact ratio, it was confirmed that the upper roll of the backrest was in contact with the lumbar under the UL condition and the lower roll was in contact with the back of the buttocks under the US condition, which might indicate the usefulness of the backrest. The results of the contact ratio supported the impressions of the surgeons' “feel to touching lumbar” and “feel to touching from buttocks to lumbar”.

In addition, It is considered that the wiggle on / off observed by the contact confirmation device in Figure 4 indicates the stimulation of postural reflex. The impression “feel to rest although not rest on the backrest” might show the postural reflex induced by the contact of the human body and backrest.

According to the research on the working posture of microsurgeons (Kondo et al. 2016), the average pelvic tilt angle during microsurgery was -13° (maximum of -7°, minimum of -15°) on a conventional medical chair that was maintained in the “correct” position, upright or forward-inclined, compared to that on a conventional chair. However, the backrest was not often used. In this research, the values of pelvic angle under both conditions were similar to that on using a conventional medical chair that was considered to be in the “correct” position. There was no obvious difference in the maximum pressure on the backrest under both conditions, and the pressure was low.

It was considered that the US condition was versatile because the average contact ratios of the upper and lower rolls were above 80 % and the variance was small. From the viewpoint of correspondence to individual differences, the UL condition might be suitable for a surgeon sitting with a forward-inclined posture, whereas the US condition might be suitable for a surgeon sitting upright, with a slightly backward-inclined posture, or conducting heads-up surgery using a 3D display.

With regard to the research limitations, a statistical analysis was not performed because the number of subjects was small. A study including a large number of subjects is necessary in the future. It is necessary to investigate the influence on surgical perfor-mance. As a measurement problem of the electrical contact confirmation device, it is necessary to devise for eliminate so-called false-positive that the human body does not contact the backrest even if the surgical gown contact the backrest.

4. Conclusion

The backrest made of two rolls of different diameters, which were mounted on the chair for ophthalmic surgeons. It was confirmed that the backrest can correct the posture of a surgeon during microsurgery, which might contribute to postural stability and a reduction in postural stress.

5. References

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