the tongue surface, dividing the tongue into different regions and excluding the tongue coating [4, 5]. Zhang et al. devised a system for tongue imaging and quantifying the tongue image information, considering both measurement values and the patient's past medical history [6]. Kanawong et al. compared the color value of tongue images with the patient's hot or cold condition [7]. In addition, they measured the RBG value of tongue images obtained in the same imaging environment and evaluated the tongue color quantitatively then used those data for early detection of diseases such as appendicitis and liver cancer [8, 9]. We first undertook research to standardize tongue diagnosis in 2008. As one of our research outcomes, we have been developing a new tongue imaging method and diagnostic support system (Tongue Image Analyzing System (TIAS)) for performing tongue diagnosis. The key characteristic of the tongue imaging method in TIAS is the exclusion of the influence of external light using an integrating sphere to achieve an evenly distributed light intensity with a halogen light source (Moritex Inc., MHAB-150W, color temperature 3200 K). Further, TIAS can remove the gloss of the tongue surface from its images. Our prior study investigated the use of spectral camera imaging [10]. We confirmed the relationships between the Kampo concept of *Oketsu* and both liver function and thyroid function in blood samples as measured by wavelength values [11–13]. Subsequently, in aiming to further promote TIAS, we changed from a spectral camera to a digital camera (Lumenera Inc., Lw115C, 1280 × 1024 pixels, Color CMOS sensor), although we are still using the basic data from the spectral camera. We changed because digital cameras are cheap and the color is superior for viewing purposes. For the quantitative measurement methods in TIAS, RGB values of digital camera images were converted into CIE1976 $L*a*b*$ color space values. Imaging by TIAS was confirmed to be stable for 3 weeks [14]. As mentioned above, our method has made it possible to perform stable quantitative measurement of tongue images by TIAS, and we have almost solved the problem of EF.

As far as we know, there are no other reports about subjective factors (SF) in TCD; the problem of SF has remained unclear. In tongue color diagnosis, age, gender, difference in color discrimination, and experience and knowledge in Kampo medicine are thought to be important influences. Thus, we set out to examine the influence of these factors. We studied the relation of age, gender, color discrimination, and duration of Kampo experience on TCD. One method to evaluate color discrimination is the Farnsworth-Munsell 100 Hue test (Hue test). The Hue test has been used for many years in industrial fields to check color discrimination. In various other fields, many studies on color discrimination have been reported using the Hue test. [15, 16]. The Hue test was evaluated for color discrimination of patients with optic neuritis in ophthalmology [17, 18]. And, the Hue test has been used by neuroscientists to study color discrimination and occipital lobe function in patients with Parkinson's disease and pituitary adenoma [19–21]. The Hue test was first devised by Farnsworth in 1943, and the present 85 colored-caps version was improved in 1957 [22]. The color caps are divided into four hues, and the 85 caps are arranged into four boxes, each containing a fixed anchor cap at both ends of each box. One box consists of 22 caps, and the other three boxes consist of 21 caps each. Color discrimination is evaluated when the subject attempts to arrange the caps into the correct hue order. The total Hue score is calculated by the number of misplacements. Thus, a lower Hue score indicates better color discrimination.

The purpose of this study was to reveal the SF involved in Kampo tongue diagnosis. We recorded data about age, gender, duration of Kampo experience, and primary occupations in Kampo medical practitioners. We evaluated color discrimination by the Hue test. Simultaneously, we examined the individual discrepancies in TCD using tongue images in which the color was adjusted by computer processing, and we studied the relationships of age, gender, color discrimination, and duration of Kampo experience with these results.

## 2. Subjects and Methods

*2.1. Subjects.* The subjects were 68 Kampo medical practitioners (48 males, 20 females). First, we questioned the subjects about their age, gender, duration of Kampo experience, and primary occupation. In order to maintain advanced color reproducibility, we had to exclude the influence of external light in the experimental environment. Thus, the experiments were conducted in a dark room (Figure 1). All subjects continuously performed the Hue test and TCD using tongue images.

*2.2. Hue Test.* We used artificial solar illumination (SERIC Inc., XC-19, 5500K) for the Farnsworth-Munsell 100 Hue test (SAKATA Inc., Farnsworth-Munsell 100 Hue test Munsell color) (Figure 2). The illumination was set on the ceiling of the darkroom, so that the angle of illumination could be about 90° and the angle of viewing could be about 60°. The subjects were ordered to rearrange the color caps of one color phase placed randomly in one slim-line box in correct order in two minutes. They performed this task on all four color phases; that is, they completed the Hue test. We calculated the Hue score according to the number of caps rearranged incorrectly compared with the correct orders of color phases. There were three levels of color discrimination ability: the superior-ability group (Hue score 0–16), normal-ability group (Hue score 20–100), and low-ability group (Hue score more than 100) [22]. In addition, we measured actual values of all the color caps in CIE 1976 $L*a*b*$ color space using the spectroradiometer (KONICA MINOLTA Inc., CS-1000A) in the experimental environment. The result shows that the tongue colors used in this experiment corresponded to those of color caps number 64–78 in CIE 1976 $L*a*b*$ color space (Figure 2). Therefore, we established a tongue color region (TCR) as the number 64–78 color caps region, and we also examined the relation between each influence factor and TCR.

*2.3. Tongue Color Diagnosis (TCD) of Tongue Images.* In creating the tongue color images, we used 1551 tongue images taken by TIAS. In order to determine the distribution of

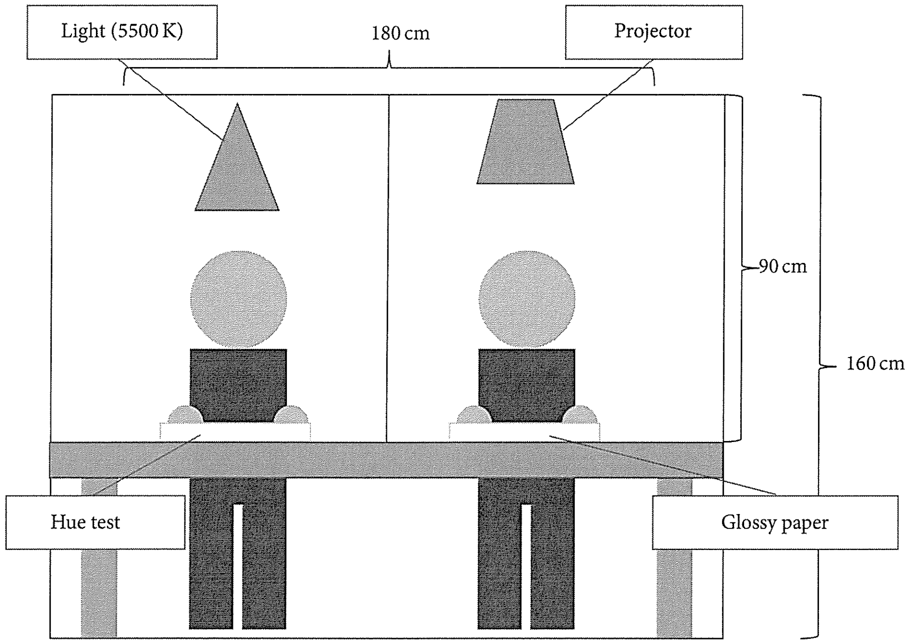



FIGURE 1: The experimental environment in this study. The experiments were conducted in a dark room with a single light source. For the Hue test, the light was positioned above so that the angle of illumination would be 90° and the angle of Hue test viewing would be approximately 60°. For the tongue color diagnosis, full-color tongue images were projected onto glossy paper by a projector.

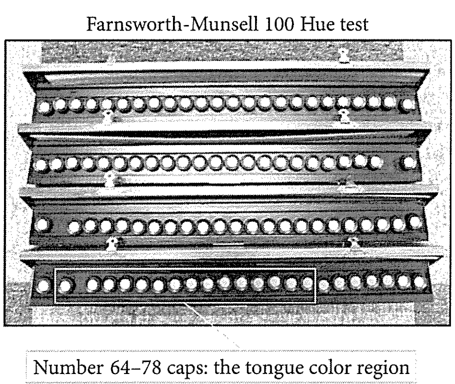



FIGURE 2: Color discrimination was evaluated by the Farnsworth-Munsell 100 Hue Test. The color discrimination is evaluated based on the subject's attempt to rearrange the caps into the correct hue order. Total Hue scores are calculated as the number of misplacements, and a lower score therefore indicates better color discrimination. The tongue color regions (TCRs) correspond to caps number 64–78.

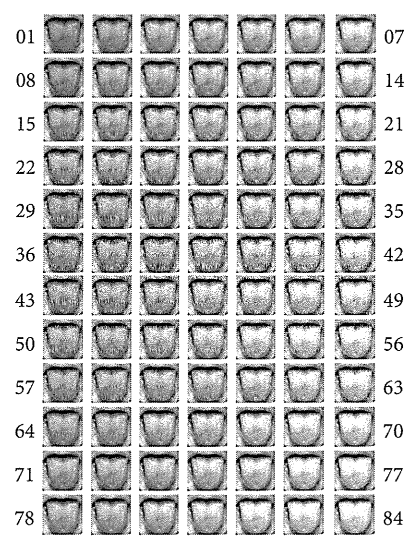



FIGURE 3: Tongue images 01–84.

the colors of the 1551 tongue images, we performed principal component analysis. By determining the color using principal component axes, it was possible to set the color gamut of the tongue without deviating far from the tongue color. The distance of the color becomes a constant interval by dividing the tongue color gamut into a 7 : 4 : 3 ratios and the 84 ($7 \times 4 \times 3$) tongue images were obtained from it (images 01–84: Figure 3). Furthermore, we measured actual values of the tongue colors on the tongue image color chart in CIE 1976 $L*a*b*$ color space in an experimental environment. The tongue color images were projected onto glossy paper by a projector (EPSON Inc., EB-1761W), and subjects were asked to diagnose the tongue color in each of the 84 tongue images. The color of the TCD was selected from among five designations: pale, pale red, red, crimson, and purple (Figure 4) [23].

*2.4. The Ethics and Statistical Analysis.* We obtained informed consent for this experiment from all subjects using descriptive text.

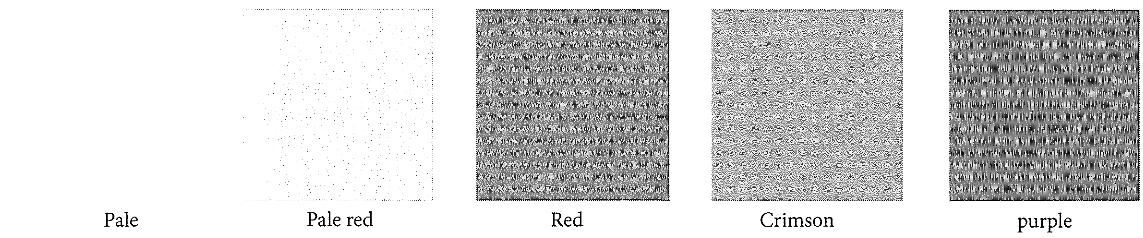



Figure 4: Tongue color diagnosis included five colors: pale, pale red, red, crimson, and purple.

Table 1: Comparison of duration of Kampo experience with subjects' age, gender, and occupation.

| | Duration of Kampo experience | | $P$ value |
|---|---|---|---|
| | <10 years | ≧10 years | |
| Age | | | |
| <43 years | 26 | 5 | 0.000** |
| ≥43 years | 9 | 28 | 0.001** |
| Gender | | | |
| Male | 19 | 29 | 0.099 |
| Female | 16 | 4 | 0.011* |
| Occupation | | | |
| M.D. | 22 | 30 | 0.186 |
| Not M.D. | 13 | 3 | 0.017* |

M.D.: medical doctor.
All $P$ values were obtained by $\chi^2$-test. $^*P < 0.05$, $^{**}P < 0.01$.

The data were analyzed by Student's $t$-test when they were assumed to be homoscedastic by the $F$-test. If the data could not be assumed to be homoscedastic by the $F$-test, they were analyzed by Welch's test. When the data were not consecutive variables, they were analyzed by the $\chi^2$-test. In each analysis, the significance level was set at less than 5%. We used the Pearson product-moment correlation coefficient.

## 3. Results

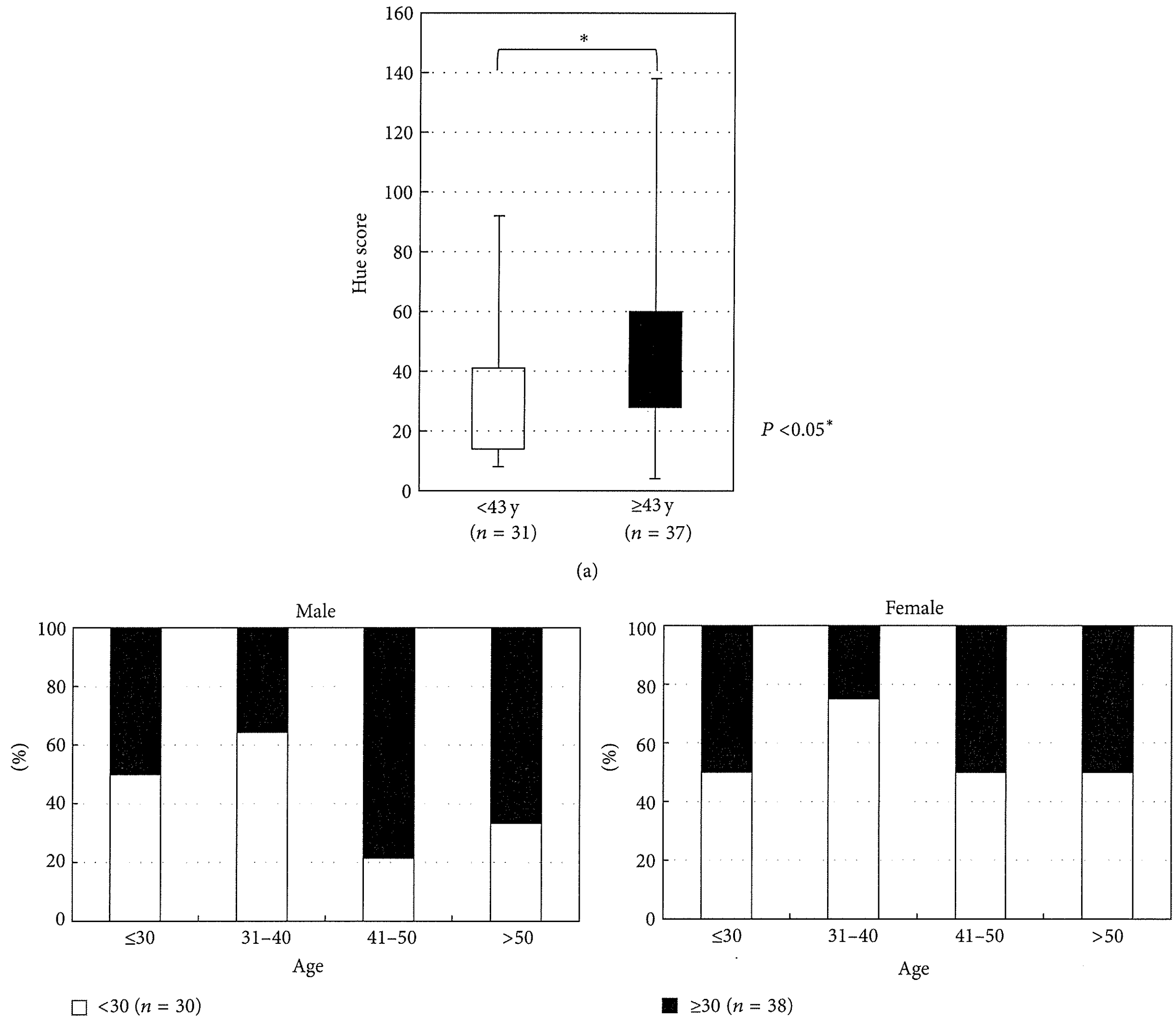
*3.1. Subjects.* In this study, we obtained data from 68 Kampo medical practitioners. Their ages ranged from 27 to 69. The average age was 44.3 ± 9.1 among all subjects, 45.9 ± 8.9 among males and 40.5 ± 8.4 among females; the median age was 43. The subjects' duration of Kampo medical experience averaged 12.1 ± 9.5 years, ranged from 1 to 40, and had a median value of 10. The subjects consisted of 52 medical doctors, 6 acupuncturists, and 10 pharmacists who made tongue diagnosis in daily operations (Table 1). There was a positive correlation between the ages and the duration of Kampo medical experience ($r$ = 0.753). There were fewer females than males in the age group ≥43 years and in the group with ≥10 years of Kampo medical experience.

*3.2. Hue Test Color Discrimination in the Entire Region and the Number 64–78 Region.* The entire region of Hue scores (EHS) ranged from 4 to 138, with an average of 39.2 ± 25.4 and median value of 30. There were 12 subjects with superior ability, 54 subjects with normal ability, and 2 subjects with low ability of color discrimination according to the Hue score. The Hue scores for the number 64–78 caps ranged from 0 to 36, with an average of 4.4 ± 6.6, and a median value of 2.

EHSs were analyzed in terms of age, gender, and duration of Kampo medical experience. The group of <43 years old ($n$ = 31) had a significantly lower EHS average (better color discrimination) than those ≥43 years old ($n$ = 37) ($t$-test, $P$ = 0.012) (Figure 5(a)). With regard to gender, there was no significant difference between the number of men and women in the groups with scores <30 and ≥30, stratified by age (Figure 5(b)). There was no significant difference between the rate of inexperienced (<10 years) and experienced (≥10 years) Kampo practitioners in the groups with scores of <30 ($n$ = 30) and ≥30 ($n$ = 38) stratified by age (Figure 6(a)).

The number 64–78 region of Hue scores (64–78 HS) was considered to correspond to the TCR. In the same way as described for EHSs above, 64–78 HS were analyzed with regard to age, gender, and duration of Kampo experience. No significant difference in the 64–78 HS between the age groups <43 years ($n$ = 31) and ≥43 years ($n$ = 37) was found ($t$-test, $P$ = 0.257). Analyzing the mean 64–78 HS for each gender in each age group, no significant difference was found between males and females. In terms of Kampo experience, we compared the ratios of experienced (≥10 years) and inexperienced (<10 years) Kampo practitioners in the group with 64–78 HS < 2 ($n$ = 33) and that with 64–78 HS ≥ 2 ($n$ = 35) (Figure 6(b)). A significant difference was found in the ratios in each score category between the two groups ($\chi^2$-test, $P$ < 0.01). In workers with <10 years of Kampo experience, age had a deleterious effect on color discrimination, with those >30 years old having a smaller ratio of good 64–78 HS scores (64–78 HS < 2). However, in the group with ≥10 years of Kampo experience, the ratio of 64–78 HS < 2 did not decrease. This tongue-color-specific region was the only one for which significant differences in color discrimination were found between workers with Kampo experience for <10 years and those with Kampo experience for ≥10 years; furthermore, in other color regions, Hue scores uniformly increased with aging.

*3.3. Tongue Color Diagnosis of Tongue Images.* We examined the total number of answers of each tongue color for TCD of the tongue images (images 1–84) projected onto glossy paper. The total number of answers was 5712 (84 images × 68 subjects). The cumulative numbers of answers of each tongue color were as follows: pale 1265, pale red 1536, red




(b)

FIGURE 5: (a) The <43 years group had significantly lower average Hue scores than the ≥43 years age group ($t$-test, $P = 0.012$). (b) The rate of subjects with Hue scores of <30 and ≥30 was compared between genders and separated by age. There were no significant differences between males and females.

1482, crimson 1142, and purple 287. For each tongue color we compared the answer distributions with regard to age, gender, color discrimination (EHS and 64–78 HS scores), and duration of Kampo experience. There were no significant differences between age, gender, and color discrimination abilities (EHS and 64–78 HS scores) for TCD of the tongue images. However, the distribution of TCD was significantly different between workers with <10 years of Kampo experience ($n = 35$) and those with ≥10 years of experience ($n = 33$) ($\chi^2$-test, $P < 0.01$) (Figure 7). Incidentally, there was no significant difference between other durations of Kampo experience. Further, we examined the relationship with TCD of the 64–78 HS groups and the duration of Kampo experience. TCDs were compared for the groups with 64–78 HS < 2 ($n = 18$) and 64–78 HS ≥ 2 ($n = 17$), first in the group with <10 years of Kampo experience, and then in the group with ≥10 years of Kampo experience (Figure 8). As a result, the distribution of TCD was significantly different between 64–78 HS < 2 and ≥2 in workers with <10 years of Kampo experience ($\chi^2$-test, $P < 0.01$), but not for with ≥ 10 years of Kampo experience.

## 4. Discussion

We studied the relationships between color discrimination on the one hand and age, gender, and duration of Kampo experience on the other. We found that overall color discrimination was associated with age but that the color discrimination of the tongue color region (TCR) was associated with duration of Kampo experience. Further, we found that duration of Kampo experience influenced TCD.

TCD and color discrimination measurement require high color reproducibility. The reason is that color is determined

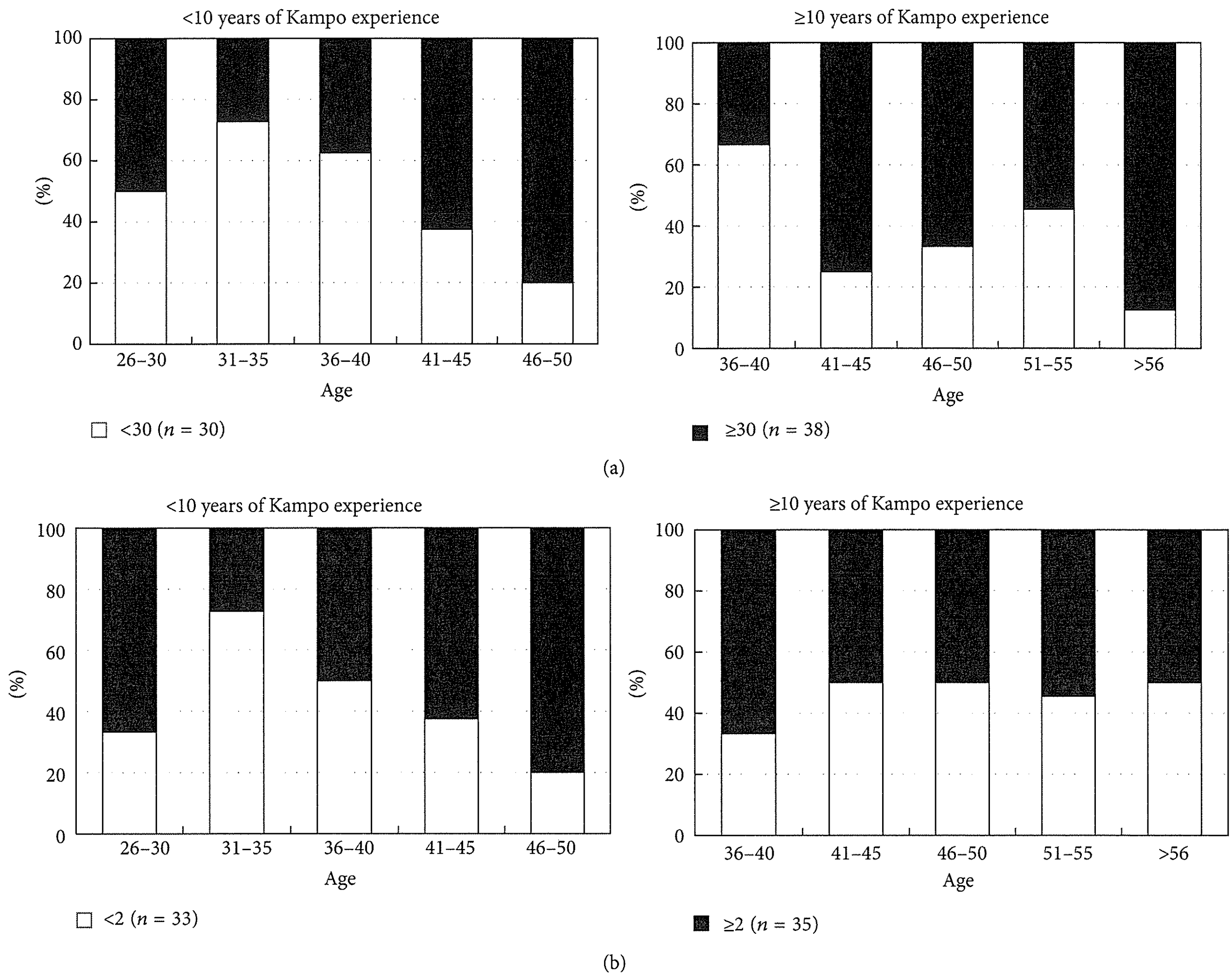



FIGURE 6: (a) The <10 years of Kampo experience group and ≥10 years of Kampo experience group were divided into EHS < 30 ($n = 30$) and EHS ≥ 30 ($n = 38$) in each age group. There was no significant relationship between Kampo experience and high/low EHS. (b) The <10 years of Kampo experience group and ≥10 years of Kampo experience group were divided into 64–78 HS < 2 ($n = 33$) and 64–78 HS ≥ 2 ($n = 35$) for each age group. A significant difference was observed in the 64–78 HS < 2 group between the <10 years and ≥10 years of experience groups ($\chi^2$-test, $P < 0.01$). The ages were higher in the ≥10 years of Kampo experience group, but the ratio of 64–78 HS < 2 did not decrease.

by both the illumination light source and the characteristics of the object. Hence, the settings of the illumination light source, the light source position, and the observation viewpoint are important in order to obtain an accurate representation of the color. Zahiruddin et al. compared two conditions for the Hue test, the conventional observation method and observation under ambient room light. They recognized that Hue scores differed in the two conditions [24]. In order to control the conditions, we followed the method of D. Farnsworth, in which the angle of illumination was vertical at 90° and the angle of Hue test viewing was about 60° in an otherwise dark room [22]. On the other hand, the human visual system has two modes of appearance of the color; that is, the two visual characteristics are the light source color mode and the object color mode [25]. Usually, we observe tongue color in the object color mode. Therefore, in this experiment, we observed the tongue color in the object color mode using a projector. The measurement value in CIE 1976 $L*a*b*$ color space had been preset using the color caps of Hue test and the tongue color images. However, as the color is affected by the experimental environment, we also measured actual values (CIE 1976 $L*a*b*$) in the experimental environment. We set a TCR that matched the color caps of the Hue test and the tongue color images in the actual measurement value. Number 64–78 caps from the Hue test were considered equivalent to the color of tongue diagnosis. The method used to identify the red-green or blue-yellow area in the Hue test has been described in previous reports [17, 26]. In this study, different results were obtained when the data of this restricted area of color were evaluated instead of the entire area of the Hue test.

In general, it has been reported that discrimination of colors represented by the entire Hue test region worsens with aging [27–29]. Similar results were observed in this study. In Kinnear and Sahraie, the average Hue scores decreased gradually to about 20 years of age, but after 20 the scores

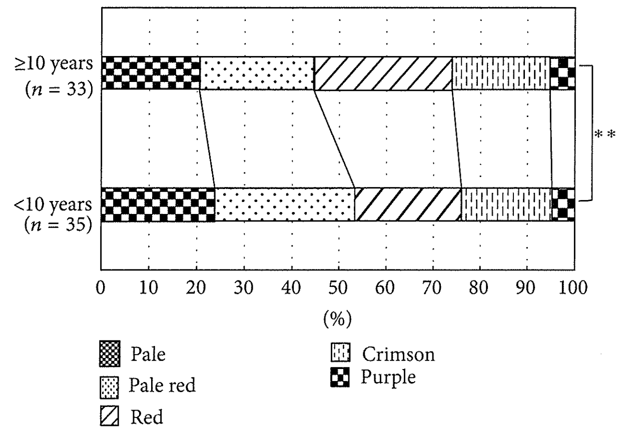



FIGURE 7: Comparison of TCD and duration of Kampo experience. The distribution of TCD showed a significant difference in the comparison of the <10 years and ≥10 years of Kampo experience groups. All $P$ values were obtained by $\chi^2$-test. $^*P < 0.05$, $^{**}P < 0.01$.

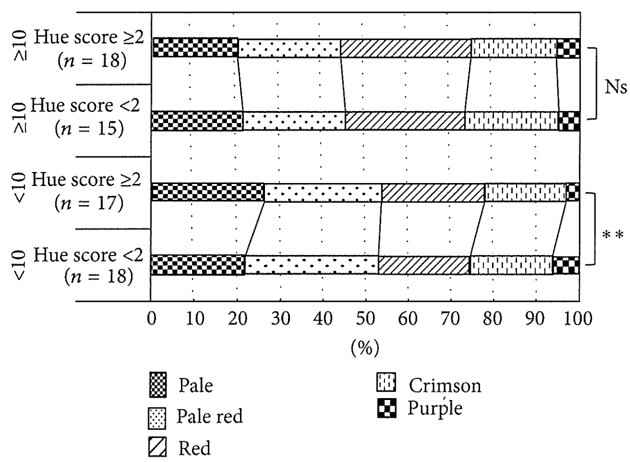



FIGURE 8: Comparison of TCD with 64–78 HS and duration of Kampo experience. The distribution of TCD was significantly different in the 64–78 HS < 2 and ≥2 groups within the <10 years of Kampo experience group. On the other hand, no significant difference was found in the ≥10 years of Kampo experience group. All $P$ values were obtained by $\chi^2$-test. $^*P < 0.05$, $^{**}P < 0.01$, Ns: no significance.

increased with aging (color discrimination worsened). The average Hue score was found to increase greatly at 50 years or more [27]. Roy et al. reported the same results [28, 29]. However, the average Hue scores in our study are lower than those in these previous reports. Likewise, the rate of increase of average Hue score for subject's ≥50 years in this study was lower than in these reports. We found an effect in this study whereby the color discrimination of the TCR does not suffer an age-related worsening in Kampo practitioners with ≥10 years of experience. We think this effect explains our results.

There was no significant difference in color discrimination by gender (Hue test entire region and TCR). Some reports have compared color discrimination by gender using the Hue test [26, 30]. Rigby et al. examined Hue test color discrimination by gender in pathologists [30] and found no significant difference between the scores of 23 males and 7 females in the 20–45 years age range. Moreover, Koçtekin et al. considered specific regions of Hue test in the dominant eye and the opposite side of eye of medical students [26]. The subjects were 31 males and 19 females whose mean age was 21 ± 2 years of age. Again, there was no significant difference between males and females in their study. Although the designs and purposes of these reports were different from those in this study, the results are consistent. Therefore, although the male-to-female ratio of this study was not 1 : 1, we think the effect of this bias is small.

In the TCD, no association was found between age, gender, and color discrimination (Hue test entire region and TCR). However, a significant difference in TCD was recognized between inexperienced (<10 years) and experienced (≥10 years) practitioners. Thus, an association was suggested between TCD and duration of Kampo experience. The inexperienced group tended to evaluate the pale-red area more broadly than the experienced group. Conversely, the experienced group tended to evaluate the pale and the pale-red areas more narrowly and to evaluate the red areas more broadly. Thus, there is a possibility that the ability to identify the pale-red area (normal tongue color area) is increased by gaining experience in Kampo medicine. We examined the TCD results by two factors, color discrimination of TCR and duration of Kampo experience. In the inexperienced practitioner group (<10 years), TCD results differed depending on the color discrimination of TCR. On the other hand, in the experienced group (≥10 years), TCD results were not affected by the color discrimination of TCR, but rather the TCD results became constant. Therefore, until having enough TCD, training of Kampo medicine may be needed for 10 years or more.

Actual clinical doctors diagnose tongue color independently. For this reason, we think this study is valuable because it involved the participation of many Kampo medical practitioners. Moreover, the finding that the TCD is affected by duration of Kampo experience is novel. Using this new finding, it may be possible to obtain more accurate results in the selection of tongue color diagnosis. We need to consider the duration of Kampo experience when judging tongue color findings. Further, in Kampo medicine education, age or color discrimination ability should not be considered a barrier, as experience and training can make up for these deficits. This study suggests the importance of TCD study, which we hope will progress in future. Finally, we believe this study can contribute to the standardization of tongue diagnosis in Kampo medicine.

## 5. Conclusions

Overall color discrimination worsened with aging, but the ability of tongue color diagnosis was not affected by aging or color discrimination ability. The ability of tongue color diagnosis and indeed ability to discern colors in the tongue color region do not degrade in those with Kampo experience. These results suggest the importance of studying tongue color diagnosis, and they are expected to contribute to the standardization of tongue diagnosis and Kampo medical education in the future.

## Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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論文

# 汎用CADによる風車ブレードの高精度3Dモデリング*

## Three-Dimensional Modeling with a High Accuracy for Wind Turbine Blades via the General Purpose CAD System

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Wind power has a great potential to be used as a renewable energy. As far as wind power turbines, the most common type is the horizontal axis wind turbine. The performance of the wind power turbine is controlled by the turbine design. If a three-dimensional model of the turbine blade with high accuracy is created by the general purpose CAD system, the model can be used for fluid dynamic simulations. Also, the CAM system can assist to machine the rib or the blade of the turbine by using the three-dimensional model. In this paper, a three-dimensional modeling method for the turbine blade is investigated in the general purpose CAD system. From the results, it has been confirmed that the model of the turbine blade with high accuracy can be created by adjusting the positions of the section profiles consisting of B-splines and using the loft function.

***Key Words***: Wind turbine, CAD system, B-spline, Loft surface, Three-dimensional model

## 1. はじめに

東日本大震災後，国内の電力供給に関する考え方は大きく変わってきている．福島第1原子力発電所の事故が収束していない福島県では，2040年頃を目途に，県内のエネルギ需要量の100%以上を再生可能エネルギで生み出すという目標を掲げている[1]．

再生可能エネルギの比率を高めるためには，様々な方式を取り入れる必要があり[2]，その有望な方式の一つが風力発電である．中でも小型の風力発電は，設置場所に制約が少なく，導入しやすい条件を揃えている．風力発電の風車の形式としては，水平軸のプロペラ形が最も一般的であり，その発電効率を左右する主要部品として風車のブレードがあげられる．

設計した風車のブレードの詳細な3次元形状を，正確に3DCADシステムに取り込むことができれば，ブレードや風車の性能をCAEシステムによって，製造する前に評価することができる[3),4]．また，ブレードの3DモデルをCAMシステムへ渡すことによって，専用のCAMシステムを用いずにリブの製造を行うことや，軽量な素材でブレード全体を削り出すことも可能となる．現在，ブレードを3Dモデルにする場合，STL (Stereolithography) ファイル[5]を用いる方法が考えられるが，滑らかな翼面を表現するには最適であるとは言い難い．このような3Dモデルの最適な作成方法の導出は，実務的な課題であるが，設計及び製造現場を支援する上で非常に重要であると考えられる．

そこで，本研究では，汎用の3DCADシステムが有する一般的な機能を用いて，風力発電用風車のブレードの3Dモデルを，高精度を保ちつつデータ量を抑えて，簡便に作成する方法を明らかにすることを目的とする．

## 2. 風車ブレードの設計方法

### 2.1 NACA 4-Digit

風力発電用風車のブレードを設計する場合，はじめにブレード断面の翼型を決定する必要がある．翼型には，Clark Y, FX, NACA型など様々な形式のものがあるが[6]，ここでは代表的なNACA 4-Digit[7]を翼型として用いることにする．

NACA 4-Digitは，4桁の数字から翼型の平面上での座標を算出することができる．図1にNACA 4-Digitの翼型を表わすパラメータを示す[7]．1桁目は，図中の最大キャンバの $m$，2桁目は最大キャンバ位置の $p$，3桁目と4桁目は最大翼厚比の $t$ を表わして

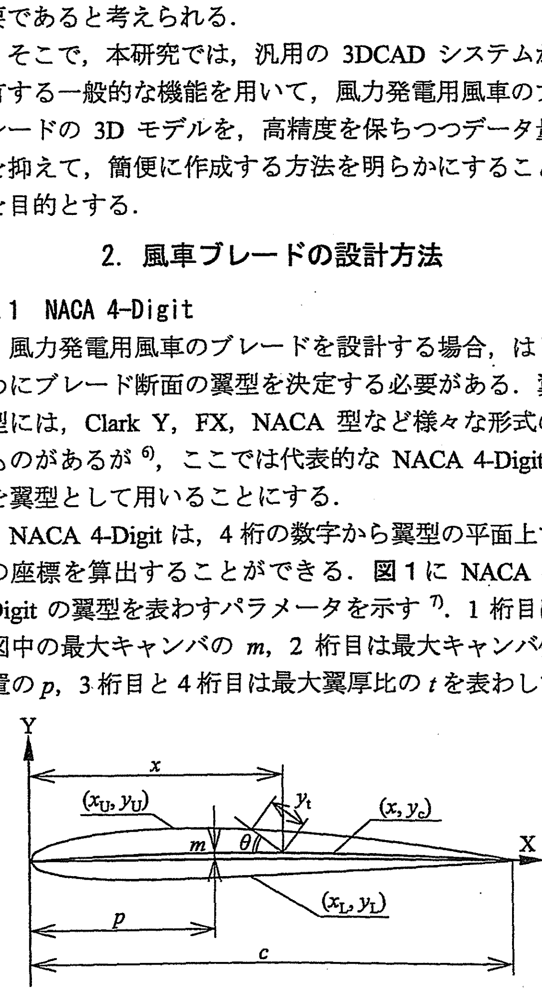


**Fig. 1** Parameters in NACA 4 digit airfoil

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いる．なお，4 桁の数字は，翼弦長 $c$ に対する比率であるため，例えば，NACA4412 の場合は，最大キャンバ $m$ =4 %，最大キャンバ位置 $p$ =40 %，最大翼厚比 $t$=12 %を意味している．

ここで，翼厚分布は，次の式(1)で求めることができる．

$$\pm y_t = \frac{t}{0.2}(0.2969\sqrt{x} - 0.1260x - 0.3516x^2 + 0.2843x^3 - 0.1015x^4) \quad (1)$$

キャンバ平均ラインは次の式(2)(3)で求めることができる．

$$y_c = \frac{m}{p^2}(2px - x^2) \qquad 0 < x < p \quad (2)$$

$$y_c = \frac{m}{(1-p)^2}\left[(1-2p) + 2px - x^2\right] \qquad p < x < c \quad (3)$$

これらの式に，任意の $x$ を代入すると，翼厚分布，キャンバ平均ラインが算出できる．さらに，角度 $\theta$ を式(4)のように定義すると，任意の $x$ に対する翼型上面の X 座標は式(5)，Y 座標は式(6)，下面の X 座標は式(7)，Y 座標は式(8)によって求められる．

$$\theta = \tan^{-1}\left(\frac{dy_c}{dx}\right) \quad (4)$$

$$x_U = x - y_t \sin\theta \quad (5)$$

$$y_U = y_c + y_t \cos\theta \quad (6)$$

$$x_L = x + y_t \sin\theta \quad (7)$$

$$y_L = y_c - y_t \cos\theta \quad (8)$$

ここで，実際に式(1)～(8)によって算出した翼型の座標を直線で結ぶと，上面と下面の後縁が一致しない．そのため，後縁が一致するように，式(1)の 5 項目の $x^4$ の係数を－0.1015 から－0.1036 へ変更した次の修正式(9)を用いる．

$$\pm y_t = \frac{t}{0.2}(0.2969\sqrt{x} - 0.1260x - 0.3516x^2 + 0.2843x^3 - 0.1036x^4) \quad (9)$$

### 2.2 翼素運動量複合理論を基にした設計

風車のブレードの代表的な設計方法として，翼素理論によるもの [6] と翼素運動量複合理論を基にしたもの [8] がある．汎用 CAD システムを用いて設計を行うためには，ブレード表面の 3 次元座標が容易に算出できることが望ましい．そこで，本研究では，ブレードの各断面の翼型の大きさと姿勢とを決定するパラメータが算出できる翼素運動量複合理論を基にした設計方法を採用する．

翼素運動量複合理論を基にした設計では，翼型データ，ブレード半径 $R$，ブレードの枚数 $B$，周速比 $\lambda$，最適迎角 $\alpha$ 及び揚力係数 $C_L$ を風車の設置環境に合わせて決定する．これらのパラメータを基にして，ブレードの断面形状を決定するために，局所周速比 $\lambda_r$ を算出する．局所周速比 $\lambda_r$ は，任意の位置を局所ブレード半径 $r$ として，ブレードの中心からの距離で表すと，次の式(10)で表すことができる．

$$\lambda_r = \lambda\frac{r}{R} \quad (10)$$

この局所周速比 $\lambda$r を式(11)に代入することで局所流入角 $\phi_r$ は求められる．

$$\phi_r = \frac{2}{3}\tan^{-1}\left(\frac{1}{\lambda_r}\right) \quad (11)$$

さらに，この局所流入角を式(12)に代入すると局所取付角 $\beta_r$ が算出できる．また局所翼弦長 $C_r$ は局所ブレード半径 $r$，局所流入角 $\phi_r$，揚力係数 $C_L$，ブレード枚数 $B$ を式(13)に代入することで求められる．

$$\beta_r = \phi_r - \alpha \quad (12)$$

$$C_r = \frac{8\pi r}{BC_L}(1 - \cos\phi_r) \quad (13)$$

任意の位置でのブレードの断面形状は，**図 2** に示すように，最大キャンバ位置において，局所翼弦長 $C_r$ の翼型を局所取付角 $\beta_r$ に傾けたものである．そのため，任意の位置でブレードの断面は，以下の手順で算出できる．

手順① 翼弦長を $C$ として，式(1)～(9)を用いて基準となる翼型の座標を算出する．

手順② 最大キャンバ位置を中心に，手順①で求めた翼型を局所取付角 $\beta_r$ だけ回転させる．

手順③ 手順②の回転中心を基準に，翼弦長 $C$ と局所翼弦長 $C_r$ との比率から，$C_r$ に合わせて翼型の大きさを変更する．

この手順を繰り返し，ブレードの全断面の形状を算出することでブレードの形状を詳細に決定できる．

## 3. 近似翼型の精度

### 3.1 設計条件

汎用 CAD を用いてブレードを設計し，作成した 3D モデルの精度を評価するために，例として**表 1** のような設計条件で小型の風力発電用風車のブレードを設計することとした．

**表 1** の設計条件では，ブレード半径 $R$ を 0.45m，ブレードの枚数 $B$ は一般的な 3 枚とした．周速比 $\lambda$ は風の強い地域を想定して 6，揚力係数 $C_L$ を 0.85，そこから最適迎角 $\alpha$ は 4° とした．また，ブレード半径の中心から 10%まではハブ部として，10%から 100%までをブレードとした．この設計条件の場合，最も大きな局所翼弦長はブレード半径の 10%の位置で約 100mm となる．ブレードはブレード半径の中心から 50%付近まで翼弦長を直線的に変化するように線形化する場合もあるが，本研究では，より翼弦長の変化が大きい線形化を行わない設計を採用した．

本研究では，ブレードの断面形状の作図には，AutoCAD 2013 を用い，ブレードの 3D モデルの作成には，AutoDesk Inventor 2013 を使用した．作図した形状や 3D モデルの精度については，CAD システムで計測して評価した．

**Table 1** Design conditions

| | |
|---|---|
| Airfoil profile | NACA2415<br>NACA4412 |
| Radius of blade $R$ | 0.45 m |
| Number of blades $B$ | 3 |
| Tip speed ratio $\lambda$ | 6 |
| Lift coefficient $C_L$ | 0.85 |
| Angle of attack $\alpha$ | 4 ° |

### 3.2 微小線分による近似とスプライン曲線

表１の設計条件にしたがって，ブレードの 3D モデルを作成する場合，はじめに 2 次元平面に翼型をどのように作図するかが問題となる．式(2)〜(9)によって翼型の座標は算出できるため，それを基にスプライン曲線又は微小線分による近似で翼型を描くことができる．どちらの場合にしろ基準となる翼型の座標を増やせば，理想的な設計形状に近づくが，座標をむやみに増やせば，CAD システムから制限を受け，作図や表示の円滑さが妨げられてしまう．

そこで，表１の設計条件の場合，局所翼弦長は，最大で約 100mm であるため，NACA2415 の翼型について，100mm を代表翼弦長 $C$ とした場合に，式(2)〜(9)によって算出される座標の特徴を調べた．算出した座標は代表翼弦長に対する百分率で表した．

図３(a)に示すように，任意の $x_n$ に対して算出した上面の点と $x_{n-1}$ に対して算出した上面の点との距離を $D_{un}$，下面の算出点間の距離を $D_{ln}$，$x_n$ と $x_{n-1}$ との差を $L_x$ と置く．この $L_x$ を小さくし，座標の算出点の数を増やした場合の算出点間の距離 $D_{un}$，$D_{ln}$ と算出点の数 $n$ との関係を図３(b)に示す．図から算出点間の距離 $D_{un}$，$D_{ln}$ は一定にはならないことがわかる．いずれも翼型の前縁部で $D_u$ が大きくなっており，それ以外では，ほぼ一定の値をとっている．

ここで，翼型の前縁部は風車の性能に影響を及ぼすため，詳細に設計形状と算出される座標との関係を調べた．設計形状と算出点の数を変更した場合の翼型の座標を図４に示す．図では算出点間を凡例のように直線で結び，$L_x$=0.001％として算出した点と点とを直線で結んだものを設計形状としている．翼型全体の算出点の数 $j$ を 2000 と増やした $L_x$=0.1％の場合においても，原点から上面の 1 番目の算出点までの距離は，0.7％程度までしか小さくならない．この部分を拡大すると，設計形状は，$x$ の負側にわずかにはみ出しているが，微小線分で近似した場合には，その特徴を表わせていない．近似による誤差を

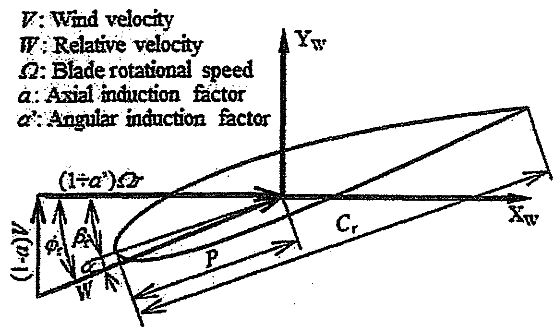
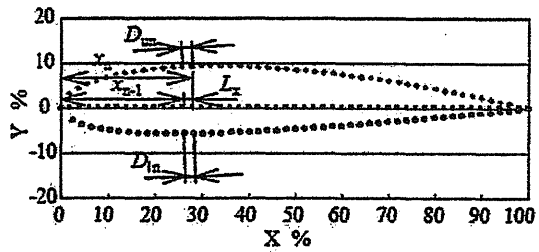
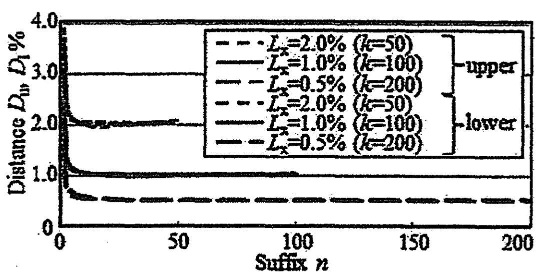



Fig. 2 Airfoil section profile, setting angle $\beta_r$, angle of attack $\alpha$ and maximum camber $P$




(a) Definition of $L_x$, $D_u$ and $D_l$




(b) Relationship between number of coordinates and distance $D_u$, $D_l$

Fig. 3 Distance between coordinates of NACA2415

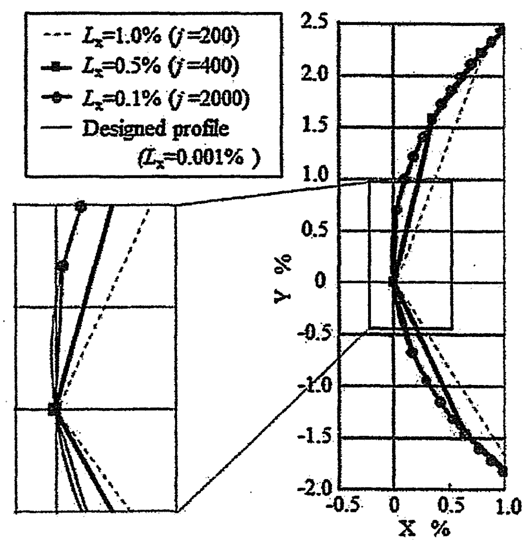



Fig. 4 Detailed profiles of airfoil leading-edge in NACA2415

調べると，設計形状から最大で 0.0253％くるうことがわかった．そこで，3 次の B-スプライン曲線を作成したところ，全体の算出点の数 $j$ = 200 では，設計形状との誤差は 0.0178％，$j$=400 では，0.0055％と

なり，NACA4-Digit の翼型の前縁部の形状の特徴も作図できることが確認できた．このように B-スプラインは接続性がよいため，算出点より滑らかな曲線を生み出せることから，翼型を描くのに適している．

### 3.3 算出点間隔がスプライン曲線による翼型の精度に及ぼす影響

3 次の B-スプライン曲線によって翼型の前縁部の形状の特徴を作図できることがわかったが，算出点間の距離をその他の部分と同じにできれば，より少ない算出点の数で精度よく設計形状が描ける可能性がある．そこで，あらかじめ多数の座標を算出し，その中から，算出点間の距離 $D$ が一定となる座標を抽出した．

NACA2415 の翼型を，算出点間の距離を一定にした座標に対して 3 次の B-スプライン曲線で描いた結果を図５に示す．ここでは，翼型全体について，10 億点の座標を算出した．算出点間の距離 $D$ を代表翼弦長の 10%とした場合には，設計形状との差は大きいものの，$D$=1.0%とし，全体の算出点の数を $j$=206 とした場合には，ほぼ設計形状と一致している．この場合，設計形状との誤差を調べると 0.001%になっており，代表翼弦長 $C$=100mm に対して誤差 1μm に相当する高い精度で翼型が描けていることがわかる．また，$D$=0.1%，$j$=2059 の場合には，誤差は 0.0001%まで小さくなる．

このように翼型の算出点間隔を一定にとり，その座標を用いて，3 次の B-スプライン曲線を作成することによって，より少ない点数で翼型を精度よく作図することができる．なお，NACA2415 を例に挙げたが，NACA4412 においても同様な結果が得られた．

## 4. 風車ブレードの 3D モデルの精度

### 4.1 3D モデルの作成手順

2.2 で述べたように，設計するブレードは，ブレード中心からの距離である局所ブレード半径 $r$ に対して，式(2)～(13)によって，断面の形状が決まる．そのため，理論上は，$r$ を連続的に変化させて，全ての断面形状を求め，それをつなぎ合わせたものがブレードとなる．

ここでは，最小限の数の断面を用いて 3DCAD システムのロフト機能によって，高精度なブレードの 3D モデルを作成する方法を検討する．ブレードの 3D モデルの作成は，次の手順で行う．

手順① 3 次元空間において，ブレードの中心から先端まで，どの位置に断面形状を配置するかを決定する．

手順② 図６に示すように，①で決定した位置へ，ブレードの断面形状を，算出点間を一定とし，3 次の B-スプライン曲線で表す方法によって作図して，配置する．

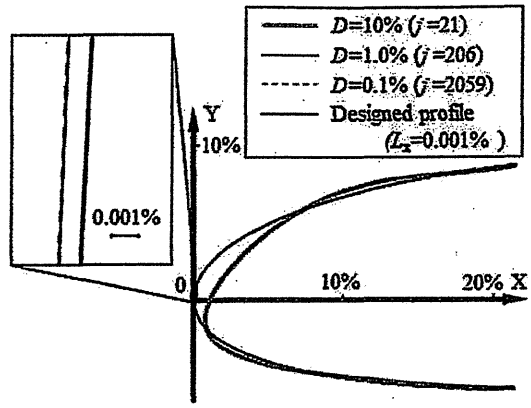


Fig. 5 Airfoil profiles by using spline curve in NACA 2415

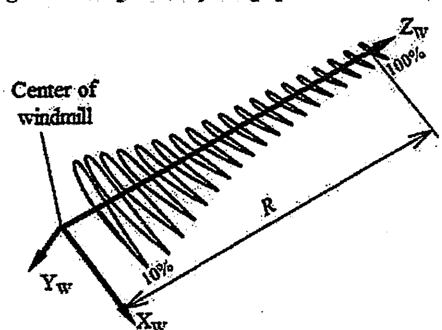


Fig. 6 Airfoil section profiles used for loft function in three-dimensional CAD

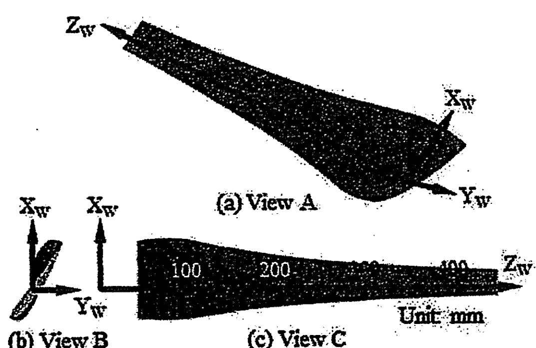


Fig. 7 Three-dimensional model using NACA4412 airfoil

手順③ ロフト機能を使い，配置された断面形状を全て選択して，各断面の重みづけは行わずに，その間を滑らかに遷移させることで，ブレードの 3D モデルを作成する．

なお，ロフト機能については，一般的な 3DCAD システムが有する機能である．本研究では，手順②において AutoCAD 2013 で作図した断面形状を，AutoDesk Inventor 2013 へ取り込んだが，使用する各 3DCAD システムに相応しい方法が存在する．

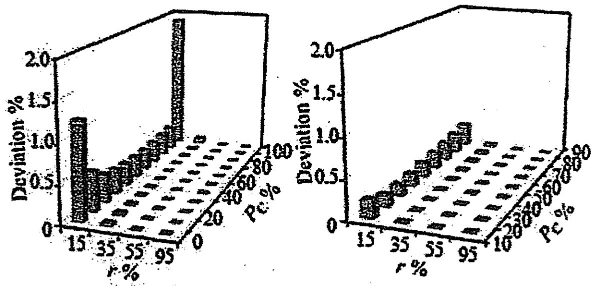
### 4.2 断面形状の配置と 3D モデルの精度との関係

表１の設計条件で，ブレードの断面形状を，ブレードの中心からブレード半径 $R$ の 10%離れた位置より，10%ごとに 100%まで配置して，NACA4412

とNACA2415の翼型の2種類の3Dモデルを作成した．目標とする形状精度は，一般的な機械部品に適用される公差[9]が代表翼弦長100mmに対して精級で±150μmであることから，その1/10以下の10μm（代表翼弦長の0.01%）とする．そのため，ロフト機能に使用する断面形状は，図5に示したような約210点の座標を用いた3次のB-スプライン曲線で作図した．この設計条件で各断面形状と設計形状との誤差は，代表翼弦長 $C$=100mm の0.001%の1μm以下となった．作成した3Dモデルの内，NACA4412の3Dモデルを図7に示す．ロフト機能を使用することによって，ブレードの中心に近い，ねじれが大きな部分も滑らかな面が作成されていることがわかる．NACA2415についても同様に滑らかな面をもったブレードが作成できた．

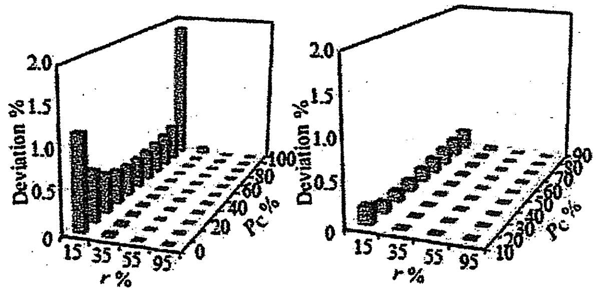
そこで，この2種類に加えて，代表的な6種類の翼型NACA0012, NACA2212, NACA2412, NACA4312, NACA4415, NACA4418を用いたブレードの3Dモデルを作成し，設計形状からの誤差を調べた．NACA2415の結果を図8に，誤差が最大となったNACA4418の結果を図9に示す．評価は，ロフト機能で使用した断面が存在しない局所ブレード半径 $r$ において，ブレードを切断し，その断面形状へ図10に示した20か所の点から接する円を描き，円の半径を測定することで誤差を求めた．この測定位置は，前縁からの距離 $P_C$ を局所翼弦長 $C_r$ に対する百分率で表し，翼型の上面と下面とに分け，0%と100%は，上面に含めた．局所ブレード半径 $r$ は，ブレードの中心からブレード半径 $R$ に対する百分率で表した．誤差は，代表翼弦長 $C$ に対する百分率で表した．どちらも $r$=15%で誤差が大きく表れている．NACA2415とNACA4418を例に挙げたが，他の翼型でも同様な誤差分布となった．そこで，8種類の中で最も誤差の合計が大きいNACA4418について，誤差を小さくする方法を検討した．

はじめにロフト機能に使用する断面の数を2倍に増やした場合の3Dモデルの誤差を調べた．その結果を図11に示す．誤差の現れる部分はさほど変わらないが，断面の数を増やしたことで，誤差の大きさが約15分の1に減少している．さらに断面を増やせば，3Dモデルの精度は高くなるが，この断面の数で最適な配置を検討する．図8，9及び11のいずれにおいても，ブレード中心に近い位置で，誤差が大きくなっている．3Dモデルを見ると，この部分でブレードのねじれが最も大きく見えるため，ブレードのねじれを表す局所取付角，局所翼弦長の変化を調べた．その結果を図12に示す．ブレード中心に近い $r$=30%までのところで，局所取付角だけ




(a) Upper surface (b) Lower surface

Fig. 8 Errors of three-dimensional model of NACA2415, Number of sections : 10




(a) Upper surface (b) Lower surface

Fig. 9 Errors of three-dimensional model of NACA4418, Number of sections : 10

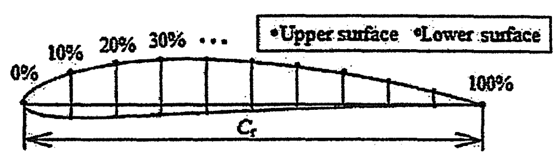
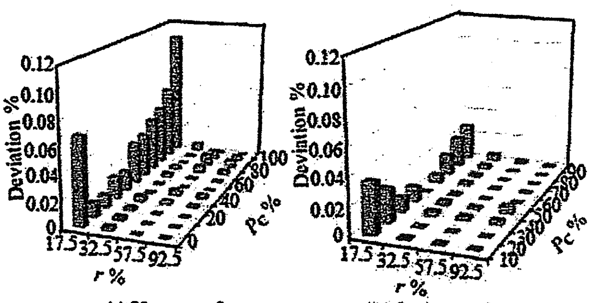



Fig. 10 Position of measurement points




(a) Upper surface (b) Lower surface

Fig. 11 Errors of three-dimensional model NACA4418, Number of sections : 19

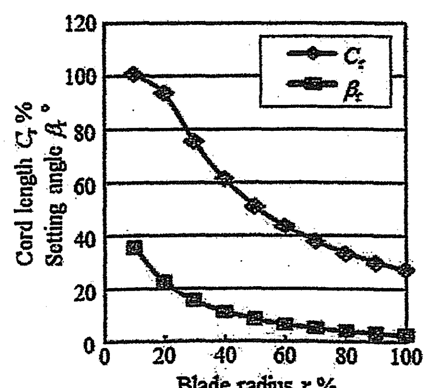
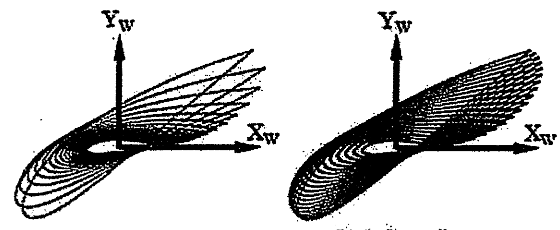



Fig. 12 Relationships between $r$ and $C_r$, $\beta_r$

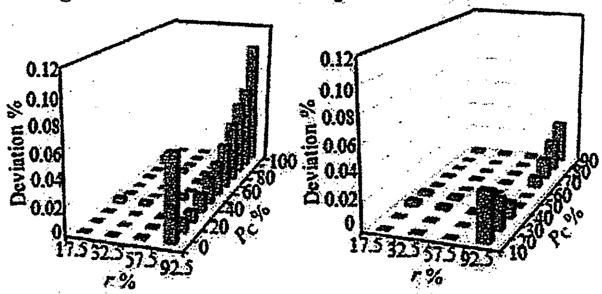
でなく，局所翼弦長も大きく変化している．しかし，ロフト機能に使用する断面は，ブレードの中心からの先端まで均等に配置されているため，図 13(a)のように，ブレードの中心から見た断面の形状の変化は，一定にならない．そこで，局所取付角に注目し，図 13(b)に示すように，その角度の変化が一定となるように修正して，再度 NACA4418 の 3D モデルを作成した．その 3D モデルの誤差を図 14 に示す．ブレード中心に近い部分の誤差は，非常に小さくなっている．しかし，ブレード先端では，修正前のブレード中心近くと同程度の誤差が表れている．修正後の断面の配置を見ると，図 15 に示すように，ブレード先端の部分で，$R$ の 23.02%の区間に断面が存在しない．この区間長さ 103.59mm と先端でない方の断面の局所翼弦長 $C_r$ との関係を調べると，区間長さは $C_r$ の 301%となっており，この比率が 150%であれば，誤差は約 0.01%になることがわかった．そこで，比率が 150%以下となるように，この区間の中央の $r$ =88.49%の位置に断面を配置し，ブレードの 3D モデルを作成した．その 3D モデルの誤差を図 16 に示す．その結果，3D モデルの誤差に大きな偏りは見られず，上面で最大 0.012%，下面で最大 0.005%の誤差で 3D モデルが作成できた．

さらに，この断面の配置で，その他の 7 種類の翼型についても，同等の精度で 3D モデルが作成できることを確認した．目標とした形状精度の代表翼弦長 $C$ の 0.01%には，わずかに達しないものの，この精度の 3D モデルがあれば，CAM システムに読み込み，NC 工作機械でブレードのリブなどを高精度に加工することを支援できると考えられる．



(a) Before adjustment　　(b) After adjustment

Fig. 13 View of airfoil section profiles from Z direction



(a) Upper surface　　(b) Lower surface

Fig. 14 Errors of three-dimensional model NACA4418, Difference of $\beta_r$ : constant, Number of sections : 19

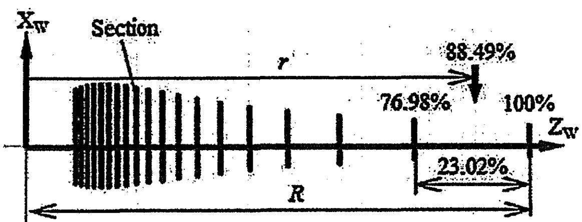
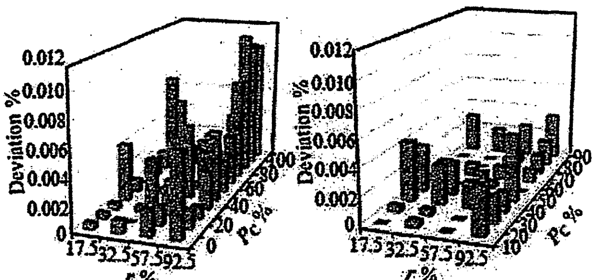



Fig. 15 Position of airfoil section profiles when difference of $\beta_r$ is constant



(a) Upper surface　　(b) Lower surface

Fig. 16 Errors of three-dimensional model NACA4418, Number of sections : 20

## 5. おわりに

3DCAD システムを使用して，NACA4-Digit の翼型を使用した風力発電用風車ブレードの 3D モデルを，高精度に，より少ないデータ量で作成する方法を検討した．その結果，以下の結論が得られた．

(1) 翼型の座標の算出点間の距離を一定にすることによって，より少ない座標を用いて，3 次の B-スプライン曲線で，前縁部の特徴を表した高精度な NACA4-Digit の翼型が作図できる．

(2) 3DCAD システムのロフト機能を使用し，局所取付角の変化が一定になる場所に断面形状を配置し，局所翼弦長を基準に配置の間隔が大きいところに断面形状を追加して配置することで，高精度なブレードの 3D モデルが作成できる．

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*Editorial*

# Acupuncture and Herbal Medicine for Cancer Patients

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## 1. Complementary and Alternative Medicine (CAM) in Cancer Care

In recent decades, cancer treatment has made remarkable progress with targeted therapy applied on targeted subpopulation [1]. Though the life expectancy of the general population is increasing, cancer is still one of the most common causes of death worldwide [2]. The sophisticated treatments are often accompanied with increased adverse events, and the survival rate is still unsatisfactory in some cancers. In advanced or recurrent cancers, the goal of cancer treatment is often not curing the disease but prolonging survival time with good quality of life. The health-related quality of life is getting value as a cancer outcome, and the effect of early palliative care is emphasized importantly [3]. Nowadays medical information is easily accessed by patients, and most of patients are looking for treatments with less side effects and all available information to prolong survival time and to improve quality of life. Therefore, complementary and alternative medicine (CAM) for cancer is increasingly being demanded by patients, and more physicians are getting interested in the use of CAM in cancer therapies.

The use of CAM in cancer therapies differs from country to country, but up to 80% of cancer patients use some kinds of CAM to support their conventional cancer treatments [4, 5]. In Southwestern China, the prevalence of Chinese herbal medicine use is up to 53.0% during cancer treatment [6], and it seems similar to that of Hong Kong [7]. In Taiwan, up to 98% of the cancer patients use any kind of CAM [8]. In Korea, 78.5% of cancer patients use CAM [9]. A Japanese study revealed that 44.6% of cancer patients use CAM [10], while 83% of cancer patients or cancer survivors use CAM treatments in Australia [11]. An European survey in 13 countries showed 35.9% of average CAM prevalence in cancer patients (range among countries 14.8% to 73.1%) [12]. In other parts of the world similar results were obtained [13]. CAM is also used by 31–84% of children with cancer [14]. This usage of CAM for cancer is more common among educated people with better health behaviour [15, 16] as well as among women [17]. In the case of female cancers, more patients use CAM; for example, 60–80% of breast cancer patients (in comparison to 50% among cancer patients in general) and 75% of female colon cancer patients use CAM [18].

Patients mostly use CAM as a complement to their conventional therapy, not as an alternative treatment [19]. Only very few patients replace conventional treatment by alternative medicine [20]. Even though the use of CAM is a fact worldwide, the view on CAM varies enormously, and the integration of CAM therapies into conventional therapies is extremely complicated in different countries.

Although the governmental support on the research on CAM for cancer therapies differs among various countries, the use of CAM for cancer patients is still debated in an ideological way by supporters and opponents of CAM. One of the causes for the reluctance of Western academia towards CAM is still the insufficient number of convincing clinical studies providing evidence for the efficacy and safety of CAM therapies. The Western concept of "evidence-based medicine" does only poorly match to the clinical practice of CAM. Nevertheless, an increasing number of clinical studies are being conducted during the past years to gain credibility and reputation of CAM. Illustrative examples on the power of CAM have been documented in cancer research with a focus on three major fields [21]:

(i) acupuncture is widely applied for treating pain, a prominent side effect encountered during cancer therapy;

(ii) reduction of severe adverse effects of standard chemotherapy;

(iii) unwanted interactions of standard therapy with herbal medicines.

Another reason for critical opinions towards CAM regards the quality of herbal products according to international quality standards [22].

Therefore, an important question for recognition and implementation of CAM into general medical practice concerns the clinical evidence for efficacy and safety of CAM treatments.

This induces confusion and fear in patients and provides a burden for the communication between patient and doctor. Only 2.4% of patients used their healthcare professional record as primary source of information on CAM in cancer care [23] and 92% of American breast cancer patients withheld information about the CAM treatment from their medical oncologists [24]. Similar results were found in a survey in Taiwan, where more than two out of three cancer patients never informed their physicians of their CAM use [8]. Reasons for this might be the expected inflexibility of medical oncologists and patients' fear of harming the relationship with their oncologists caused by the use of CAM. It is not common for patients to have a communication between Western medicine-oriented doctors and CAM practitioners in clinical practice. However, the integrative cancer care is increasingly required by patients and recently it is getting popular in cancer treatment.

## 2. Acupuncture and Herbal Medicine for Cancer Patients

Acupuncture and herbal medicine are the most qualified CAM treatments. Their effectiveness is still under debate, although they have been used in many fields of cancer treatment and palliative care [25, 26]. The efficacy of the acupuncture and herbal treatment is not currently well recognized by the Western academia and clinical scholars, so that advantages of these therapies in treating cancer or supporting cancer treatment are not adequately reflected. One reason of this estimation is because of the quality of clinical research. Many studies still have the level of case studies [27], which seem like an anecdotal, and the generalization of CAM results might be questionable for scholars who are familiar with well-designed clinical trials.

Acupuncture and herbal medicine have been used for the treatment of cancer pain [25, 26] and for attenuation of side effects of cancer treatments. Acupuncture has been shown to be effective for chemotherapy-induced nausea and vomiting [28], as well as acupressure [29] and herbal medicine [30]. However, acupuncture has not been systematically evaluated with well-designed clinical trial for its effect on it, while new drugs got approvals from FDA for the relief of chemotherapy-induced nausea. Other studies showed an effect of acupuncture on xerostomia after radiation therapy [31, 32]. There are reports that acupuncture was effective on the chemotherapy-induced peripheral neuropathy [33] and herbal medicine was effective on the oral stomatitis [34], which lead patients to higher acceptance of Western cancer treatment with less interruption or discontinuation of therapy. Many studies were focused on the relief of cancer-related symptoms such as fatigue [35–37] and the improvement of quality of life [38].

Recently, randomized controlled trials (RCTs) have been conducted to seek evidences on acupuncture and herbal medicine [39–41]. These therapies are usually considered as supportive for major treatment, in order to attenuate side effects of surgery, radiotherapy, and chemotherapy.

One of the issues of RCTs on acupuncture and herbal medicine is how to deal with the individualized approach of treatments based on the Asian tradition. Asian herbal therapy is commonly a combination of multiple herbs; sometimes approximately up to 15 herbs are in one prescription, while a single herb already contains multiple tentative active compounds. The daily practice in acupuncture and herbal medicine with its individualized approach cannot be easily transferred into standardized controlled trials. The conclusion of systematic review studies that better qualified studies are necessary [42–44] is not so surprising. The study design to solve these issues should be developed.

Even though the effects of acupuncture and herbal medicine are still under debate and further clinical research is necessary, the clinical use of acupuncture and herbal medicine has already been recommended to control cancer-related symptoms in some of the clinical practice guidelines. According to the evidence-based guidelines of the *American College of Chest Physicians for Lung Cancer*, acupuncture has been recommended as a complementary therapy for lung cancer when pain is poorly controlled or when side effects such as neuropathy or xerostomia are clinically significant [45].

Acupuncture and herbal treatment have been used as a complementary treatment in combination with highly effective and partly aggressive Western medicine such as chemotherapy or hormonal therapy. But interactions are quite unknown, underestimated, or under debate. For instance, the herbal treatment with hormone-active herbs in patients with hormone-sensitive cells of breast or ovarian cancers is an important topic of ongoing debates [46, 47]. The interaction of acupuncture and especially herbal medicine with conventional treatments is not all known. Guidance on the safety of herbal medicine to prevent potential risks to cancer patients is necessary, but data have not yet been collected systematically in Mainland China but are now being established in Hong Kong.

In Japan, Kampo, traditional Japanese medicine, is extensively used for cancer patients as supportive measures, covered by National Health Insurance. Japanese medical doctors can prescribe both Western and Kampo drugs, knowing the natural history of diseases and the indication and limitation of Kampo. But, there are no strong recommendations on the Kampo use based on high-quality evidence in clinical practice guidelines in Japan [48]. The Japanese medical system is a unitary one, and Kampo is practiced in this system. From this point of view, the system of Japanese traditional medicine is different from those of China and Korea, where traditional medicine is generally practiced in a dual system, but in the recent years integrative approaches were developed. Japanese Kampo practitioners take advantage of this unitary system, conducting high-quality clinical practice and research. This situation consequently leads to the integrative medicine by a single doctor, whereas the integrative medicine in other countries is usually done by a Western medicine doctor and a traditional medicine practitioner. The system of Japanese Kampo medicine well fits the methodologies of modern medicine, and many clinicians utilize Kampo, accumulating evidence data. This unified situation might be an inspiring example for countries with a unitary medical system.

In Korea, the government health insurance covers only acupuncture treatment for cancer patients. In Western countries, acupuncture and herbal medicine, in spite of frequent use, for years were not in the main focus of the medical academic society. So, research in this field was limited leading in consequence to a situation that especially treatments with Asian herbs often had a lack of scientific controls. But due to increasing interest of patients and practitioners, acupuncture had partly become an integrative therapy in pain management, and, for example, in Germany the use of Western herbs as a complementary medicine is common and Asian herbs are increasingly used.

Since herbal therapy is the most commonly used CAM treatment [49], in recent years, the search for active compounds has mainly focused on Asian herbs, whereby the emphasis has been on classical product-based leads for Western drug discovery, usually performed by screening the extracts or compounds from diverse biological sources. Many *in vivo* experiments showed effectiveness on cell cultures and in animal models [50–53], but translation from bench to bedside is still a difficult challenge. This research, mainly focusing on single active compound, has been done often without regard to preexisting knowledge of the therapeutic utility of the plant source [54]. While interactions of ingredients during the preparation procedure are sometimes essential to the therapy, an extraction of the active ingredients is often not a simple task, and evidence shows that single components extracted from plants are less potent than the crude extract [55]. Scientists of many countries worldwide have tried to apply modern experiment-based research methods to isolating active compounds from herbs, characterizing their pharmacodynamic and pharmacokinetic properties and defining their molecular modes of action with limited success. This reductionist paradigm of a "single chemical entity" is not easily applicable to the multidimensional complexity of Asian herbal prescriptions. Researchers often do not use any concepts of traditional theory as the basis for their investigations on these compounds [56].

Studies on the influence of single herbs or their components on different microbiological pathways of human physiology are necessary and important, but this research is not likely to lead to single-component treatments for multifactorial diseases such as cancer. Cancer is a systemic disease of the entire body. A single-target approach has limited effectiveness, and there is evidence that a multitarget approach might be more effective [57, 58]. It seems only rational to apply a multitargeted therapy to a multifactorial disease. The realization that multicomponent medicines may have advantages over single-component drugs has a scientific foundation. The pharmacological advantages of mixtures may lie in the potentiating action of their multiple bioactive components and the advancement of individualized therapy [59, 60].

Modern research methods on a single herb aimed at isolating active compounds from herb have to be the fundament for future researches in herbal medicine. But when basic information is found and made available, experiments with herbal combinations might be the productive direction for further research to control cancer. While cancer is a multifactorial disease with diverse heterogeneous mechanisms, a combination of components might provide a promising opportunity to focus on multiple targets. Furthermore, these efforts may eventually offer an individualized approach to the treatment. Basic research on single herbs and their active compounds is still essential for the scientific understanding of traditional herbal medicine. But research should not stop at this level but continue with research on multicompounds, their interactions, and increasing or decreasing activity in combinations. Gaining knowledge from tradition might be helpful, not ending in a dead end. This approach is ambitious and time-consuming but has a chance not to fail like conventional drug discovery procedure in the field of herbal medicine in recent years.

While it is difficult to get a patent on natural products, the further interest of pharmaceutical companies might be limited. Progress in this research area can only be found in intense national as well as international cooperation, founding international joint working groups to overcome the obstacles of this sophisticated challenge.

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*Review Article*

# Role of Kampo Medicine in Integrative Cancer Therapy

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Clinical trials to date demonstrate that standard cancer treatments are currently the most efficient treatments for large numbers of cancer patients. Cancer treatments will increasingly require approaches that allow patients to live with cancer, by increasing their natural healing power and tumor immunity, as well as attenuating the progression of their cancers, instead of only attacking the cancer cells directly. Complementary and alternative medicine, including Kampo medicine, compensates for the drawbacks of western medicine by increasing patients' self-defense mechanisms. In Japan, clinicians who have studied both western medicine and Kampo treat cancer patients by fusing the two medical systems into a unitary one. The goal of the system is to assist the functional maintenance and recovery of the living body complex with the physical, mental, social, and spiritual balance, rather than addressing direct antitumor effects. In this review, we describe the usefulness of Kampo medicine, especially juzentaihoto, and outline the reports on evidence, in addition to the report on an attitudinal survey about the use of Kampo medicine in cancer treatment in Japan.

## 1. Limitations of Standard Cancer Treatment

Western medicine should be used in preference to Kampo medicine in the diagnosis and treatment of cancer. Medical diagnosis based on western medicine is essential to determine the exact degree of progression and malignancy of cancer [1–4]. Western medicine successfully treats many types of cancer, when the appropriate treatment is used. Clinical trials to date demonstrate that standard cancer treatments are currently the most efficient treatments for large numbers of cancer patients [5–8]. The current standard cancer treatments include surgery, chemotherapy, and radiation therapy. Reliable therapy has not been established yet for refractory cancer, including advanced or recurrent cancer.

Advanced experimental therapies using special anticancer agents, radiation, immunotherapy, and gene therapy have been attempted. Radiation therapy, chemotherapy, and surgery are called "invasive treatments" [9–12]. The term "invasive" means "harmful to the body" as well as "attacking the cancer." Aggressive treatment has the disadvantage of damaging normal tissue and reducing tumor immunity and physical strength. This is especially true in bone marrow cells or intestinal mucosal epithelia, in which the cell cycle is vigorous [13–18]. The tissues and organs of the whole body maintain order in their structure and function by incorporating nutrients and oxygen from the blood into cells, excreting waste, and repairing old and scar tissues. This is called "natural healing power" or "self-healing power." Abnormal cells such as cancer cells are constantly produced in our body, but as long as the immune system is maintained properly, they are eliminated prior to growth or progression. This means that as long as the immune system is working