นิพนธ์ต้นฉบับ
(Original article)

# ระบบช่วยในการตัดสินใจเพื่อการพยากรณ์ความจำเป็นในการรักษาทางทันตกรรมจัดฟัน

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## บทคัดย่อ

จากการศึกษาที่ผ่านมา ในทวีปเอเชียพบชาวเอเชียมีปัญหาการสบฟันในฟันแท้ที่ผิดปกติซึ่งจำเป็นต้องได้รับการรักษามากถึงร้อยละ 50-80 ซึ่งการสบฟันผิดปกติดังกล่าว ก่อให้เกิดปัญหาด้านความสวยงามและการทำงาน ทั้งนี้บุคลากรที่มักพบผู้ป่วยก่อนเพื่อที่จะต้องให้คำแนะนำเบื้องต้น รวมถึงส่งต่อเพื่อรับการรักษาที่เหมาะสม คือ ทันตแพทย์ทั่วไปหรือทันตแพทย์สาขาอื่น ซึ่งบางครั้งพบปัญหาในการส่งต่อ เช่น ไม่มีเอกสารในการส่งตัว หรือบางครั้งผู้ป่วยที่ถูกส่งตัวไปแล้วไม่มีความจำเป็นต้องได้รับการรักษาทางทันตกรรมจัดฟัน ทำให้ผู้ป่วยเสียเวลา รวมถึงสิ้นเปลืองค่าใช้จ่ายในการเดินทาง การศึกษานี้จึงเกิดขึ้นโดยมีวัตถุประสงค์เพื่อสร้างระบบช่วยการพยากรณ์ความจำเป็นในการรักษาทางทันตกรรมจัดฟันในผู้ป่วยที่มีการสบฟันเป็นฟันแท้โดยใช้เทคนิคเบย์เซียนเน็ตเวิร์ค (Bayesian network, BN) เนื่องจากเป็นเทคนิคที่สามารถเชื่อมโยงความสัมพันธ์ของหลายๆ ปัจจัยที่มีผลต่อการตัดสินความจำเป็นในการรักษาทางทันตกรรมจัดฟันได้ โดยขั้นตอนการพัฒนาระบบช่วยในการตัดสินใจใช้การสุ่ม 5 ครั้งจากข้อมูลแบบศึกษาจำนวน 401 คู่ หลังจากนั้นประเมินระบบช่วยในการตัดสินใจที่พัฒนาแล้ว โดยดูความสอดคล้องในการวินิจฉัยเทียบกับทันตแพทย์จัดฟัน 2 ท่าน ผลการศึกษาพบว่าระบบช่วยในการตัดสินใจนี้มีความถูกต้องในการประเมินความจำเป็นในการรักษาทางทันตกรรมจัดฟันในระดับสูง โดยพบพื้นที่ใต้กราฟอาร์โอซี (ROC, Receiver operating characteristic curve analysis) มีค่า 0.80 และมีความสอดคล้องในการประเมินความจำเป็นในการรักษาทางทันตกรรมจัดฟันเมื่อเทียบกับทันตแพทย์จัดฟัน 2 ท่านในระดับสูง (kappa index = 0.859)

คำสำคัญ: เบย์เซียนเน็ตเวิร์ค ความจำเป็นในการรักษาทางทันตกรรมจัดฟัน การสบฟันผิดปกติ ระบบช่วยในการตัดสินใจ

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# Decision support system
## for orthodontic treatment needs

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## Abstract

According to several studies conducted in Asia, the major malocclusion problems of permanent dentitions found in patients belong to orthodontic treatment needs (50 to 80%). Some degree of malocclusions can contribute to aesthetic and functional problems. Patients receive general information, and advice about orthodontic treatments from non-orthodontic dentists to be transferred to an orthodontic specialist. Often, patients are transferred without referring documentation, without a need for a treatment; incurring in unnecessary costs and time wasted. This study aims to develop a decision support system to assess the orthodontic treatment needs in permanent dentition patients by using a Bayesian Network (BN). BN was used to describe the mutual relationships among multiple variables contributing to orthodontic treatment need. The data-sets were prepared from 401 pairs of study models. BN was applied to learn algorithms to the training data-sets to develop decision support system for orthodontic treatment need using 5-fold cross-validation. To evaluate the system performance, a comparison between dental diagnosis agreement between the developed system and 2 orthodontists was performed. Receiver operating characteristic curve analysis showed that the model was highly accurate in predicting the orthodontic treatment need; the area under the curve (AUC) was 0.80. There was a high degree of dental diagnosis agreement between the decision support system and orthodontists (kappa index = 0.859).

Keywords: bayesian network, orthodontic treatment need, malocclusion, decision support system

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## Introduction

According to several studies conducted in Asia, the major malocclusion problems of permanent dentitions found in patients belong to orthodontic treatment needs (50 to 80%).[1-2] Some degree of malocclusions can contribute to the aesthetic and functional problems.[3] Generally, at initial stage, patients had taken the general information, and advices about orthodontic treatments from non-orthodontic dentists (the first dentist who meet patients).[4] After that, they were transferred to the appropriate orthodontic treatments. The mentioned evident affected Thai orthodontists in terms of the burden of patients' referral. Sometimes, patients were transferred to the orthodontic treatments without any referring documentations or incomplete data about their present malocclusion problems.[5] The patients in addition may not need those orthodontic treatments. Therefore, these evident may raise patient's reluctances with losing their time, and losing their money for unnecessary costs. The factors that may relate to this situation were stated by a number of orthodontists that non-orthodontic dentists may not have enough experiences. They also may lack of guidelines for a case selection.[5] Consequently, the index of orthodontic treatments have been developed to solve these problems. It used to allocate patients into categories of treatment needs6 or to evaluate treatment success.[7] The example for occlusal indexes which are used in various countries such as Handicaping Malocclusion Assessment Record (HMAR)[6], Index of Orthodontic Treatment Need (IOTN)[8], Dental Aesthetic Index (DAI)[9], and Index of Complexity, Outcome and Need (ICON)[10]. Different details and the use of each index was established, though it can be claimed that all concerned factors have not been covered. Some indexes are used only for mixed or permanent dentition. On the other hand, some indexes are complicated, especially for non-orthodontic dentists.[11] The orthodontic treatment need index has not been developed in Asia. Thus, indexes which were developed in Europe and America were instead applied. Nowadays, it can be claimed that the relationship between orthodontic treatment needs of patients and non-orthodontic dentists has a great impact on the decision of receiving the orthodontic treatments. Nonetheless, the appropriate information and referral steps were also found mistake.[5]

Computer technology currently plays an important role in driving businesses such as engineering, marketing, management science, medical and dentistry. Bayesian Network (BN) or belief network is computer technology or machine learning technology, which developed in 1980. BN has been used to assist understanding the causal relationship of multiple variables. Furthermore, BN is used as probabilistic model for predicting the outcome.[12] Since 1980, the studies of clinical decision support system have been conducted in order to support doctors and dentists in evaluating their case studies by employing computer technology. Suebnukarn et al[13], examined Thai population by using a Bayesian decision support model for the assessment of endodontic treatment outcome. Receiver operating characteristic curve analysis (ROC) showed that the model was highly accurate. The BN has not been applied for orthodontics yet. Therefore, this study aims to develop decision support system by using the BN. The present study is focusing on the assistance of non-orthodontic dentists to provide information and suggestions to patients more effectively. Consequently, the referral of orthodontic treatments can be performed with the reference of documentations. The patients will be obtained the effective orthodontic treatments which reach to their appropriate needs.

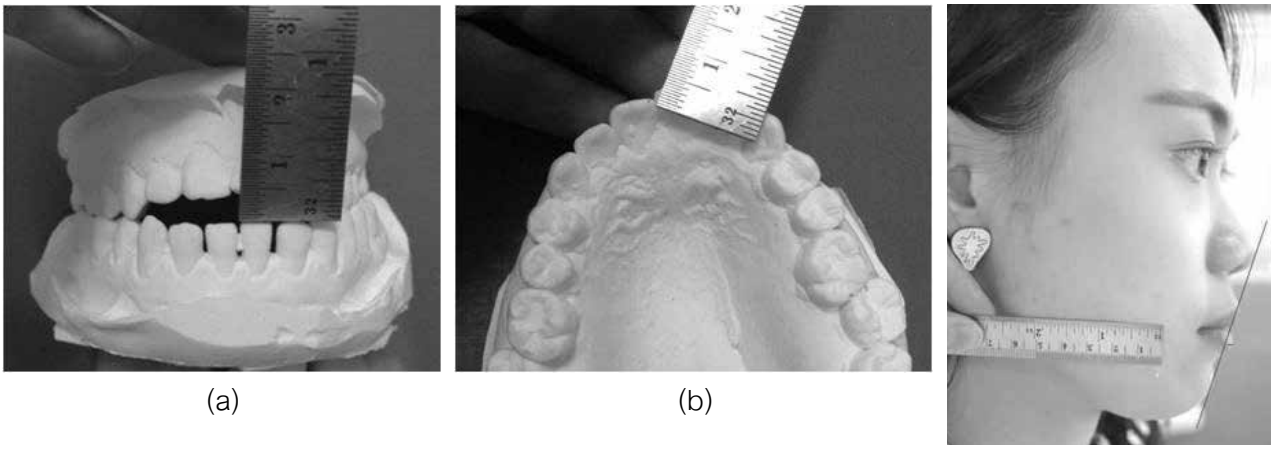
## Objective

To develop a decision support system to assess the orthodontic treatment needs in permanent dentition patients by using a Bayesian Network.

## Materials and Methods

The research procedure is developed by the reviewing of related English language articles in terms of "orthodontic treatment need index". The reviewing was gained from the previous to present studies. After, reviewing the related literature, the researcher has found 3 most popular indexes (IOTN, DAI and ICON). This study found 15 variables which affected the orthodontic treatment plans, consist of missing, overjet, overbite, anterior open bite, posterior open bite, diastema, anterior crossbite, posterior crossbite, anterior displacement,

posterior displacement, supernumerary tooth, ectopic eruption, anterior-posterior molar relationship, upper lip to E-line and lower lip to E-line. The researcher examined 15 variables in 401 pairs of study models from 18-24 year-olds patients (Figure 1). 226 pairs of study models were the orthodontic treatment needs patients. They were treated in Orthodontic Clinic, faculty of dentistry, Srinakharinwirot University, during 2003 to 2013. 175 study models of patients who did not need orthodontic treatment, were also examined. All data were computed and prepared in excel format. The researcher used BN as a system to measure the patients' necessary of orthodontic braces. In a BN, each variable was modeled as a node and the causal relationship between two variables which may be represented as a directed arc. Each node included a condition probability table which was described the probabilities of each values of this node, given the conditions of its parents. The algorithm used to learn the structure of the network was the Necessary Path Condition (NPC) algorithm. An Expectation-Maximization (EM) was used to find maximum likelihood estimates of parameters. The data were classified into 5 groups by using random sampling. Each 80% were used in turn for training. The remainder (20%) were used for testing the structure and parameter of the decision support system. The procedure was repeated 5 times resulting with 5 candidate decision support systems. The researcher selected the model that gives the highest performance for development the decision support system and comparison with orthodontists predictions (Figure 2). This study used 20 cases to comparison of the dental diagnoses accuracy with 2 orthodontists. The Kappa statistic was used to test the statistic significance of the agreement between orthodontists and decision support system.



(a) (b) (c)

**Figure 1** Fifteen variables were examined from study models and lateral face pictures (a) Anterior open bite measurement (b) Anterior displacement measurement (c) Upper lip to E-line and lower lip to E-line measurement.

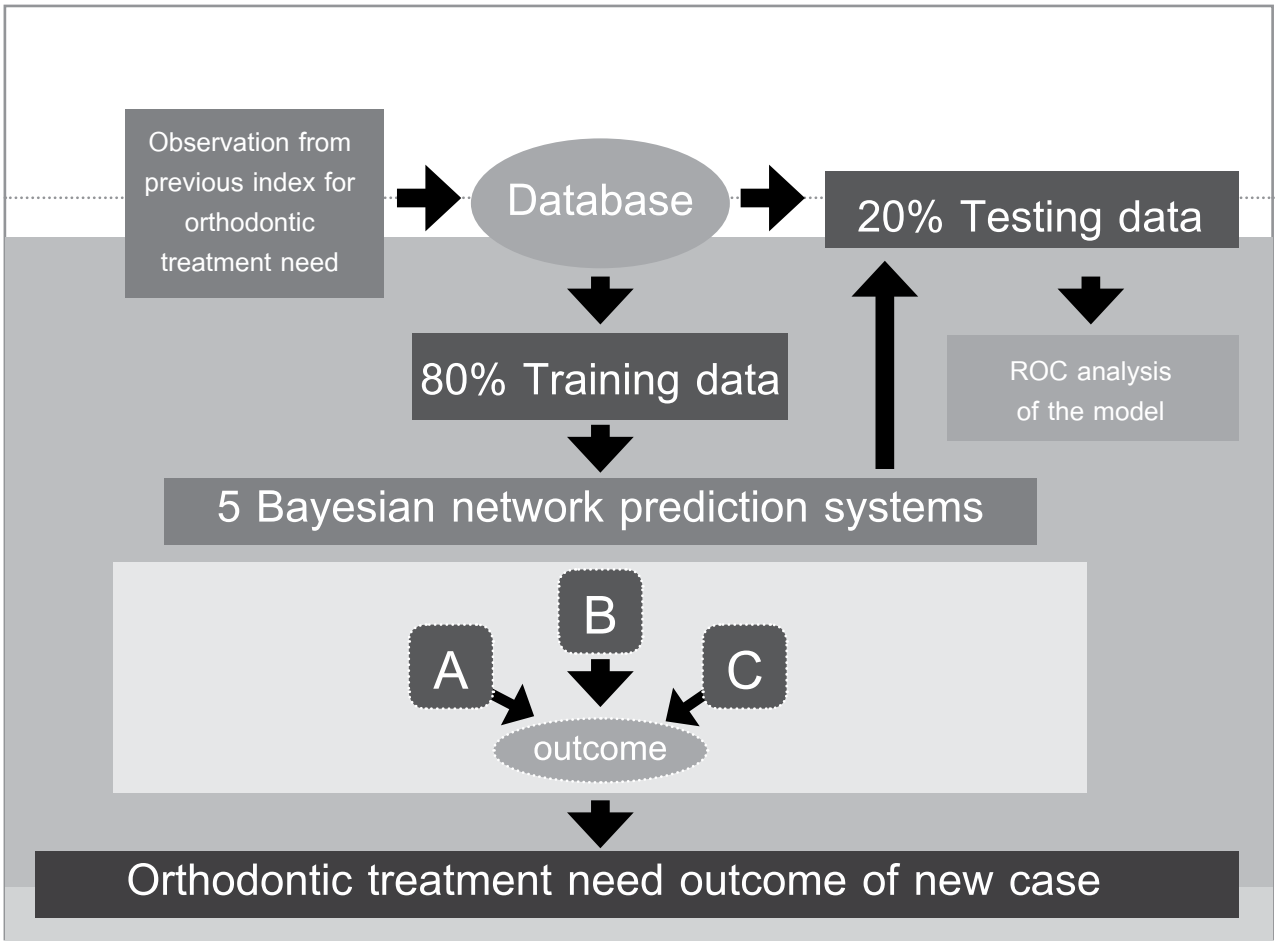



**Figure 2** System overview, the process of data preparation and analysis to model performance testing.

## Results

The data contains 15 variables affecting the orthodontic treatment need from 401 pairs of study models were shown in Table 1. 226 pairs of study models were from the orthodontic treatment need patients. 66 males and 160 females were treated in an orthodontic clinic, Faculty of Dentistry, Srinakharinwirot University, during year 2003 to 2013. Another 175 pairs of study models were from patients who do not need to be treated in the orthodontic, 55 males and 120 females. BN was used as a system to measure the patients' necessary of orthodontic braces. The structure along with the conditional probability distribution of the BN was built up using training data-sets obtained from study models and lateral face picture measurement (Figures 3, 4).

**Table 1** Part of the database used to develop the structure and parameters of BN system.

| No. | Miss-ing | Over-jet | Over-bite | Ant. Open.* | Post. Open.* | Dias-tema | Ant. Cross.* | Post. Cross.* | Ant. Dis* | Post. Dis* | Su-per-num* | Ecto-pic erup-tion | Ant-Post Mo-lar* | Up* lip To E-line | Lo* lip To E-line |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 151 | 0 | 5 | 4.5 | 1.5 | 2 | 0.5 | N | N | 5 | 5 | N | Y | 2 | 0.5 | 1 |
| 152 | 0 | 2 | 1.5 | 2 | 1.5 | 2.5 | Y | N | 0 | 5 | N | N | 1 | -1.5 | 0 |
| 153 | 2 | 5.5 | 5.5 | 0 | 0 | 0 | N | N | 1.5 | 0 | N | N | 1 | 0.5 | 0.5 |
| 154 | 0 | 5 | 3 | 0 | 0 | 0 | N | Y | 2.5 | 2 | N | N | 1 | N/A | N/A |
| 155 | 0 | 3.5 | 5 | 0 | 0 | 0 | N | N | 3 | 0 | N | N | 0 | N/A | N/A |
| 156 | 0 | 5 | 3.5 | 0 | 0 | 0 | N | N | 3.5 | 2.5 | N | N | 0 | -2 | 0 |

* Ant.Open. = Anterior Open bite, Post.Open. = Posterior Open bite, Ant.Cross. = Anterior Crossbite, Post.Cross. = Posterior Crossbite, Ant.Dis. = Anterior Displacement, Post.Dis. = Posterior Displacement, Supernum = Supernumerary tooth, Ant-Post Molar = Anterior-Posterior Molar relationship, Up lip to E-line = Upper lip to E-line, Lo lip to E-line = Lower lip to E-line

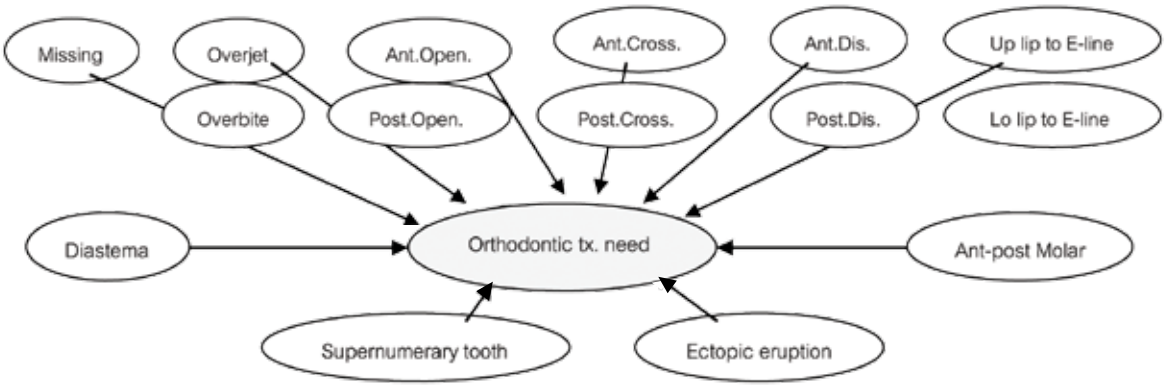



**Figure 3** A BN representing the possible relationships among factors influencing orthodontic treatment needs. Each arc indicates a causal relationship.

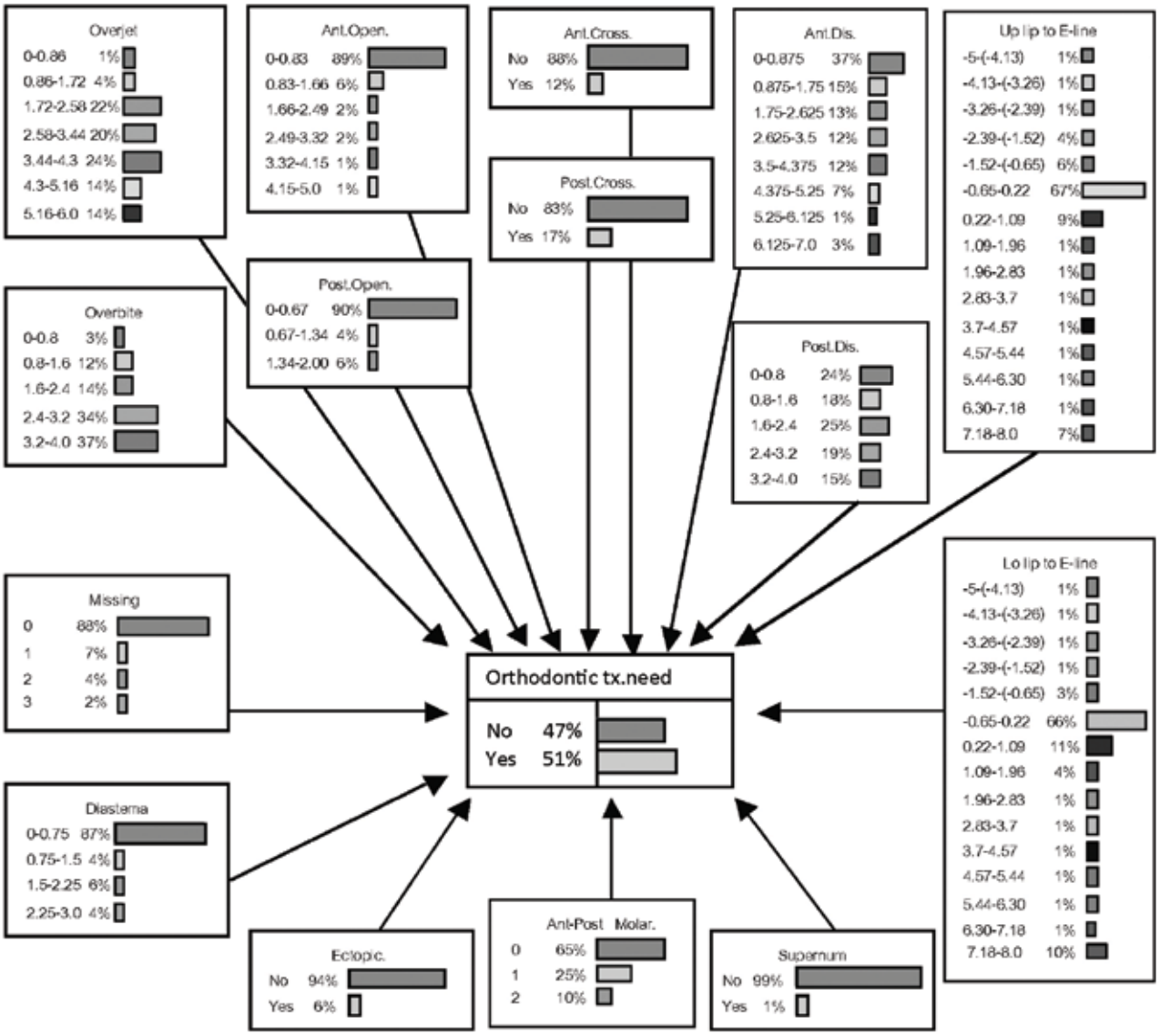



**Figure 4** Condition probability distributions on all node after learning.

The data sampling, which showed the highest performance (the specificity, sensitivity, accuracy were 100%, 94.74% and 96.24% respectively), was selected and developed with the software (Figure 5). Receiver operating characteristic curve analysis showed that the system was highly accurate in predicting the orthodontic treatment need; the area under the curve (AUC) was 0.80 (Figure 6).

When compared the dental diagnoses accuracy with 2 orthodontists, the Kappa coefficient of Cohen was used. There was high degree of dental diagnosis agreement between the decision support system and orthodontists (kappa index = 0.859, p-value < 0.01).


**Figure 5** Software form showed 15 variables' box where user could fill in. These 15 variables consist of both descriptive texts and pictures. The result will be showed automatically when pressed the output button.

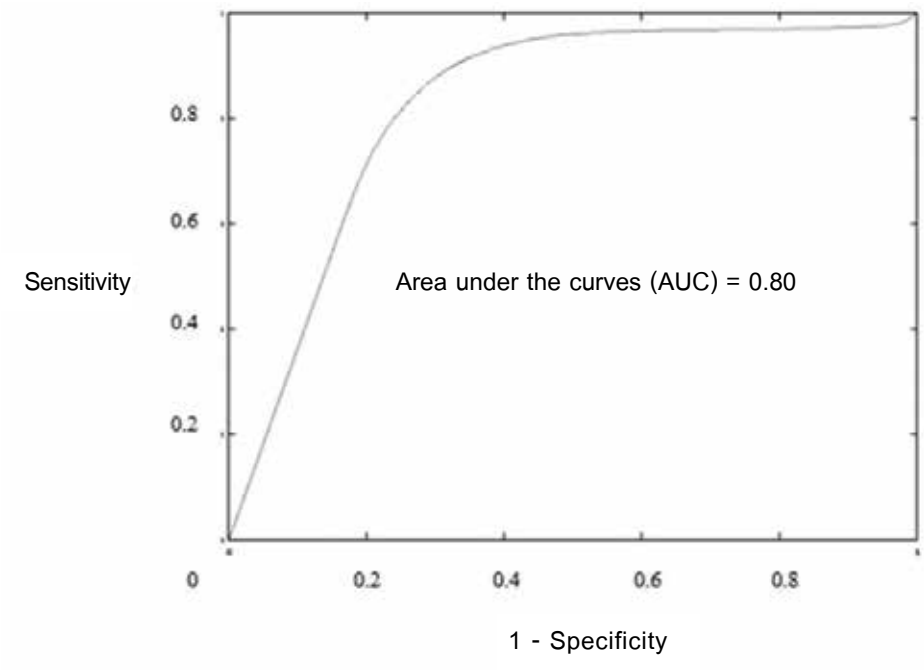



**Figure 6** The area under the curve .

## Discussion

The study of Tarvit and Freer[14] found that the development of teeth affected occlusal abnormalities. The result showed that a patient had occlusal abnormalities as well as different in mixed and permanent dentition. Therefore, this study was conducted with people age 18 to 24 years old had definitely permanent teeth and usually needed for orthodontic treatment.[15]

In this study, there were the adaptation of indexes used in Thailand and other countries with selected variables. Those indexes include 3 indexes (The IOTN, The ICON and The DAI) of which allowed the selection of 13 variables included missing, overjet, overbite, anterior open bite, posterior open bite, diastema, anterior crossbite, posterior crossbite, anterior displacement, posterior displacement, supernumerary tooth, ectopic eruption and anterior-posterior molar relationship. And those 3 indexes shared the similar variables: overbite, anterior open bite, diastema, anterior crossbite, anterior displacement and anterior-posterior molar relationship. This can be suggested that those indexes were focused on front teeth which can be seen when people smile or talk. In other words, people satisfaction was influenced by facial aesthetics. 16 Other variables were upper lip to E-line, lower lip to E-line being added in this study because several studies and articles suggested that bimaxillary protrusion greatly found in Asians.[17,18] Moreover, the study of Ricketts[19] and Lamberton et al.[20] indicated that bimaxillary protrusion patients needed to receive orthodontic treatment. According to the intra-oral examination, the researcher found that patient's occlusion was good despite that the patients' profiles as shown by E-line (A line drawn from the tip of the nose to the chin) protruded.[19,20] Ten pictures that appeared in the IOTN and the ICON used to evaluate the need for orthodontic treatments were excluded. This was because the present method requires somewhat more discretion of the investigator.[21] These pictures were not consistent with the objectives of this research because they should be evaluated by orthodontic dentists, but this study focused on non-orthodontic dentists.

To evaluate the system, four performance measures were used: accuracy, sensitivity, specificity, and AUC. The closer the AUC is to 1.0, the more accurate the system is. From 5 candidate decision support systems showed that the highest performance were 100% specificity, 94.74% sensitivity, 96.24% accuracy and AUC 0.80. The results are consistent with the study of Choi et al.[22] who developed BN model for predicting breast cancer prognosis using 294,275 data. Their model showed high performance of specificity (58.3%), sensitivity (88.5%), accuracy (70.9%), and AUC (0.813). After the software was developed, the system was evaluated by comparison of dental diagnosis agreement of 20 subjects between developed system and 2 orthodontists. The results presented the high degree of agreement between the predictions given by the orthodontists and the software (kappa index = 0.859). The present study was in addition consistent with the studies of Suebnukarn et al.[13] who developed BN model for assessment of endodontic treatment outcome. When compared the assessment by 3 endodontists, it showed high degree of agreement (kappa index = 0.793).

BN is very attractive for medical diagnosis systems since they can be applied to make inferences in many cases when the input data is incomplete. This can be happened in several clinical settings when using BN with limited diagnostic decisions data, and the system can be revised later when data become available.[23] According to report of the 4th National Oral Health survey conducted in Thailand, in 1994, using DAI. The result showed that 23.2% of 2,801 twelve year-old children had the malocclusion problem.[24] In addition, they needed orthodontic treatment and 21.8% were the population who lived in the rural area. As a consequence, the decision support system allows non-orthodontic dentists to use in evaluating and advising the patients appropriately. Even in rural area, where lacking of orthodontic dentists, when patients have good occlusion, it can reduce the risk of other oral health problems.[25, 26] The limitation of this study is lack of time, thus examination of 401 data in the process of system development is less than other studies.[22] However, the performance of the system was in a high level (the specificity, sensitivity, accuracy are 100%, 94.74% and 96.24% respectively).

## Conclusions

The results showed the examining 15 variables of the need for orthodontic treatment which was mainly focused on the dentist's perceptions. The patient's perceptions and their condition were not investigated. The decision support system is a useful tool that allows non-orthodontic dentists to evaluate and advise patients appropriately as well as the principles of medical with high accuracy comparable assessment. However, to be treated in orthodontic, patients should be treated after talking, exchange opinions and making decisions between patients and orthodontic dentist. In further study there should be developed decision support system for orthodontic treatment need in mixed dentition.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