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Design and development of Dental Identification System in Forensic Medicine

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Introduction : *Nowadays, dental identification has become importance in forensic medicine; nevertheless, it has some limitations. There are insufficient standards for both dental documentation and electronic dental chart systems necessary for human identification. It is difficult to gather complete dental data for each individual. The huge quantity and redundancy of related documentation requires an abundant amount of identification time. Moreover, there is a shortage of qualified personnel.*

Purposes : *To design and develop Intelligent Dental Identification System (IDIS) that will be useful in assisting dentists regardless of their affiliation to forensic odontology.*

Setting : *The Dental Department of Police General Hospital of Thailand.*

Subjects : *A random selection of 500 patients were chosen and simulated to create a population of 3,000 patients. From the original 500 patients, 100 were randomly selected to create a sample of 600 unidentifiable subjects with either complete or incomplete dental information.*

Design : *Action Research.*

Methods : *Attempts were made to identify 600 unknown subjects utilizing 13 non-redundant identification models designed to support a variation within the data structure of each unidentified individual and analyze the data that were poorly characterized mathematically. The 13 models were divided into 3 subgroups: elementary method (6 models), moderate method (4 models), and advanced method (3 models).*

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Results : *The use of IDIS elementary method resulted in outstanding identification in the range of 71.11 % to 88.81 % with error of 1.43 % to 8.57 %. The use of IDIS moderate method resulted in outstanding identification in the range of 61.14 % to 99.22 % with error of 0 % to 6.16 %. The use of IDIS advanced method resulted in consistent outstanding identification in the range of 82.61 % to 100 % with minimal error of 0 % to 0.88 %.*

Conclusions : *The results of this study indicate that IDIS can be used to support dental identification process of primary, mixed, and permanent dentition, even when incomplete dental information is obtained. IDIS is particularly useful given the huge quantity and redundancy of related documentation associated with forensic odontology. As a computerized system, IDIS can reduce the time necessary for identification and store the dental digital images with many processing features. Furthermore, IDIS establishes enhancements of documentation with odontogram and dental identification codes, dental database, and identification methods and algorithms. IDIS was conceptualized based on the guidelines and standards of the American Board of Forensic Odontology (ABFO) and International Criminal Police Organization (INTERPOL).*

Keywords : *Dental Identification, Odontogram, Dental Record, Forensic Odontology, Forensic Medicine, IDIS.*

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บทนำ : *ปัจจุบันการพิสูจน์บุคคลด้วยข้อมูลทันตกรรมนั้น ได้ถูกนำมาใช้ในงานด้านนิติเวชศาสตร์เป็นจำนวนมาก แต่ก็ยังมีปัญหาและอุปสรรคหลายด้าน ได้แก่ การขาดมาตรฐานของระบบเอกสารและระบบคอมพิวเตอร์ที่ใช้บันทึก และจัดเก็บข้อมูลทันตกรรมที่เหมาะสมสำหรับงานด้านนิติเวชศาสตร์ ความไม่สมบูรณ์ของข้อมูลทันตกรรมที่ถูกบันทึกไว้ จำนวนและความซ้ำซ้อนของเอกสารที่เกี่ยวข้องมีจำนวนมาก ทำให้ต้องใช้เวลานานในการดำเนินการและเกิดความผิดพลาดได้ง่าย และปัญหาการขาดแคลนบุคลากรที่มีความเชี่ยวชาญ*

วัตถุประสงค์ : *ออกแบบและพัฒนาระบบพิสูจน์บุคคลด้วยข้อมูลทันตกรรม (IDIS) เพื่อช่วยงานด้านนิติเวชศาสตร์ โดยนำความรู้ทางด้านข้อมูลทันตกรรม การพิสูจน์บุคคล และการค้นหาความรู้จากฐานข้อมูล (Knowledge Discovery in Databases) มาใช้ในงานวิจัย*

สถานที่ทำการศึกษา : *แผนกทันตกรรม โรงพยาบาลตำรวจ*

ตัวอย่างที่ทำการศึกษา : *การสุ่มเลือกผู้ป่วย จำนวน 500 คน ซึ่งจะได้รับการตรวจทางทันตกรรมแบบทั้งปาก (มีข้อมูลของฟันครบถ้วนทั้ง 52 ซี่) และบันทึกข้อมูลลงในเอกสารบันทึกข้อมูลทันตกรรม (IDIS Dental Record) ที่ได้ถูกออกแบบขึ้นในงานวิจัย จากนั้นจะถูกจำลองเป็นผู้ป่วยจำนวน 3,000 คน ที่มีโครงสร้างความสมบูรณ์ของข้อมูลที่แตกต่างกัน และจากตัวอย่างเริ่มต้น 500 คนแรกนั้นจะมีการสุ่มเลือกจำนวน 100 คนแล้วผ่านการจำลองเป็นบุคคลที่ต้องการพิสูจน์บุคคลจำนวน 600 คน ที่มีโครงสร้างความสมบูรณ์ของข้อมูลที่แตกต่างกัน*

รูปแบบการวิจัย : *การวิจัยเชิงปฏิบัติการ*

วิธีการศึกษา : *บุคคลที่ต้องการพิสูจน์บุคคลจำนวน 600 คนจะถูก IDIS ทำการพิสูจน์บุคคลจากผู้ป่วยจำนวน 3,000 คน โดย IDIS จะใช้โมเดลพิสูจน์บุคคลจำนวน 13 แบบซึ่งถูกแบ่งเป็นโมเดลขั้นต้น (Elementary Method) จำนวน 6 แบบ โมเดลขั้นกลาง (Moderate method) จำนวน 4 แบบ และโมเดลขั้นสูง (Advanced method) จำนวน 3 แบบ*

ผลการศึกษา : *ผลจากการใช้โมเดลขั้นต้น (Elementary Method) IDIS สามารถพิสูจน์บุคคลด้วยข้อมูลทันตกรรมด้วยความถูกต้อง (Outstanding Results) ร้อยละ 71.11 ถึง 88.81 และมีความผิดพลาด (Error Results) ร้อยละ 1.43 ถึง 8.57 ผลจากการใช้โมเดลขั้นกลาง (Moderate method) IDIS สามารถพิสูจน์บุคคลด้วยข้อมูลทันตกรรมด้วยความถูกต้อง (Outstanding Results) ร้อยละ 61.14 ถึง 99.22 และมีความผิดพลาด (Error Results) ร้อยละ 0 ถึง 6.16 ผลจากการใช้ โมเดลขั้นสูง (Advanced Method) นั้น IDIS สามารถพิสูจน์บุคคลด้วยข้อมูลทันตกรรมด้วยความถูกต้อง (Outstanding Results) ร้อยละ 82.61 ถึง 100 และมีความผิดพลาด (Error Results) เพียงร้อยละ 0 ถึง 0.88*

สรุป : *จากผลการวิจัยแสดงให้เห็นว่า IDIS สามารถสนับสนุนงานด้านการพิสูจน์บุคคลด้วยข้อมูลทันตกรรมที่มีเอกสารที่เกี่ยวข้องเป็นจำนวนมาก มีความซ้ำซ้อนและความไม่สมบูรณ์ของข้อมูล โดย IDIS เป็นเครื่องมือแรกที่สามารถพิสูจน์บุคคลด้วยข้อมูลทันตกรรมของบุคคลทั้งที่มีชีวิตและไม่มีชีวิตที่มีข้อมูลทันตกรรมอยู่ทั้งในระยะฟันน้ำนม ระยะฟันน้ำนมผสมฟันแท้ และระยะฟันแท้ ด้วยความสามารถของระบบคอมพิวเตอร์ ทำให้ IDIS สามารถช่วยลดระยะเวลาการทำงาน และยังสามารถบันทึกและปรับแต่งภาพดิจิตอลได้อีกด้วย IDIS ประกอบไปด้วยองค์ประกอบต่าง ๆ ที่ได้ถูกออกแบบและพัฒนาขึ้นสำหรับงานด้านนิติเวชศาสตร์ และข้อมูลส่วนบุคคล ได้แก่ เอกสารการบันทึกข้อมูลทันตกรรมที่ประกอบด้วยแผนภาพฟัน (ODONTOGRAM) และรหัสข้อมูลทันตกรรม ฐานข้อมูลทันตกรรม (Dental Database) หลักการและวิธีการพิสูจน์บุคคลด้วยข้อมูลทันตกรรม โดย IDIS ได้รับหลักการและพื้นฐานความรู้จาก American Board of Forensic Odontology (ABFO) และ International Criminal Police Organization (INTERPOL)*

คำสำคัญ : *การพิสูจน์บุคคลด้วยข้อมูลทันตกรรม, แผนภาพฟัน, เอกสารการบันทึกข้อมูลทันตกรรม, นิติทันตวิทยา, นิติเวชศาสตร์, IDIS.*

With the increase in crimes, wars, terrorism, missing-person cases, mass disasters, and modifications of identity for criminal activities, human identification in forensic medicine has grown in importance especially with the help of dental evidences. [1-11] There are three scientific methods admissible as evidence in legal practices and insurance claims: medical and dental identification, fingerprint identification, and DNA profiling.

Dental identification has several consistent advantages. It is a low cost method, and human teeth are the best preserved parts of the body due to their hardness and resistance to corrosion.[12-15] Past dental records are readily available,[1] and dental characteristics are unique to each individual.[4, 16-21]

Nevertheless, dental identification also has certain limitations. There are insufficient standards for both dental documentation and electronic dental chart systems necessary for human identification.[16, 18, 22, 23] It is difficult to gather complete dental data for each individual.[24] The huge quantity and redundancy of related documentation requires an abundant amount of identification time.[24] Moreover, there is a shortage of qualified personnel.

In Thailand, there is currently no offered education or development within the field of forensic odontology. The need for national and international standardization in record-keeping styles and abbreviations for forensic purposes [25-27] and the lack of dentists specialized within this area contribute to the above limitations.

Few studies have been completed in computerized dental identification. Further research may increase the efficiency of forensic dentists.

The purposes of this study were to design and develop a computerized dental identification system that will be useful in assisting dentists regardless of their affiliation to forensic odontology. It will support identification of both living and postmortem subjects. Its odontogram (Figure 1 and 2), codes (Figure 1) and identification methods will espouse data of both primary and permanent teeth. This was based on the guidelines and standards of the American Board of Forensic Odontology (ABFO) [17] and the International Criminal Police Organization (INTERPOL).[18, 24]

Materials and Methods

This study comprised of 500 randomly selected patients from the Dental Department of Police General Hospital of Thailand (Figure 3). There were 222 male subjects and 278 female subjects ranging in age from 3 to 83 years old. A full mouth clinical examination was completed for each patient and documented in Intelligent Dental Identification System (IDIS) dental records (Figure 1) by the Chief of the Dental Department.

From the original 500 dental records, a simulation was used to create a total of 6 distinguishable personal dental records for a total of 3,000 patients. The 6 unique personal dental records for each individual included:

1. **Full data profile** – contained information of all 52 teeth (20 primary teeth and 32 permanent teeth).

2. **P4 data profile** – contained information of all 20 primary teeth, lacked information for at least 1 permanent tooth, and each of the 4 quadrants of permanent teeth contained information for at least 4 teeth.

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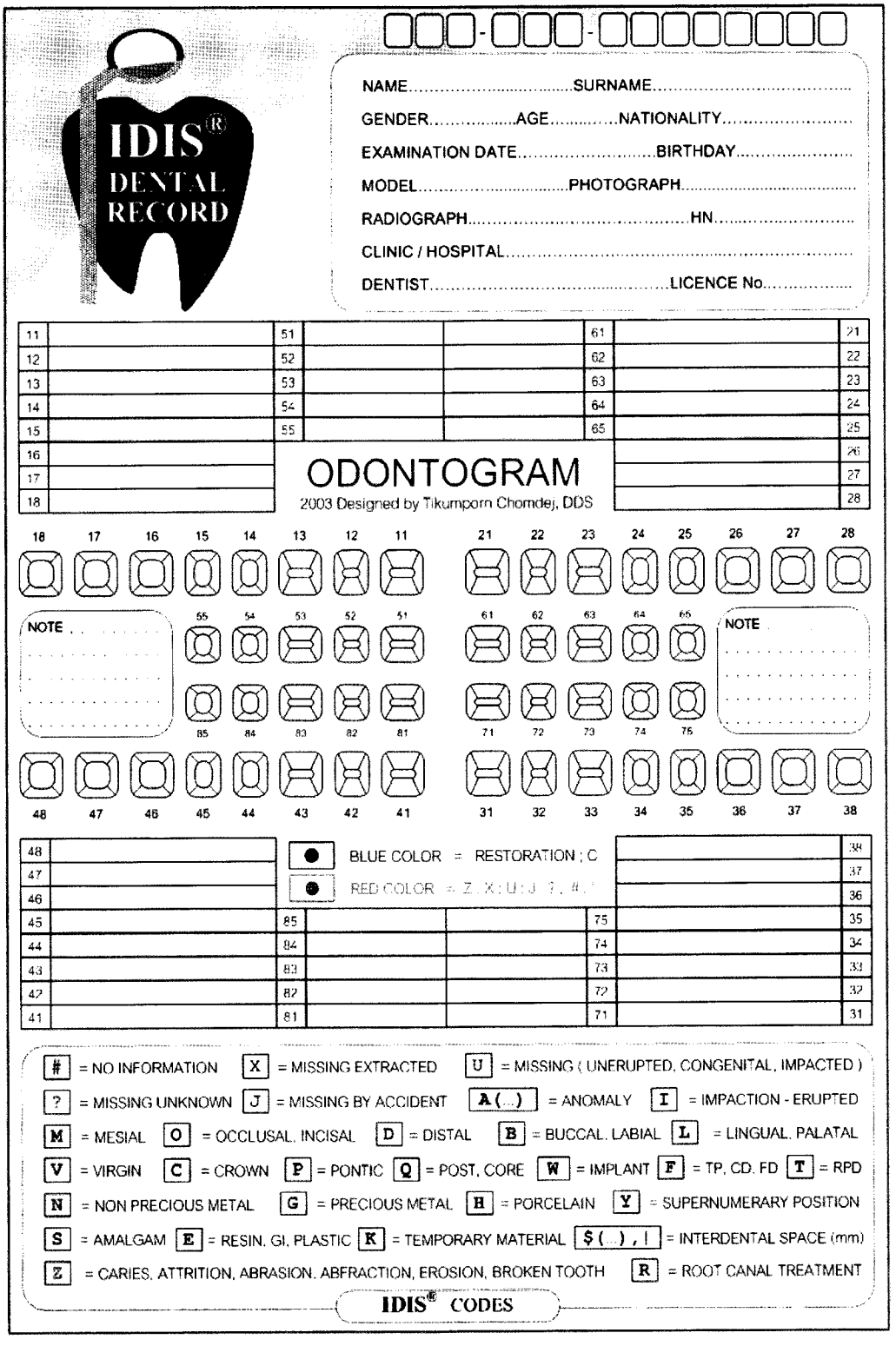

Figure 1. IDIS dental record.

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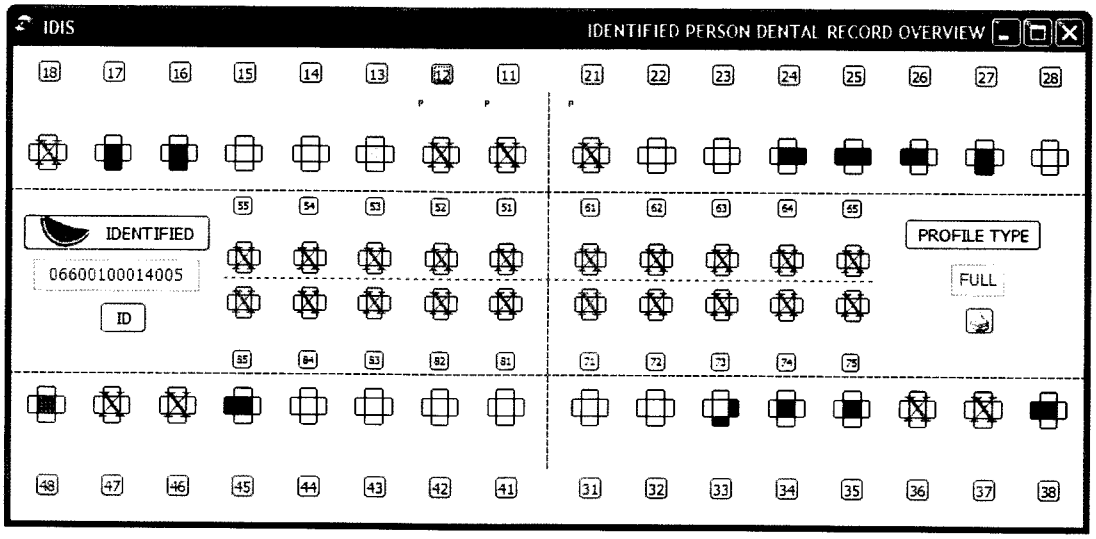

Figure 2. Example of computerized odontogram.

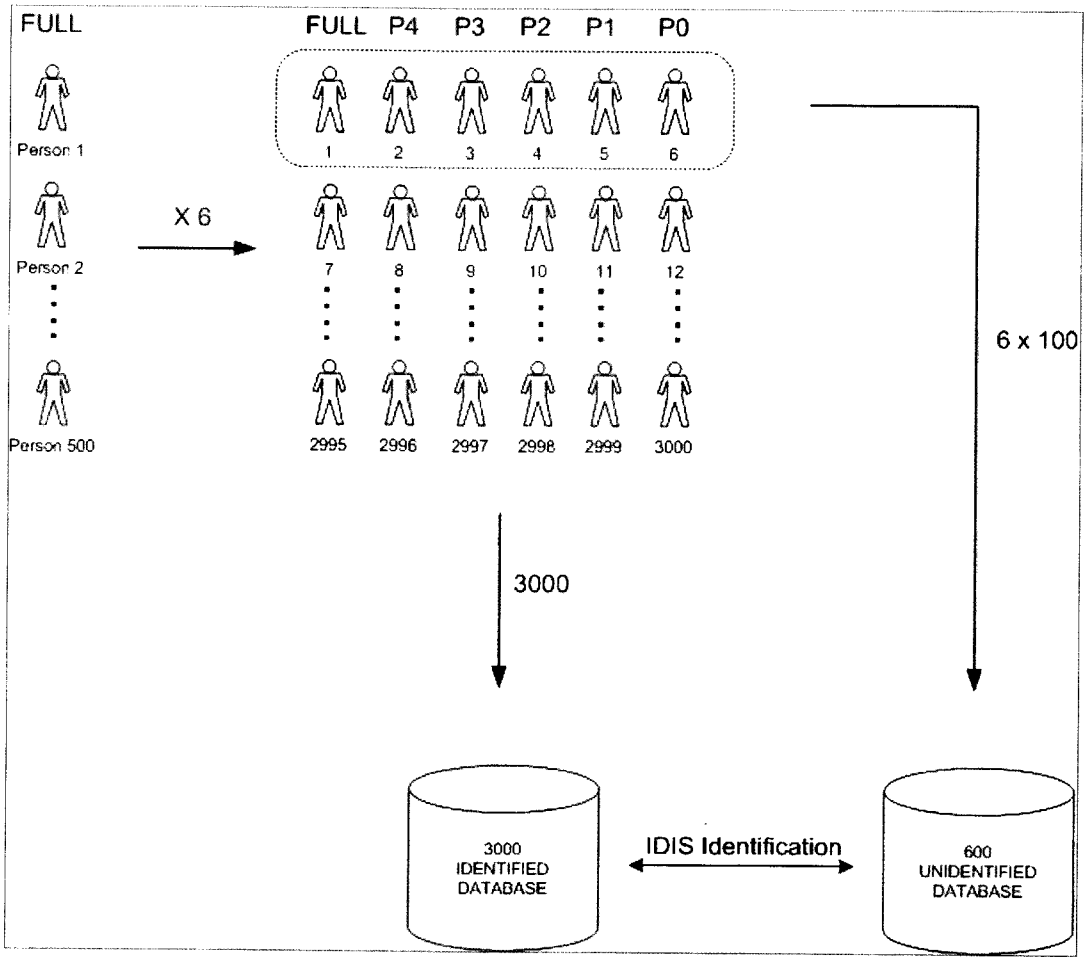

Figure 3. Subjects of this study.

3. **P3 data profile** – contained information of all 20 primary teeth, and 3 of the 4 quadrants of permanent teeth contained information for at least 4 teeth.

4. **P2 data profile** – contained information of all 20 primary teeth, and 2 of the 4 quadrants of permanent teeth contained information for at least 4 teeth.

5. **P1 data profile** – contained information of all 20 primary teeth, and 1 of the 4 quadrants of permanent teeth contained information for at least 4 teeth.

6. **P0 data profile** – contained information of all 20 primary teeth and at least 1 permanent tooth. Each of the 4 quadrants of permanent teeth contained information for less than 4 teeth.

These 3,000 dental records were stored as identified people of IDIS database. Also from the original 500 dental records, 100 records were randomly selected to create unidentified people of IDIS database. This consisted of the 6 corresponding distinguishable personal dental records as simulated from above for a total of 600 unidentified people (Figure 3).

IDIS was setup with specific identification guidelines, models, and scoring methods to map from observed variables of dental information to a number interpreted as probability of identification of the each 600 subject. There were five matching criteria:

1. **Outstanding** – the correct identification was the top ranked individual of the 3,000 identified people database.

2. **Excellent** – the correct identification was within the 2^{nd} to 10^{th} ranked individuals of the 3,000 identified people database.

3. **Good** – the correct identification was within the 11^{th} to 20^{th} ranked individuals of the 3,000 identified people database.

4. **Fair** – the correct identification was within the 21^{st} to 30^{th} ranked individuals of the 3,000 identified people database.

5. **Error** – the correct identification was not within the top 30 ranked individuals of the 3,000 identified people database.

IDIS contained 13 non-redundant identification models designed to support variations within the data structure for each unidentified individual and analyze data that were poorly characterized mathematically. The 13 models were divided into 3 subgroups: elementary method (6 models), moderate method (4 models), and advanced method (3 models).

The elementary method classified the identifications based on minimal discrimination. The results yielded more repetition of possible matches. The moderate method differentiated identifications yielding less repetition of possible matches. The advanced method isolated the identifications in order to find the actual match with greatest probability. It eliminated more possibilities of identifications with the least amount of repetition.

The 600 unidentified people went through the identification procedure to determine the reliability of IDIS. Based on the rules established, IDIS determined the identity of the individuals by utilizing up to 13 of the identification models. Then, percentages were calculated for the number of outcomes within each matching criteria, as specified above.

Results

IDIS utilized up to 13 identification models

per each of the 600 unidentified people which in total generated 4,543 trials (2,247 trials by elementary method, 1,393 trials by moderate method, and 903 trials by advanced method).

Examination of the elementary identification method resulted in an error range of 1.43 % to 8.57 %, while the outstanding results ranged from 71.11 % to 88.81 % (Figure 4). Regarding the moderate identification method, the error results were 0 % for all data profiles except for P0 which was 6.16 %, whereas the outstanding results ranged from 61.14 % to 99.22 % (Figure 5). The advanced identification method was the most successful in identifying unidentifiable individuals. There were no error results for all data profiles except for P0 which was 0.88 %. Most of the results were categorized as either excellent or outstanding. The outstanding results ranged from 82.61 % to 100 % (Figure 6).

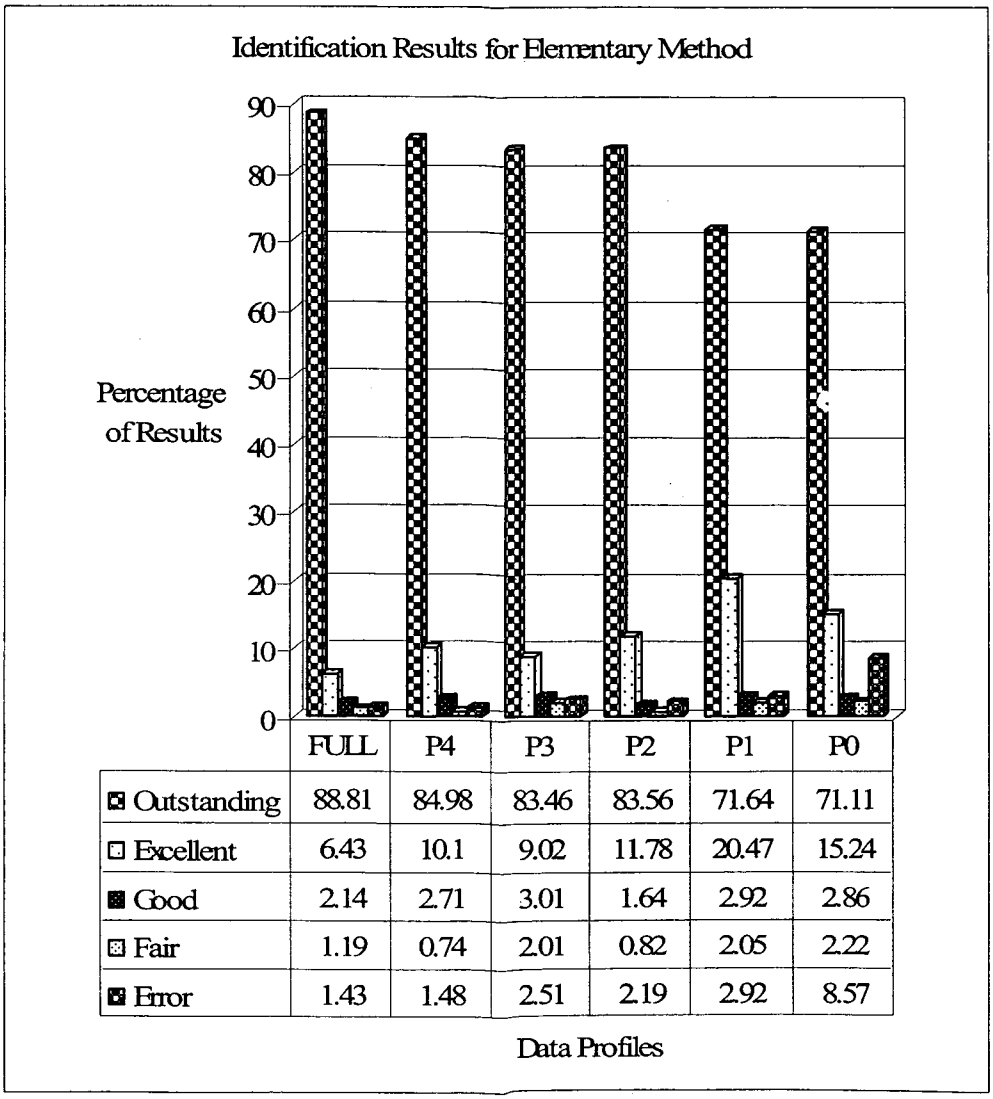

Figure 4. The results of the elementary identification method based on the matching criteria (2,247 trials).

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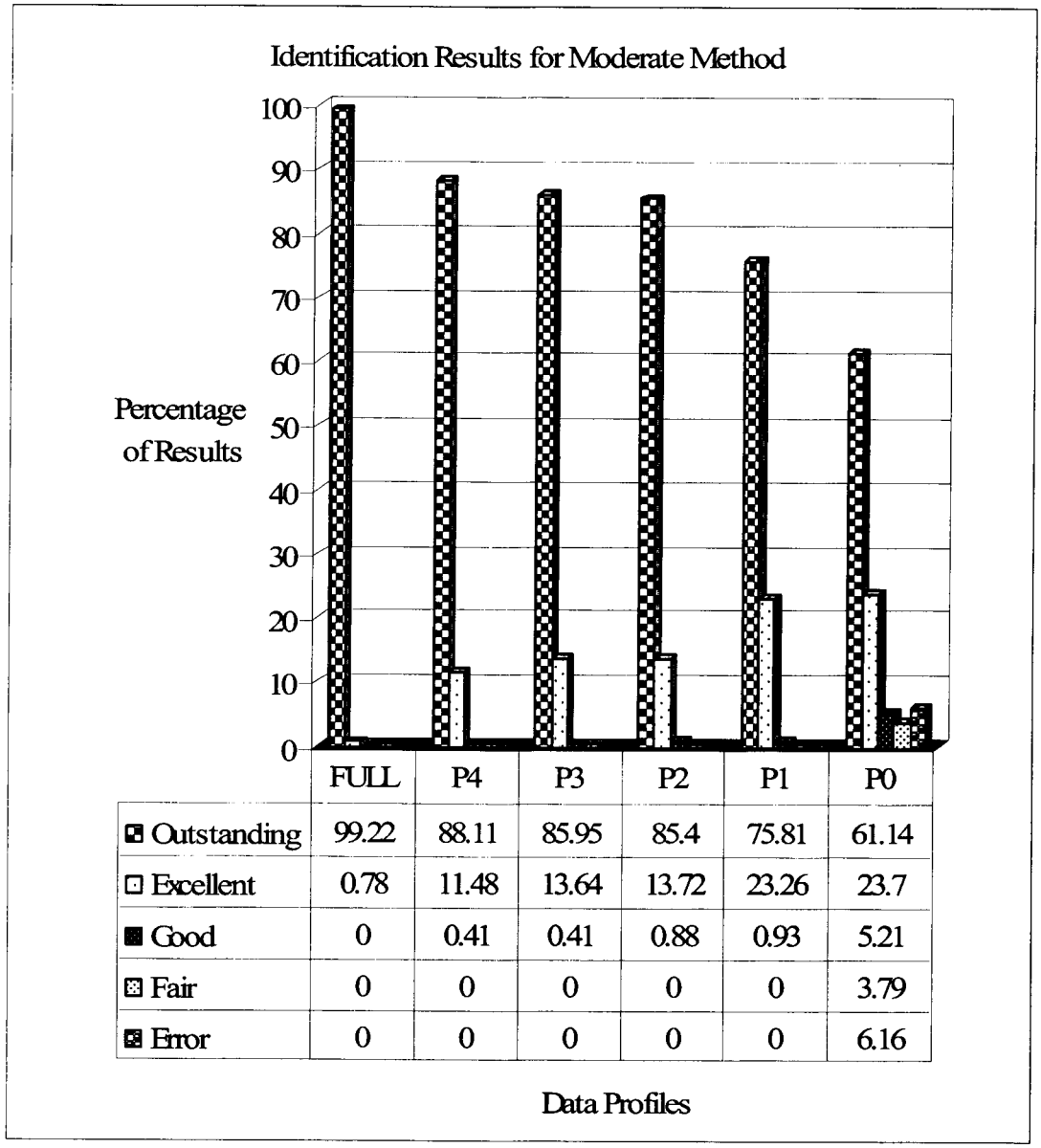

	FULL	P4	P3	P2	P1	P0
Outstanding	99.22	88.11	85.95	85.4	75.81	61.14
Excellent	0.78	11.48	13.64	13.72	23.26	23.7
Good	0	0.41	0.41	0.88	0.93	5.21
Fair	0	0	0	0	0	3.79
Error	0	0	0	0	0	6.16

Figure 5. The results of the moderate identification method based on the matching criteria (1,393 trials).

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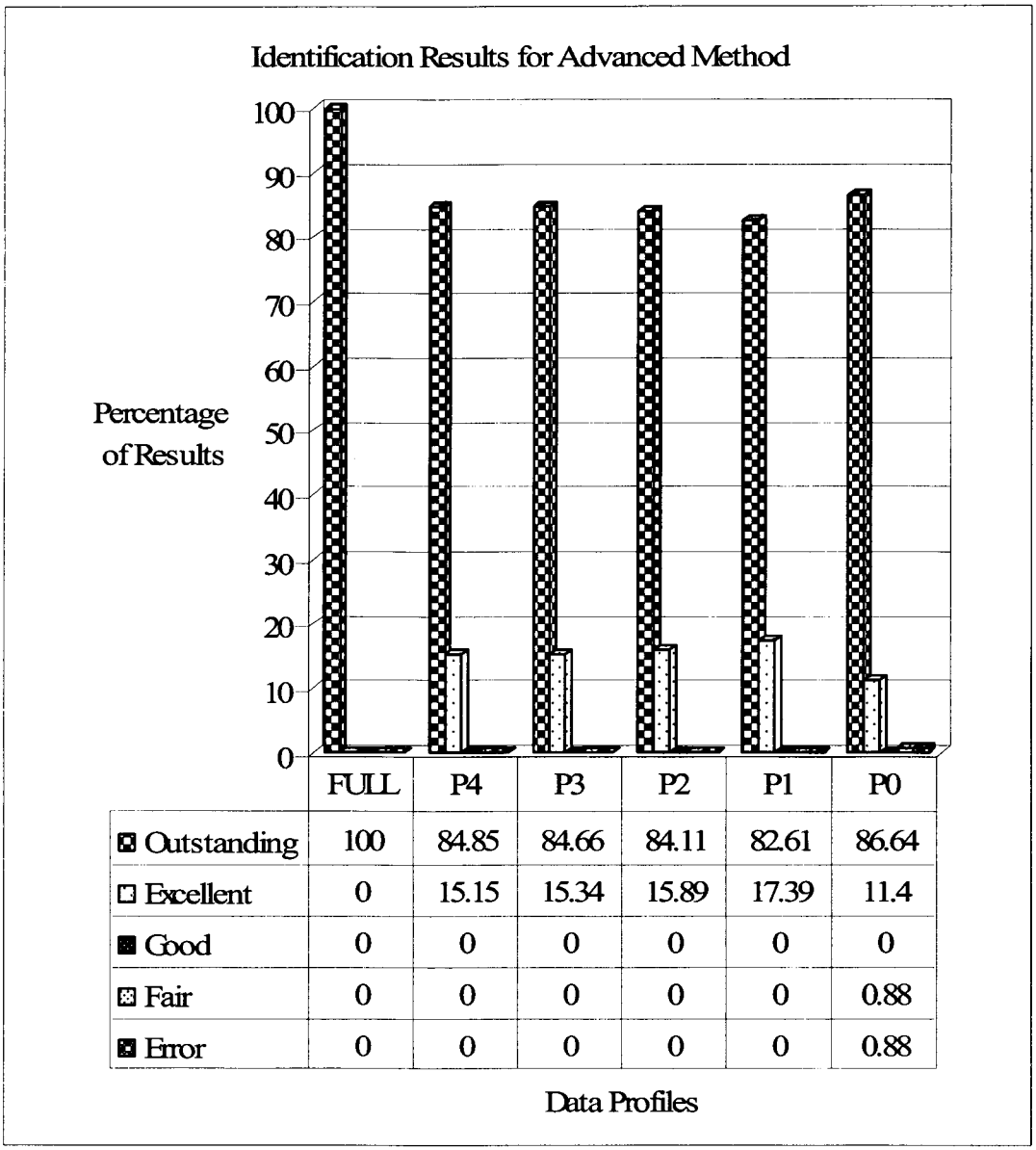

	FULL	P4	P3	P2	P1	P0
Outstanding	100	84.85	84.66	84.11	82.61	86.64
Excellent	0	15.15	15.34	15.89	17.39	11.4
Good	0	0	0	0	0	0
Fair	0	0	0	0	0	0.88
Error	0	0	0	0	0	0.88

Figure 6. The results of the advanced identification method based on the matching criteria (903 trials).

Discussion and Conclusion

The design and development of a computerized dental identification system from this study significantly supported the work of dentists regardless of their affiliation to forensic odontology. IDIS has several benefits: 1) IDIS is user-friendly application, which readily accepts many varieties of dental documentations; 2) IDIS reduces the amount of redundancy data; 3) compare to manual dental identification procedures,[2, 3] IDIS eliminates the amount of time needed to identify an unknown individual by being able to organize and maintain information from many pertinent documents; 4) IDIS evaluates only important and practical knowledge necessary for dental identification from its database; 5) IDIS can store the dental digital images with many processing features (Figure 7).

According to the findings found in this study, IDIS significantly identified correctly the unidentifiable subjects even in circumstances hindered by the incompleteness of dentol informotion. The highest percentage of error occurred within the P0 data profile, those with information for less than 4 permanent teeth of each 4 quadrants. This was due to the limited amount of information available for comparison. However, this was still a minute amount of error and the results were still reliable. The greatest amount of success was found for individuals with Full data profile. Clearly, there was a correlation between the amount of information available for each individual and the reliability of results.

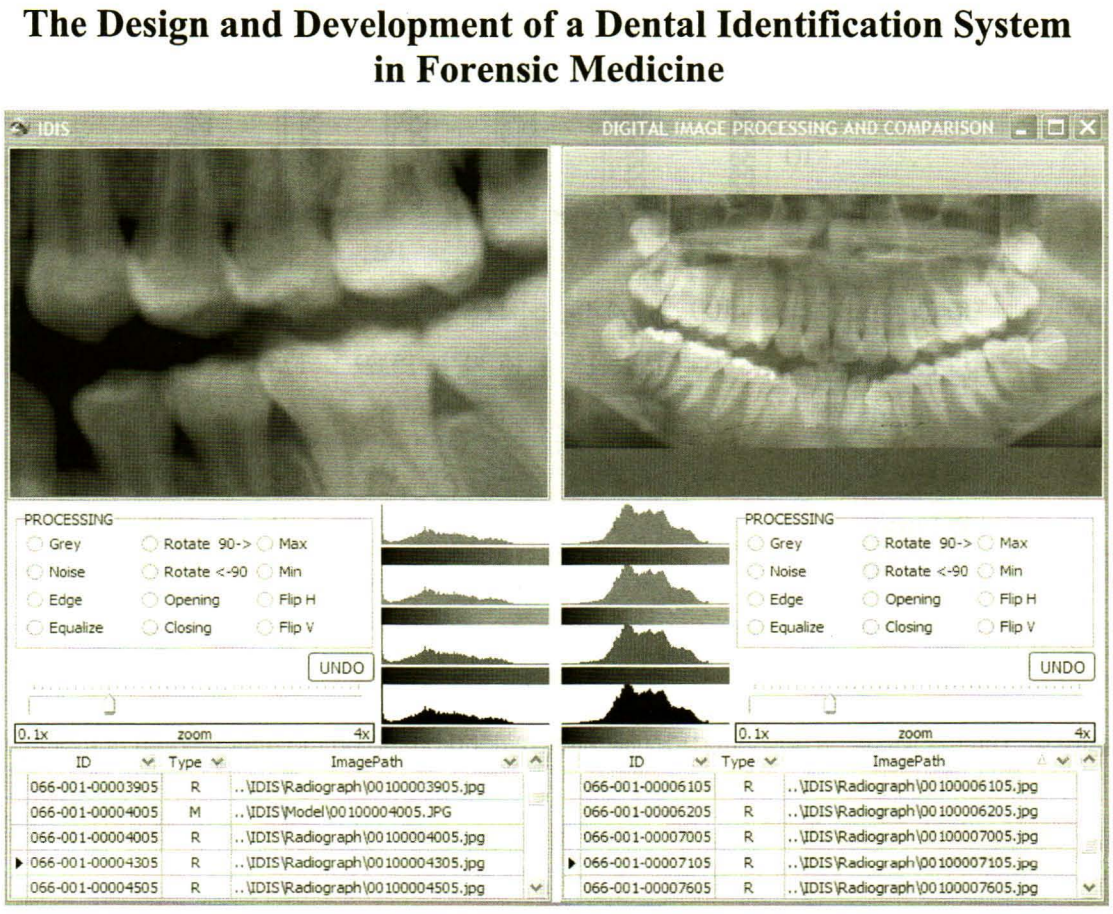

Figure 7. Digital Image processing of IDIS.

There is sufficient evidence to conclude that IDIS is dependable in assisting dentists in identifying unidentifiable individuals with incomplete dental information regardless of whether the dentists are specialized or not in forensic odontology. The unidentifiable subjects may have primary, mixed, or permanent dentition.

The results of dental identification may be hindered by the alterations of dental information due to natural occurrences and general dental treatments after the last clinical examination. Further study is recommended to develop a computerized intelligent dental identification system addressing this concern.

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