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2022년 8월
박사학위논문

The analysis of forensic odontological examinations at the National Forensic Service of Korea from 2007 to 2016

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최근 10년간(2007-2016) 국립과학수사연구원 법치의학 감정유형 분석과 실무적 제언

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지도교수 안 종 모

이 논문을 치의학 박사학위신청 논문으로 제출함

2022년 4월

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국문초록

최근 10년간(2007-2016) 국립과학수사연구원 법치의학 감정유형 분석과 실무적 제언

노 병 윤
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연구목적: 국립과학수사연구원은 형사사건의 증거물에 대한 법과학적 분석을 담당하는 한국의 국가기관으로, 국립과학수사연구원 내의 법치의학실은 시신에 대한 법치의학적 감정을 수행하고 있다. 본 연구는 국립과학수사연구원에서 수행한 10년간의 법치의학 감정의 현황과 추세를 분석하여 향후 연구와 훈련의 방향을 모색하기 위하여 이루어졌다.

연구대상 및 연구방법: 본 연구는 2007년부터 2016년까지 국립과학수사연구원 법치의학실에 의뢰된 감정건들의 의뢰패턴, 의뢰건수, 감정물 종류, 감정의뢰 사항 등을 조사하였으며, 5년씩 나눠서 그 결과를 비교하여 변화양상을 파악하여 보았다.

결 과: 감정물의 연간 의뢰량은 매년 유사한 수준으로 의뢰되었고, 따뜻한 계절에 많이 의뢰되었다. 감정물의 의뢰는 외부기관에서 직접 의뢰되지 않고, 부검 후 추가적인 검사를 위하여 의뢰되는 경우가 점점 많아졌다. 도심 지역에서 의뢰되는 경우가 많았지만, 지방에서 의뢰되는 비율이 증가하였고, 산악 지역에서 증거물들이 주로 발견되었다. 법치 검사 및 법의인류학 검사 모두를 위하여 치아와 뼈가 같이 의뢰되는 경우가 많았다. 감정의뢰는 불상의 시신의 생물학적인 프로필 확인을 위하여, 특히 연령감정을 위해

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의뢰되는 경우가 많았고, 그 비중은 점점 증대되었다. 연령 감정, 성별 추정의 결과는 40-50대, 남성의 비중이 높았다.

결 론: 본 연구는 국립과학수사연구원에 의뢰된 법치의학 감정을 분석해보고 변화 양상을 파악하여 보았다. 특히나 감정의뢰항목에서 프로파일링, 특히 연령감정의 비율이 높게 나타났으며, 치과적 신원확인, 교흔 분석 등의 비율을 낮고 그 경향은 심해졌다. 이 결과는 향후 법치의학 연구 및 훈련에 중요한 참고자료가 될 것으로 사료된다.

주제어: 법치의학, 연령감정, 신원확인, 국립과학수사연구원

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I. Introduction

The F d ration Dentaire Internationale defines forensic odontology as the branch of dentistry that, in the interest of justice, deals with the proper handling and examination of dental evidence and the evaluation and presentation of dental findings [1].

Tooth enamel is the hardest substance in the human body and is highly resistant to decomposition, water immersion, and fire [2]. The presence, arrangement, shape, and restoration of teeth are characteristic of individuals and thus useful in forensic odontological examinations to identify individuals, particularly in mass casualties [3-6]. Age estimation using teeth is highly accurate; therefore, forensic odontology has been widely used for age estimation [7-10]. Moreover, with the increasing trend of immigration worldwide, forensic odontology has been widely applied to estimate the age of immigrants [11-15].

The National Forensic Service (NFS) was established to conduct forensic analysis and research crime evidence in 1955, and is now affiliated with the Ministry of the Interior and Safety of Korea. The NFS conducts most forensic examinations for criminal cases in South Korea. The Section of Forensic Odontology of the NFS was established in 1969 to conduct dental examinations of criminal evidence. The Section of Forensic Odontology is usually responsible for identification, age estimation, bite-mark analysis, and forensic anthropological examinations [16]. In particular, forensic odontologists have played an important role in identifying victims of several mass disasters in Korea, such as the Mosan school trip bus crash in 1970 and the Daeyeonggak hotel fire in 1971. More recently, forensic odontology was used to identify the 502 victims of the Sampoong Department Store collapse in 1995, Korean Air Flight 801 crash in

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1997, Air China Flight 129 crash in 2002, Daegu subway fire disaster in 2003, Indian Ocean earthquake and subsequent tsunami in 2004 [16], Icheon warehouse fire in 2008 [17], and sinking of MV Sewol in 2014.

In 2011, Lee et al. [18] analyzed forensic odontological cases referred to the NFS between 2007 and 2010. They reported that most cases were referred for "postmortem profiling" and proposed a multi-team approach for examination, education of law enforcement personnel, and establishing an antemortem database to improve the quality and quantity of forensic dental analysis. In 2018, Roh et al. [19] examined forensic odontological cases referred to the NFS from 2011 to 2015 and compared them with those in the study by Lee et al. (2011), to observe and confirm trends in practical cases in forensic odontology. Some studies have analyzed autopsy cases [20, 21]; however, no reports analyzing forensic odontological examinations, especially those performed at the national level, have been published internationally. This study was based on the study by Roh et al. (2018) and analyzed evidence referred to the NFS for 10 years from 2007 to 2016, compared the results between 2007-2011 and 2012—2016, identified their trends, and sought future research and training directions for more accurate and efficient forensic odontological practices.

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Ⅱ. Materials and Methods

All materials analyzed in this study were submitted to the Section of Forensic Odontology from 2007 to 2016 as evidence in suspected criminal cases, mainly those involving unidentified bodies, especially skeletonized remains. Materials from 1227 cases were examined and divided into 5-year intervals, and the results were compared between the 2007-2011 and 2012-2016 periods. The examined data of the evidence materials included the origin of the request, yearly and monthly distributions, regional distribution, type of evidence, discovery locations, requested examination criteria, and examination results. If evidence from two or more individuals was included in one case, each piece of evidence was regarded as independent material when analyzing the examination results. Six cases were identified by fingerprint and DNA analyses during examination, but forensic dental analyses of these cases were not completed. Therefore, they were excluded from the analysis of the examination results; however, these cases were included in the analysis of the referral patterns.

2.1 Origins of request

The origins of requests were classified as either "internal" (from other departments in the NFS for further dental examination after autopsy) or "external" (directly from police departments or prosecutors).

2.2 Types of evidence materials

The evidence materials were categorized into four types: "teeth," "bone", "bone and teeth", and "others". The category "teeth" included loose teeth and resected jaws. "Bone" included skeletal remains, except skulls with teeth. If examinations of the teeth and bone were

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both requested, the material was classified into the "bone and teeth" category. Likewise, for examinations of a skull with teeth, the material was classified into the "bone and teeth" category. The category "other" included bite marks and dental records (i.e., dental charts, insurance information, and radiographs).

2.3 Yearly and monthly distributions

The yearly and monthly distributions were classified according to the date of request.

2.4 Regional distribution

The regions where the evidence was found were classified based on police districts.

2.5 Discovery locations

The locations of the recovered evidence were classified as ground or water. The "ground" category included mountains, construction site, flat land (i.e., roadside, paddy fields, etc.), and other (i.e., automobiles). Water was classified as freshwater or saltwater. Water tanks and other locations were classified as "other".

2.6 Requested examination criteria

The criteria for the requested examinations were classified as dental identification, bite-mark analysis, or postmortem biological profiling, such as the estimation of age, sex, or stature.

2.7 Examination results

The distributions of age and sex according to the examination results were analyzed.

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Differences in the number of requests for each year, each region, and the estimated age group were tested using the Chi-square goodness-of-fit test. With regard to annual distribution, the Mann-Whitney U test was conducted to evaluate significant differences in the annual distribution between 2007-2011 and 2012-2016. For other examinations, the results for 2007-2011 and 2012-2016 were compared using the Chi-square test and were checked for consistency. All analyses were performed using R software (ver. 4.0.5; R Foundation for Statistical Computing, Vienna, Austria).

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Ⅲ. Results

The examined objects were mostly unidentified bodies, especially skeletonized remains. Most cases were internally referred for further examination after autopsy (843 cases), whereas few cases were directly referred from requesting agencies, such as police departments (384 cases; Figure 1-A). Internal and external requests accounted for 57.8% and 42.2% and 80.1% and 19.9% of cases in the 2007-2011 and 2012-2016 groups, respectively. Most cases tended to be internally requested for further examination after autopsy (Table 1, Figure 1-B).

The number of annual requests from 2007 to 2016 is shown in Table 2 and Figure 2-A. There was a statistically significant difference in the number of annual requests. The number of case requests increased in 2011 and 2012, decreased in 2013 and 2014, and recovered in 2015 and 2016. The results for 2007-2011 and 2012-2016 are shown in Figure 2-B, and there was no statistically significant difference between the two groups. ($p = 0.548$).

The monthly distribution of accumulated requests from 2007 to 2016 is presented in Table 3 and Figure 3-A. The monthly distributions were significantly different. A comparison of the results for 2007-2011 and 2012-2016 is shown in Figure 3-B. Overall, there was a trend for cases to be commissioned frequently during the warm seasons, and there were few requests during the winter season (December to February). From 2007 to 2011, the number of examinations was high in summer and fall; and from 2012 to 2016, the number of examinations increased in April and September, and decreased in July. However, the results for 2007-2011 and 2012-2016 do not show a significant difference ($p = 0.127$).

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The most common examination materials were "teeth and bones" (579 cases), followed by "teeth" (487 cases). "Bone" was the evidence material in relatively few cases (115 cases). There was no significant difference between the results of 2007-2011 and those of 2012-2016 ($p = 0.391$) (Figure 4).

A significant difference was observed in the number of regional distributions (Table 4). Most requests originated in the regions of Gyeonggi-do (26.5%), followed by Incheon (12.6%), Seoul (11.5%), Gangwon-do (7.9%), Jeollabuk-do (6.3%), and Gyeongsangbuk-do (7.1%), while a few requests originated in Ulsan (1.1%) and Gwangju (1.0%). The proportion of requests from metropolitan cities (Seoul, Incheon, Gwangju, Daejun, Daegu, Ulsa, and Busan) was 31.3%, and that from small- and medium-sized cities and suburban and rural areas was 68.8%. The proportion of requests from metropolitan cities in 2012-2016 (29.7%) was smaller compared to that in 2007-2011 (32.8%) [17], and requests from suburban and rural areas increased ($p = 0.000$) (Figure 5).

Regarding the location of the evidence, 640 cases were recovered from the ground and 310 from water (Table 5). Among the materials found on the ground, 390 were recovered from mountains and 250 were found on flat land and buildings. In many cases, the material is exposed on the surface rather than being buried. Among the bodies found in water, 205 were recovered from the sea. Comparing the results between 2007-2011 and 2012-2016, this trend showed a more intense pattern ($p = 0.000$) (Figure 6).

Regarding the examination criteria, most requests were for postmortem profiling (age, sex, and stature estimation) of unidentified bodies (90.4%; Figure 7, 8-A). Compared with the results for 2007-2011 (86.7%), the number of requests increased significantly in 2012-

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2016 (94.2%) (p = 0.000) (Figure 8-B). Most requests were for age estimation, with few requests for identification using dental records (3.6%), and those for bite analysis were very rare (0.6%). Requests to determine the cause of death (4.8%) and postmortem interval (4.3%) were also very rare, as were commissions for differentiating human bones from animal bones (1.7%).

Among the examination results, the estimated age was 40-49 years in 33.8% of cases and 50-59 years in 25.1% (Table 6). More than 50% of the identification results were obtained for individuals aged 40-59 years. The proportions were similar between the five-year periods (p=0.057; Figure 9-A). Among the requests for sex discrimination, 79.4% of the cases were identified as male and 20.6% as female. The identification of males was four-fold greater than that of females and was similar for the two five-year periods (p=0.496; Figure 9-B).

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Table 1. Comparison of the of origins of requests in 2012-2016 with the results in 2007-2011

	2007-2010	2011-2016	
Internal request	361 (54.8%)	482 (80.1%)	p =.000
External request	264 (42.2%)	120 (19.9%)	
total	625	602	

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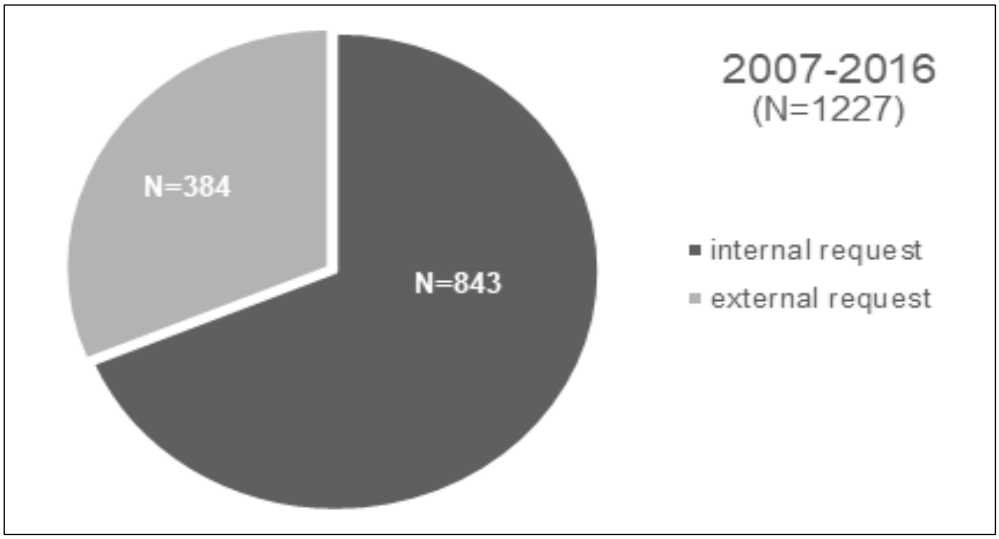
Fig. 1. Origins of requests of cases (Internal request means the request from other departments in NFS after autopsy, while external request means the request directly from police departments or prosecutor.)

(A) Distribution of origins of request in 2007-2016



(B) Comparison of the percentage of origins of requests in 2012-2016 with the results in 2007-2011

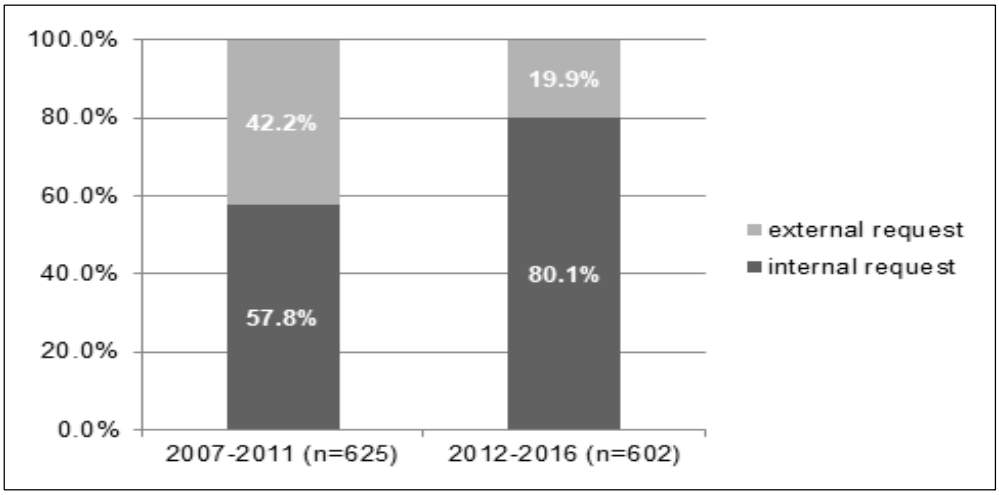


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Table 2. Yearly distribution of cases referred in 2007-2016

year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
number of cases	90	146	145	121	123	142	109	99	115	137	p=.000

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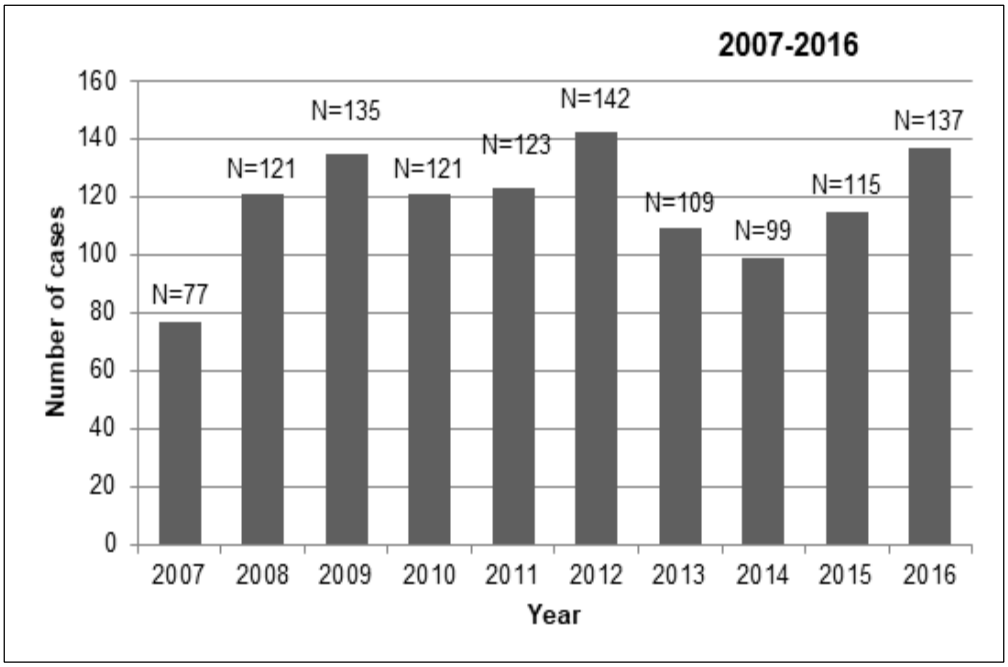
Fig. 2. Yearly distribution of requested cases

(A) Yearly distribution of cases referred in 2007-2016



(B) Comparison of the average of number of cases referred in 2012-2016 with those in 2007-2011

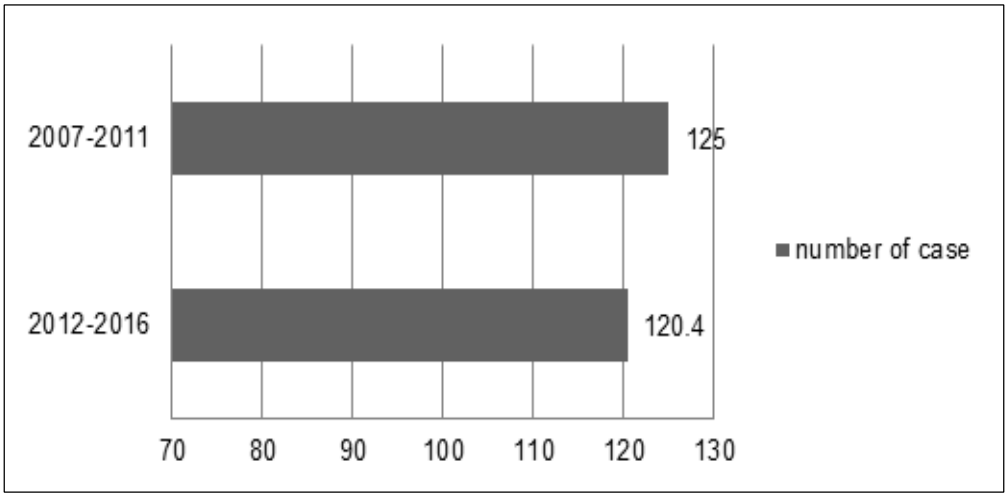


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Table 3. Monthly distribution of the accumulated cases in 2007-2016

month	1	2	3	4	5	6	7	8	9	10	11	12	
number of cases	87	61	68	109	99	96	140	118	175	126	84	64	p=.000

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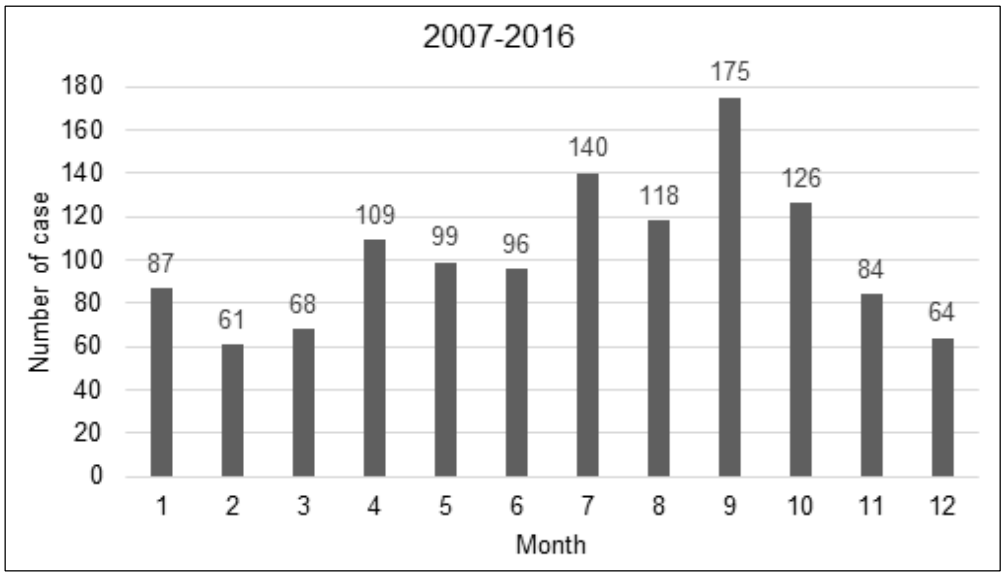
Fig. 3. Monthly distribution of the accumulated cases

(A) Monthly distribution of the accumulated cases in 2007-2016



(B) Comparison of the proportion of monthly distribution in 2012-2016 with those in 2007-2011

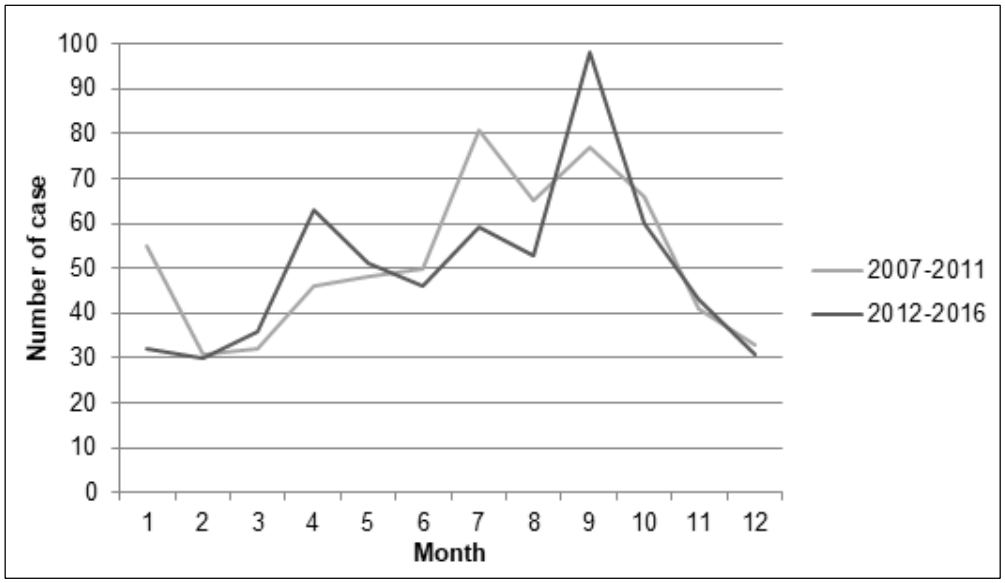


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Fig. 4. Distribution on the types of evidence materials requested in 2007-2011 and in 2012-2016

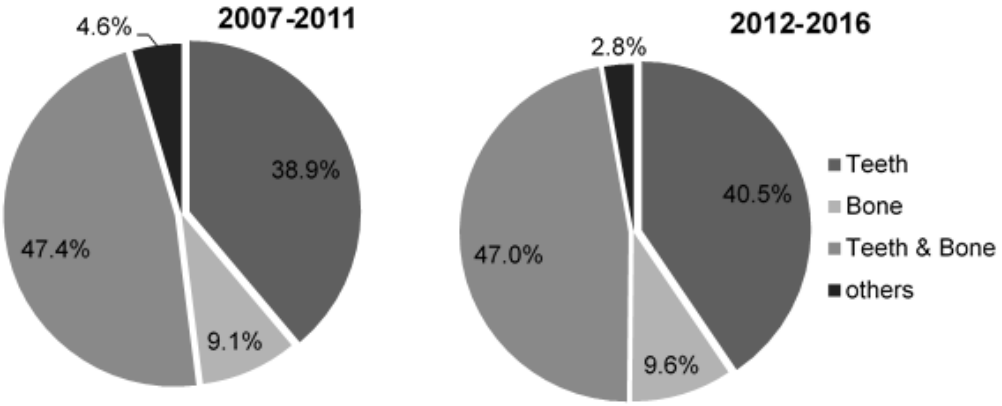

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Table 4. Regional distribution of requested cases in 2007-2016

Region	2007-2016	
Seoul	141 (11.49%)	p=.000
Gyeonggi-do	325 (26.49%)	
Incheon	155 (12.63%)	
Daejeon	12 (0.98%)	
Chungchongbuk-do	48 (3.91%)	
Chungchongnam-do	48 (3.91%)	
Gangwon-do	97 (7.91%)	
Gwangju	12 (0.98%)	
Jeollabuk-do	77 (6.28%)	
Jeollanam-do	72 (5.87%)	
Daegu	17 (1.39%)	
Ulsan	13 (1.06%)	
Busan	34 (2.77%)	
Gyeongsangbuk-do	72 (5.87%)	
Gyeongsangnam-do	65 (5.30%)	
Jeju-do	23 (1.87%)	
Other	16 (1.30%)	
Total	1227	

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Fig. 5. Regional distribution of requested cases in 2007−2011 and in 2012−2016

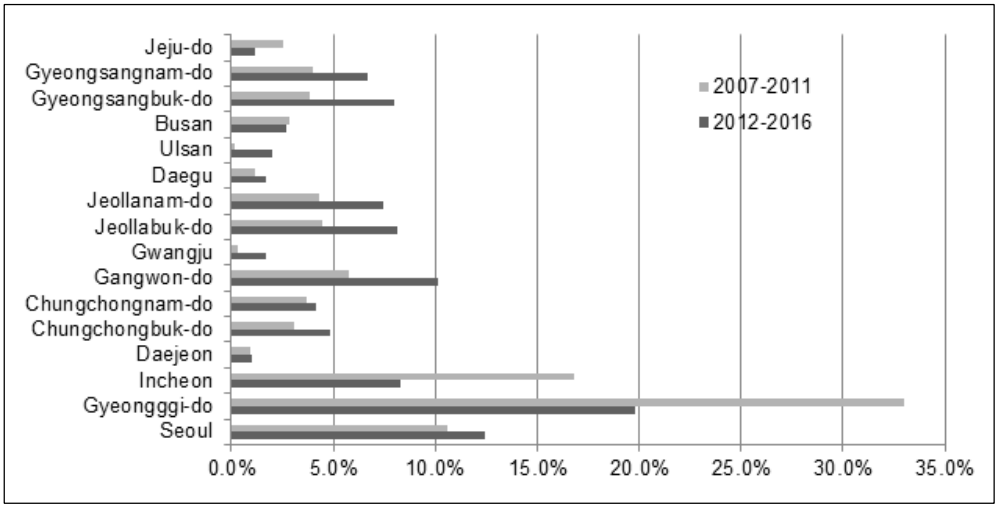

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Table 5. Distribution of discovery locations of evidence materials in 2007-2016

		number of case	
Ground	Buried (mountain)	57 (4.6%)	p=.000
	Surface (mountain)	333 (27.1%)	
	Buried (flat land)	55 (4.5%)	
	Surface (flat land)	86 (7.0%)	
	Buried (construction site)	25 (2.0%)	
	Surface (construction site)	84 (6.8%)	
Underwater	Sea	205 (16.7%)	
	River	87 (7.1%)	
	Other	18 (1.5%)	
Other		126 (10.3%)	
Unidentifed		151 (12.3%)	
	Total	1227	

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Fig. 6. Distribution of discovery locations of evidence materials in 2007-2011 and 2012-2016

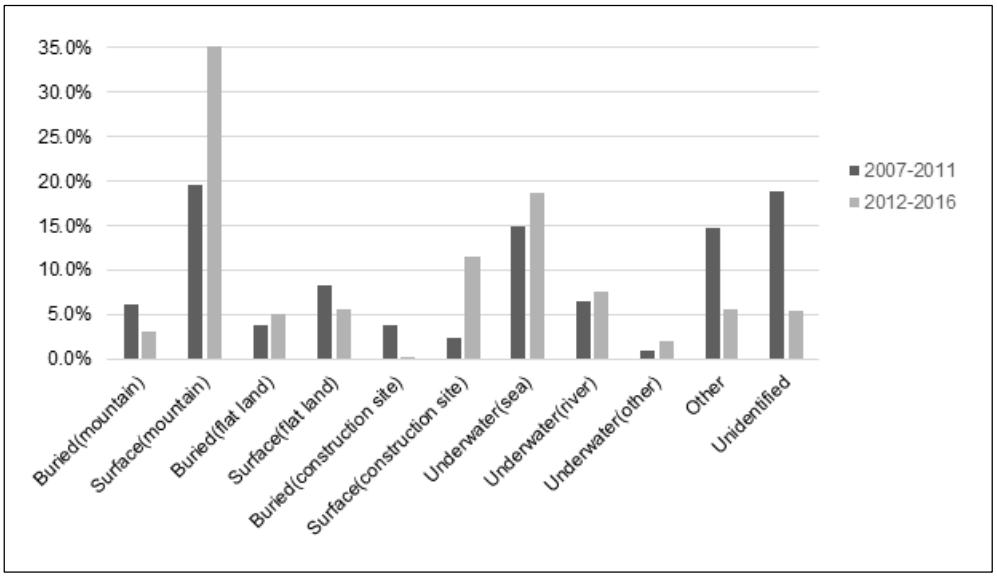

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Fig. 7. Distribution of the type of requested examinations in 2007-2016

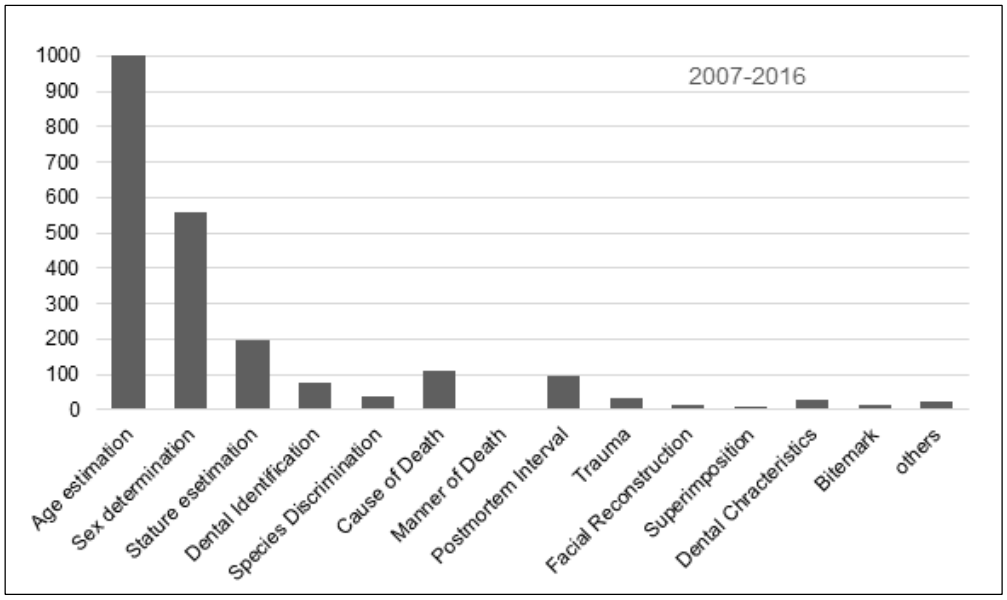

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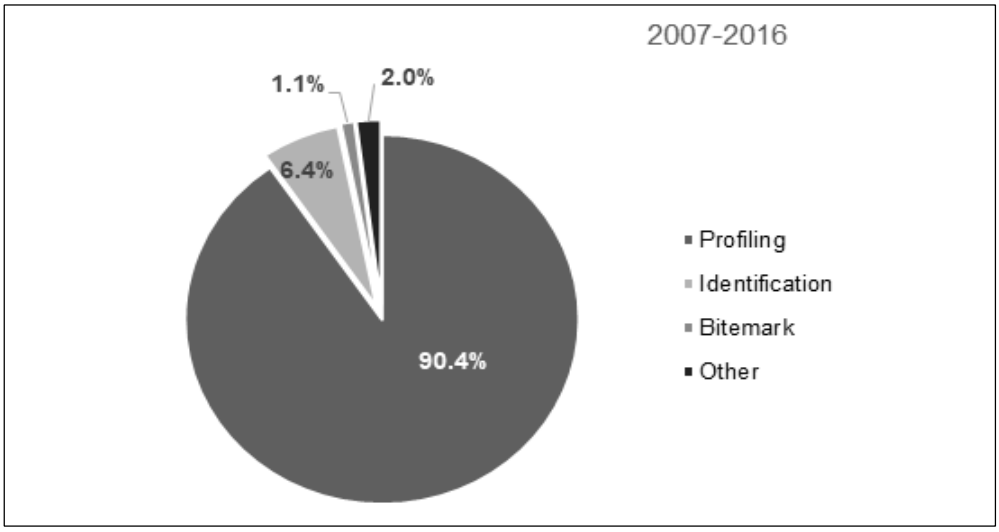
Fig. 8. Examination criteria ("Profiling" means that cases without antemortem records were requested for age/sex/stature estimation, whereas "Identification" means that cases with antemortem data were requested to compare between antemortem and postmortem data.)

(A) Distribution of the examination criteria in 2007-2016



(B) Comparison of the proportion of examination criteria in 2012-2016 with the data in 2007-2011

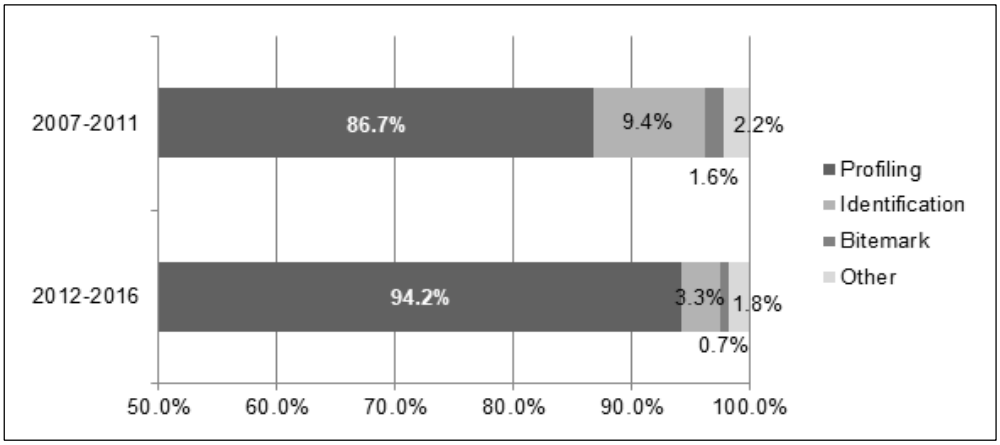


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Table 6. Distribution of estimated ages in 2007-2016

Age (year)	2007-2016	
0-9	26 (2.71%)	p=.000
10-19	29 (3.02%)	
20-29	48 (4.99%)	
30-39	154 (16.02%)	
40-49	325 (33.82%)	
50-59	241 (25.08%)	
60-69	115 (11.97%)	
70~	23 (2.39%)	
Total	961	

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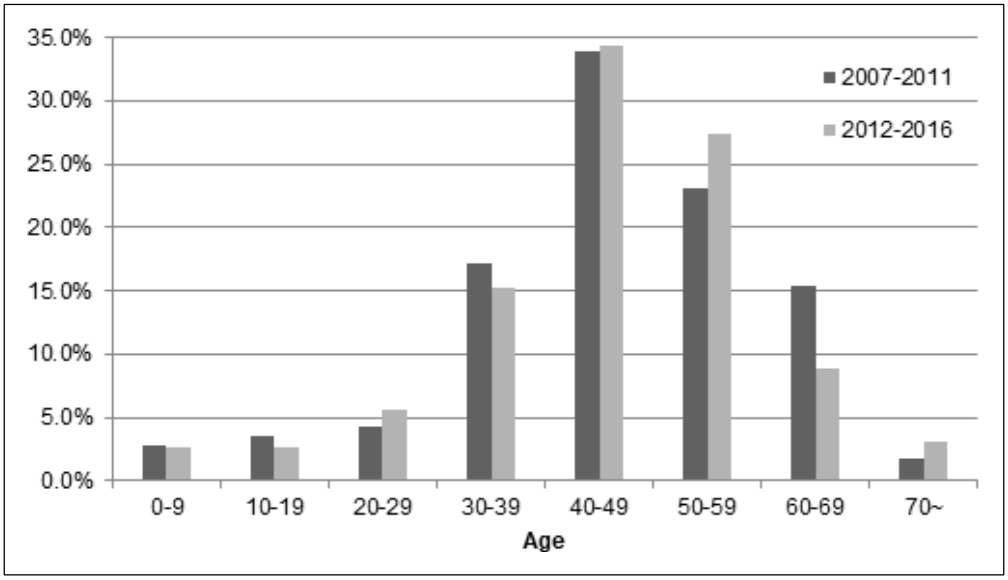
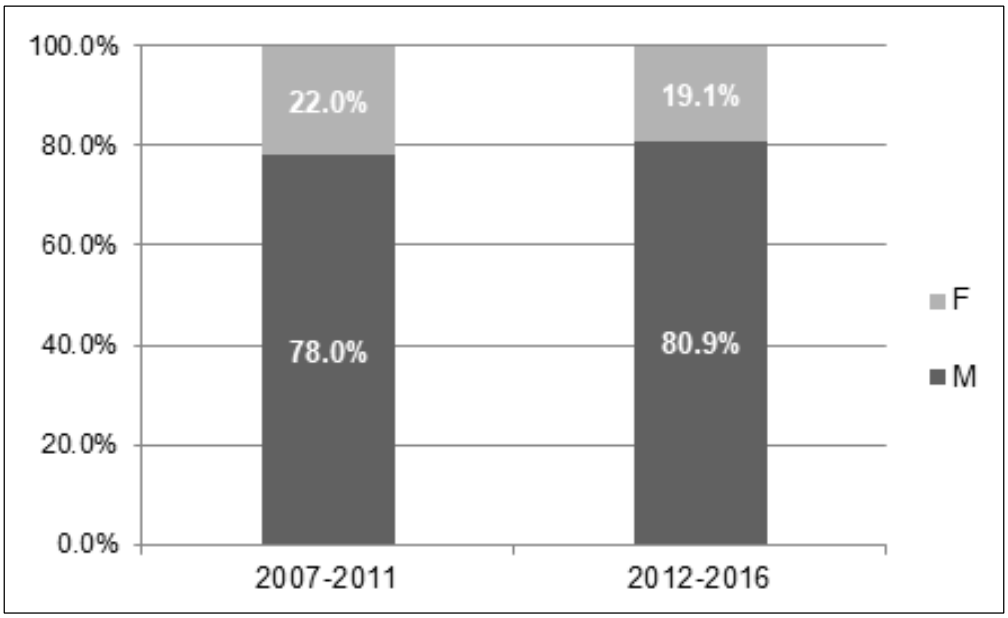
Fig. 9. Distribution of estimated ages (separated in eight different age groups) and sexes

(A) Percentage of estimated age in in 2007-2011 and 2012-2016



(B) Percentage of estimated sexes in 2007-2011 and 2012-2016



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Ⅳ. Discussion

This study analyzed cases referred to the Section of Forensic Odontology of the NFS between 2007 and 2011 and compared the results between 2007-2011 and 2012-2016. A total of 1277 cases were examined, and most of the materials were from suspected crime victims, as the NFS of Korea mainly handles evidence in criminal cases. When there is a need to estimate an individual's age in South Korea, the estimation is usually performed at a university dental hospital [22]. Furthermore, there are fewer requests to identify immigrants and refugees in South Korea than in European countries [23-25].

Regarding the origin of requests, the maximum cases were internal requests (68.7.0%; Figure 1). In the past, skeletonized bodies were often referred directly to the Section of Forensic Odontology for identification purposes by requesting agencies. However, the number of internal requests has recently increased significantly because the perception of bone evidence by police departments has changed from being considered examination materials to being regarded as human bodies. The increase in the number of autopsies performed in Korea may also have contributed to this increase. Meanwhile, regarding the types of evidence materials, teeth were submitted routinely, and forensic odontological and anthropological examinations of entire skulls were frequently requested. For accurate and effective forensic odontological examination, close cooperation with other forensic experts, especially forensic anthropologists and forensic pathologists, is required, considering the routes of requests and types of evidence materials. It is also important to share information about the examination methods with other forensic experts.

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With regard to yearly distribution, there was no significant difference between 2007-2011 and 2012-2016. However, the number of cases decreased slightly in 2013 and 2014, which may be attributed to the confusion caused by the relocation of the NFS head office from Seoul to Wonju. In 2015 and 2016, the number of examinations returned to the previous levels (Figure 2). The increase in the number of examinations conducted in 2015 and 2016 was also likely influenced by the increase in the number of autopsies after the identification of Yoo Byung-eun, the de-facto owner of the ferry MV Sewol, which sank in April 2014. After the accident, he was found dead two months after his disappearance. There were strong doubts about his identity and cause of death, which caused severe social confusion [26]. Thereafter, the police department decided to refer all decomposed and skeletonized remains to the NFS for autopsy, which significantly increased the number of cases of autopsy and forensic odontological examination. Regarding monthly distributions, the number of monthly examinations was high in the warm season, which is likely due to the increase in the chance of coming across skeletal human remains as outdoor activity increases. Two peaks in the number of cases occurred in April and September, from 2012 to 2016 (Figure 3). Compared to the results from 2007 to 2011, requests increased considerably in spring, especially in April. The relatively small number of requests in April from 2007 to 2011, particularly in 2009 and 2010, likely contributed to this result. Further studies are needed to clarify this trend. In contrast, there were fewer requests from November to February as outdoor activities are commonly avoided in the winter season. Annual and monthly statistics are important for effectively allocating manpower and resources to perform forensic dental examinations efficiently. It

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should be noted that the reason the number was relatively high in January in the 2007-2011 group was that disaster victim identification cases due to a fire in 2008 were included [17].

Regarding regional distributions, although metropolitan cities (Seoul, Incheon, Gwangju, Daejun, Daegu, Ulsa, and Busan) have large populations and high population densities, the proportion of requests from these areas was relatively lower than that from other regions. This is because of the high population density and many developments in metropolitan cities, suggesting that the frequency of discovering skeletonized remains is lower. As suburban and rural areas have relatively lower population densities and more mountains and fields, it is more likely that severely decomposed bodies will be discovered. In addition, the increase in the number of requests for suburban and rural areas may have been affected by the increase in lonely deaths owing to the decrease in the population of rural areas and the aging population [27]. It is believed that manpower should be deployed to consider regional distribution for effective examinations.

Meanwhile, the discovery locations of the evidence materials were mainly mountains. This is related to the geographical characteristics of Korea, since more than half of the terrain is mountainous, and abandoning a dead body or committing homicide or suicide in remote areas is not uncommon. Because remains in mountainous areas are usually found too late, they are often badly decomposed or skeletonized. Therefore, the proportion of examination requests from mountainous areas was relatively higher than that from other locations. This is similar to the results of a previous study [18]. Because evidence materials were primarily collected in mountainous areas, it is believed that training is required for more accurate collection. In addition, this result should be referred to in future studies on body

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putrefaction and postmortem intervals.

Age estimation and sex determination revealed that most remains were from bodies aged 40–50 years, with a much higher percentage of males. These results are consistent with the sex and age of suicide and murder victims in Korea [28]. Since there is a small influx of refugees and immigrants in Korea, the number of requests for age estimation of minors is low. Currently, age estimation based on dental development in various demographic groups is actively being studied; however, these results suggest that more research on age estimation for adults, including the elderly, is necessary to increase the accuracy of the estimation.

Concerning the criteria of the requested examinations, the proportion of requests for profiling, such as age estimation, was overwhelmingly high (90.4%), while requests for dental identification were few (6.4%) and those for bite mark analysis were very rare (1.1%). Comparing the results for 2012–2016 with those for 2007–2011, the proportion of profiling increased from 86.7% to 94.2%. In Korea, people's fingerprints are registered, so the proportion of dental identification is relatively low compared to that in other countries [29, 30]. However, the decrease in dental identification is because DNA matching is mainly performed for human identification and is regarded as the first choice in Korea. DNA analysis provides quantitative results that are easy for police, lawyers, and the general public to understand. In Korea, the government bears the cost of DNA analysis in criminal cases. Moreover, collecting evidence is relatively simple for the police in Korea. According to the “Medical Service Act” of Korea, medical information, including dental data, is regularly protected. Medical records can be revealed only to patients or their families, after verifying documents showing that they are

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related. Even if data are to be used for identification, the only way to obtain dental information for non-family members is to obtain a warrant from the court. Therefore, it is time-consuming to obtain dental information from a local clinic. However, DNA samples can be easily obtained from family members. Therefore, DNA analysis is widely used in Korea. This trend is similar to that observed in other countries. The examination criteria in this study suggest that future training and research in forensic odontology should focus on profiling, particularly age estimation.

Various methods are used for age estimation (Table 7). Recently, artificial intelligence technology has been widely introduced in the field of forensics and many studies have been actively performed, with highly accurate and precise results, especially in forensic odontology and age estimation [31, 32]. For more accurate and precise forensic odontological practice in Korea, further research using artificial intelligence for age estimation is required.

However, in Korea, there is no database of dental examination records of missing person or unidentified bodies. Therefore, dental identification is not widely performed. For the active use of dental identification, the establishment of a database for dental records of missing persons and unidentified bodies is needed.

This study had some limitations because the available data were limited. Because only data from 2007 are available and there were restrictions of time and procedure to obtain data, we could only collect the data for a 10-year period (2007-2016). In future, collecting data of forensic odontological examination and the analysis of trends will be needed continuously.

This study was conducted to analyze cases referred to the Section of Forensic Odontology in the NFS and to use the results as basic

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data for more accurate and efficient forensic odontological practice. In particular, regarding the examination criteria, this study showed that forensic profiling, especially age estimation of unidentified bodies accounted for an overwhelming majority of cases, and the proportion has increased compared with the past. These trends can provide a reference for designing studies and creating training protocols for forensic odontologists.

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Table 7. List of Dental Age Estimation Methods used at the NFS [18]

Auther(s)	Year of Publication
Anderson et al. [33]	1976
Bang & Ramm [34]	1970
Chailet et al. [35]	2005
Choi & Kim [36]	1991
Demirjian et al. [37]	1973
Drusini et al. [38]	1997
Johanson [39]	1971
Kvaal et al. [40]	1995
Lamendin et al. [41]	1992
Lee et al. [9, 42]	2010, 2011
Maples [43]	1978
Moorrees et al. [44]	1963
Paewinsky et al. [45]	2005
Prince & Ubelaker [46]	2002
Takei [47]	1984
Willems et al. [48]	2001
Yun et al. [49]	2007

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