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Radiographic analysis of alveolar sockets for human dental identification.

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Summary

Postmortem tooth loss is a phenomenon that occurs in skeletonized remains and can complicate the human identification process. To examine if the shape of alveolar sockets could aid in the human identification process in case of postmortem tooth loss, 100 panoramic radiographs were collected. Eight tooth elements per radiographs were examined. The roots of these radiographs were traced and a range of measurements were conducted. The measurements were processed and compared among each other. Afterwards a part of the tracings got placed on top of one another and the percentage of overlap got calculated. We concluded that there is a lot of variation in root morphology. Because of this variation, they can aid as an identifier in the process of human identification. Therefor the empty alveolar sockets should be visualized and registered during this process of human dental identification.

Samenvatting

Postmortem tandverlies is een fenomeen dat voorkomt in geskeletteerde lichamen en dit kan het identificatie proces bemoeilijken. Om te onderzoeken of de vorm van alveoli kunnen bijdragen in het identificatie proces wanneer postmortem tandverlies heeft plaatsgevonden, werden 100 panoramisch radiografieën verzameld. Acht tandelementen per radiografie werden onderzocht. De wortels werden getraced en een reeks metingen werd uitgevoerd. De metingen werden verwerkt en vergeleken met elkaar. Daarna werd een deel van de tracings over elkaar geplaatst en het percentage van overlap berekend. We concludeerde dat er veel variatie is in de morfologie van de wortels. Door deze variatie kunnen zij gebruikt worden als een identifier voor het proces van identificatie. Daarom zouden de lege alveoli gevisualiseerd en geregistreerd moeten worden tijdens dit proces van dentale identificatie.

1. Introduction

The forensic odontologist plays an indispensable role by the identification of human remains, because a dental identification is the most common biometric method for identifying burned, decomposed, skeletonized, and fragmented remains. The reason here for is that dental material is the most resilient of the human body and in the same time well protected by the soft tissues. The human dentition is unique and individual, but becomes even more distinctive by the dental treatment a person receives during his lifetime. When human remains are discovered the oral and dental tissues are examined and carefully cataloged. This is the postmortem (PM) data collection. These registrations will be compared with ante mortem (AM) data from (a) potential victim(s). According to the guidelines of the American Board of Forensic Odontology (ABFO) this leads to one of the four following conclusions[1]:

I. A positive identification: the ante mortem and postmortem data match in sufficient detail to establish that they are from the same individual.
II. A possible identification: ante mortem and postmortem data have consistent features, but due to the quality of the data it's not possible to establish dental identification
III. Insufficient evidence: the available information is insufficient to form the base for a conclusion
IV. Exclusion: the ante mortem and postmortem data are clearly inconsistent.

Dental identification is in first instance based on the comparison of dental restorations, registered descriptively, photographically (visual) as well as radiographically. However, it becomes more difficult when there are little to no restorations available. A situation that occurs increasingly in pre-teens and young adults in Europe and North-America, as a result of a more preventive dental approach[2]. Other morphological features in the dentition, combined with additional identification methods will gain more importance in order to establish dental identifications. These methods are based on a photographically and radiographically comparison. The identification process is certainly complicated when teeth got lost postmortem. Decomposition of the periodontal ligament (PDL) causes the teeth to become loose in the alveolar socket. Incautious handling or movement of remains during body recovery and transport, also enable the teeth to come out of the alveolar socket. The frequency of post mortem tooth loss (PMTL) various and depends a lot on the extent of which the remains are decomposed and in what kind of environmental circumstances they were left[3]. The following question emerges: Can this empty alveolar socket contribute to a positive identification? In other words, is there enough variation in the dental root morphology, (not including the pulp), to consider this feature in the comparative identification process?

When AM dental radiographs exist, the morphology of the root and inherent of the alveolar root socket contour, in mesio-distal plane can be registered. PM radiographs of the zones with PMTL enable to register the alveolar bone contours of the missing tooth/teeth's root. Both evidences can be morphologically compared. The aim of the current study was to compare on panoramic radiographs root shapes and related alveolar root contours between individuals to detect if the alveolar bone contours can be used as an identifier in the human dental identification process. Accordingly, the following research questions will be answered:

- Can the shape of the radiographically registered alveoli be used as an identifier in the human identification process.
- Is there a difference in variability of this identifier in males or females, per jaw or per tooth.

2. Literature research

2.1. Body decomposition and bone healing

When during the examination of human remains an empty socket is discovered, it mainly appears as a result of two causes. First the tooth got lost post mortem. PMTL can occur because the teeth become lose in the alveolar socket. Due to decomposition of the human body after death and more particularly the decomposing of the periodontal ligament. Second, an empty alveolar socket remains after a tooth extraction until the alveolar socket is filled with new bone. In next paragraph the different stages of body decomposition are described and related to the likelihood of PMTL. Further on the stages of bone healing after tooth extraction and how long the extraction site can be registered radiographically are described.

2.1.1. Body decomposition

After death the human body starts to decompose. This process can be classified in several ordinal stages. The time it takes to reach a following stage depends on how the body was preserved.

Once the heart stops functioning, blood will cease to circulate. The body goes through a series of changes. Starting with the triad of livor, rigor and algor mortis[4]. Liver mortis or post mortem hypostasis is the result of the blood flowing, under influence of gravity, to the lower parts of the body. This process causes a discoloration and is called post mortem hypostasis. The muscles stiffen, also known as rigor mortis, caused by the breakdown of ATP and the build-up of lactic acid. The body start to cool down, algor mortis, to the ambient temperature. Next the body will start to decompose. This process of decomposition is divided in four deferent stages. These stages are dominated by two destructive processes, namely autolysis and putrefaction. The first stage is the fresh stage which last for about a week. Here the soft tissues start to decompose by means of autolysis or self-digestion, caused by a buildup of acid in the cells. After this first week we enter the second stage, the bloating stage, which last for about two weeks. Bacteria, from the body as well as from the surroundings start to attack the tissues, producing gasses. These gasses stay trapped in the body, causing it to swell up. The next couple of weeks is the stage of active decay. Insects and carnivores assist the bacteria in removing the remaining soft tissues. The remaining tissues are almost completely liquefied at this point. Eventually the fourth and last stage is reached, the dry stage or the stage of skeletonization, which will starts about six to seven weeks after death. The soft tissues are decomposed, while other body components like bone, hair, nails, … remain. These will eventually also decompose, but this happens over a longer period in time.

During the stage of active decay the fibers of the periodontal ligament also dissolve, causing the teeth to become lose in the alveolar socket. Once the teeth become lose in the socket there is a higher likelihood to fall out of this socket, especially when there is movement of the remains. This movement can for example occur when remains are located in water, by the current in a stream of the tides of the sea. Another possibility situation is because of carnivorous activity. But movement of the remains also occurs during the discovery and the excavation of the remains and the transport for further examination. Due to the decay and movement, the teeth have a higher likelihood to fall out of the alveolar socket and get lost as a result.

2.1.2. Bone healing

The extraction of a tooth initiates a series of reparative processes involving both hard and soft tissues[5]. After the tooth is extracted, the now empty socket fills with blood forming a blood clot. In the first week after the extraction, this blood clot will remodel into granulation tissue, consisting mostly out of newly formed vascular structures. Two weeks after the extraction deposition of mineralized tissue begins. Cells from the PDL differentiate and invade granulation tissue. They cause a formation of provisional matrix, starting from the residential PDL towards the center of the extraction socket. After six to eight weeks most of the granulation tissue is replaced by provisional matrix and woven bone. The provisional matrix consist out of densely packet mesenchymal cells, collagen fibers and vessels. Osteoprogenitor cells from the ruptured PDL differentiate into osteoblast and start the formation of woven bone[6]. The provisional matrix and woven bone will get remodeled and replaced by lamellar bone and bone marrow. This final stage of the healing begins three to six month after the extraction.

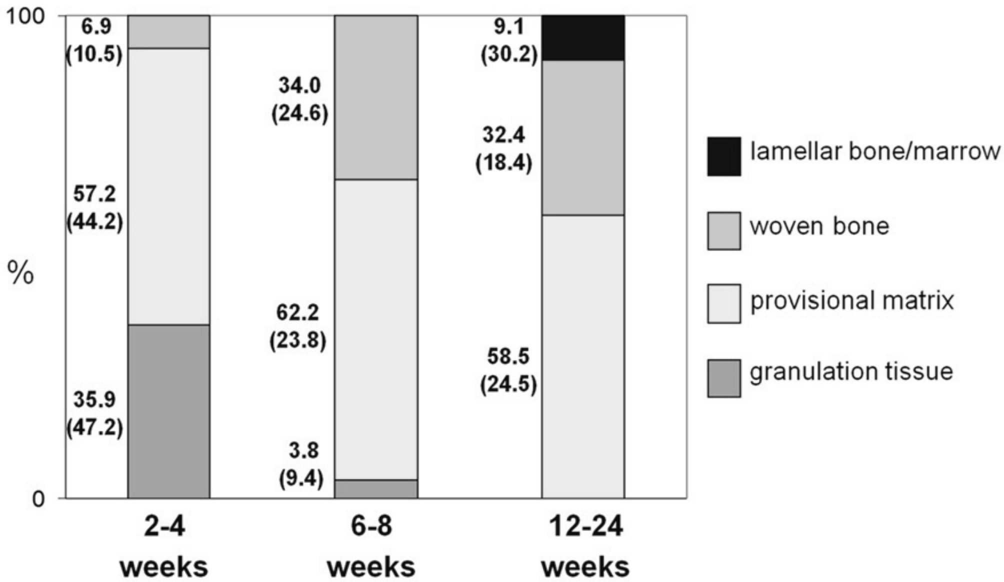


Fig. 1: *Distribution (mean %, standard deviation in parenthesis) of the tissue components (granulation tissue, provisional connective tissue, woven bone, lamellar bone/bone marrow) at different stages of the healing (i.e. 2-4 weeks, 6-8 weeks an 12-24 weeks) of human extraction sockets.* From: R. Farina, L. Trombelli. (2012) [5].

Because of the time laps between the extraction and the start of the mineralization, there is an interval in which the empty alveolar socket can be visualized on a radiograph. The first month after the extraction the wound contains little to no new bone, but consist mostly out of provisional matrix and granulation tissue. After this month there is more and more formation of woven bone, started from cells of the former PDL. This causes less clear margins of the extraction site (*Fig 1*). So even when a tooth got lost (AM), as long as the bone was still within the first stage of healing, it could add extra information and contribute in the identification process.

2.2. Factors affecting postmortem tooth loss

The frequency of PMTL is effected by an array of different factors, namely the exhumation process, the PM interval and related stage of decay, the root morphology and the environment in which the body was preserved. Following in the next paragraph is an overview of these factors .

2.2.1. Exhumation process

Teeth are useful for monitoring the quality of exhumations and body recoveries[7]. Careless handling in search, collection, transportation, preparation, packing and dispatch for examination of human remains from crime scene or in exhumation, contributes to tooth loss[3]. In the study of *H. Brkic et al. (2004)*[7] the dental evidence from remains recovered from sixty mass graves located in five Croatian counties were reported. They found, that PMTL was on average 20%, but it differed between counties and ranged from 14% to 40%. The quality of the recovery process can be assessed by the percentage of PMTL. A higher number indicates a lack of attention for the recovery of all available evidence. The described results confirmed that there was no presence of a dental expert during the exhumations in the counties with a high prevalence of PMTL. In cases where the remains are severely damaged, for example by fire, or when teeth are mobile, it ought to be considered to take photographs and dental radiographs on site, because of the higher likelihood of PMTL and damage of the teeth during excavation and transport[8]. Situation that required also extra caution during handling were remains of children with mixed dentition, victims with severe periodontal diseases and severely decomposed bodies.

2.2.2. Postmortem interval

The PM interval is the time between death and the recovery of the remains. This interval has a big influence on the percentage of PMTL. The body had a longer time to decompose and when teeth become dislodged they could easily get lost during the recovery process. A longer PM interval, allows more soft tissue to decompose, including the attachment apparatus of teeth. In a study of 2004 the contribution of postmortem interval on PMTL was analyzed. The result of excavations of two mass graves, made within the same period in 1999, were compared. One was excavated in 2001 and the other in 2002. The result of that study suggested that the PM interval influenced PMTL more than the excavation method[9].

2.2.3. Environment

The environment where the body was found also contributes to the process of PMTL. The soft tissues which bind the tooth into the alveolar bone, are correlated to the rate of decomposition observed in general soft and are dictated by the environment[10]. This study was set up to investigate if PMTL could be an indicator to estimate time since death. Eleven cadavers were placed on locations under different conditions. With weekly intervals decomposition and thus PMTL was examined. The result was that temperature greatly influenced decomposition. Bodies decomposing in summer months lost teeth more rapidly than those decomposing in late fall or winter. Bodies placed in direct sunlight, a micro-environment where rapid decomposition has been noted, lost teeth before those placed in shaded locations.

2.2.4. Root morphology

Not all teeth are equally susceptible for PMTL, this is because of the root morphology. The conical shape of the single rooted teeth gives them a higher chance to get lost postmortem. The maxillary incisor is most affected, followed closely by the remaining incisors of the maxilla and mandible[9]. Second most affected are the premolars. Canines with their long roots and molars with their complex and multiple root structures are least susceptible for PMTL (*Fig 2*). Third molars are more susceptible then the other molars, because of their more conical shape and often appearing of root fusions. So in overall the anterior teeth have a higher likelihood to exfoliate postmortem then the posterior teeth. There is no significant difference in PMTL between teeth from the maxilla and mandible caused by the difference in the trabecular arrangement of the bone. The reason that the maxillary central incisor is most susceptible for PMTL is due to its morphology. It's usually conical, rounded in any horizontal plane without any curvatures[9].

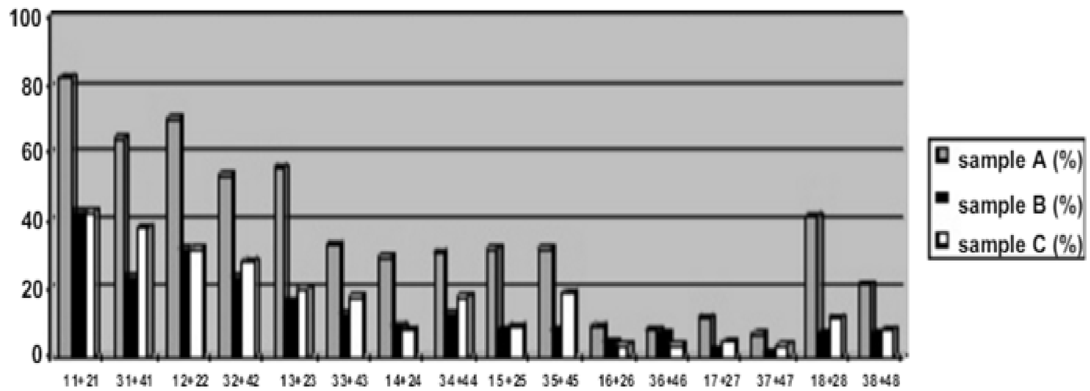


Fig. 2: *Frequencies of PMTL in different teeth groups and this for three different grave sites.* From: M. Duric, et al [9].

2.3. Reconstructing root morphology

In 1992 Dr. Smith presented a reversible technique to reconstruct root morphology of missing teeth in skeletonized remains. A human skull laboratory specimen was used and a radiograph was taken prior to postmortem tooth extraction. After the extraction the root morphology was reconstructed using an impression material. First the alveolar socket walls were sealed with a coat of cyanoacrylate cement and then the socket got injected with a mixture of dental impression material and barium sulfate. A radiograph was taken with the radiopaque mixture in place, recreating the AM root morphology (*Fig. 3*). The impression material could be removed, without alteration of the evidence and stored for later use. Dr. Smith concluded that this simple and inexpensive technique enables reconstruction and documentation of dental evidence in skeletal remains[11].

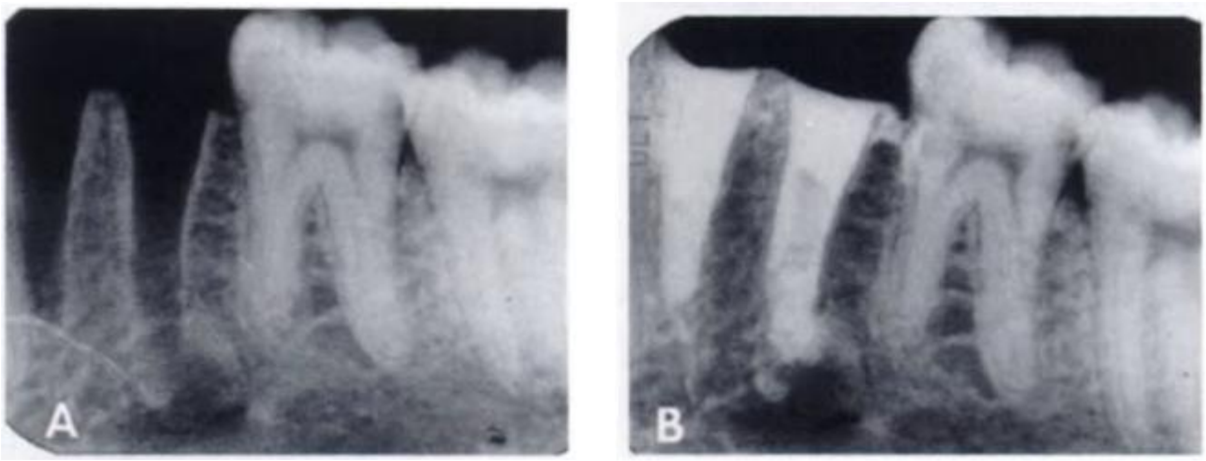


Fig. 3: *The morphology of teeth lost postmortem (A) can be restored with radiopaque barium sulfate added to dental impression material and pressed into sockets(B).* From B. Smith (1992) [11].

This technique was used on a human skull that showed perimortem and/or postmortem tooth loss. It deemed to have no usable dental information due to severe alveolar bone destruction. They used Dr. Smith's technique to reconstruct root morphology and after radiographic analysis previously unobserved dental information was revealed. The case study showed that root morphology can be reconstructed and may add useful information for the human dental identification process[12]. This technique is a way to better visualize empty alveolar sockets to add extra dental information. However it was not noted if there is enough variation in the root morphology to use this technique more often in the identification process.

2.4.Data collection by dentists

Forensic dental identification depends mainly on the availability of AM dental records. It is the social responsibility of each and every dentist to maintain dental records of their patients for the noble cause of body identification in single or mass disaster cases[13]. The availability and accuracy of dental records determine the success of identification[14]. However there is no clear consensus, regarding record keeping, making that related guidelines and legal prescriptions differ from country to country. Not in all countries it is obligated to keep dental records and the duration for preservation of records also differs between countries.

2.4.1. Dental records

The dental record is a legal document, kept by the dentist, which contains subjective and objective information about patients. The dentist is responsible for keeping complete and accurate patient records. It is important to keep structured records and therefor recommended to always follow the same record keeping format. For example, the universally accepted record keeping format SOAP, which is an acronym for:

- S – subjective date: information about the reason for the visit to the dentist, including complains and symptoms
- O – objective findings: finding after clinical examination and diagnostic tests in a unbiased manner
- A – assessment: diagnostic judgement is reached based on subjective and objective findings
- P – Plans: various treatment plans and the eventual choice of treatment

All results of physical examination of the dentition and supporting oral and surrounding structures have to be recorded. As well as laboratory test results, study casts, photographs and radiographs. Special attention should be payed to radiographic examination. The comparison of AM and PM radiographs is the most accurate and reliable method of identifying remains. Making the original AM dental radiographs of immense value[14].

2.4.2. Record keeping by dentists

Some examples to illustrate the variety in record keeping between different countries.

2.4.2.1. Situation in Belgium

In a Belgium study from 2006[15], they tried to assess the quality of the average dental records, kept by Belgium dentists and evaluated their potential use for forensic cases. It was based on a survey. Since 2004 a new law on patients' rights, made it mandatory to keep patient records, including dental records. However there is no clear consensus on what information needs to be included in these files, consequently a big variety between records exists. Between 80-90% of the dentist take dental radiographs at the first visit of the patient. Digital records are more complete and kept significantly longer than analogue files. Also dentist who have faced litigation or insurance cases are more aware of the possibilities and importance of the dental records. On average younger dentists keep more complete files compared to older colleagues. Reasons for this are probably that forensic dentistry is part of the universities curriculum, the awareness of medico legal consequences, but also the increased media attention for forensic dentistry.

2.4.2.2. Situation in Australia

Using an online self-administered questionnaire, the knowledge and behavior of Australian dentist relevant to forensic odontology, was evaluated in 2016[16]. In Australia dentists have the legal and professional obligation to create and maintain dental records. The Dental Board of Australia has set up guidelines with minimal requirements that dental records have to meet. There was an overall reasonable awareness for forensic odontology. In terms of record keeping, Australian dentists kept in their patient files basic personal information and recorded in high detail information of restorative treatment and prostheses. However dental anomalies, routine panoramic radiographs, dental photographs, retention of dental casts, additional patient details and denture marking were recorded inadequately.

2.4.2.3. Situation in India

In a systematic review from 2016[17], four studies out of four different Indian states were included. The results show an overall awareness of forensic odontology is above 85%. However only about 80% of dentists kept dental records, but only 12% of dentists kept complete dental records, which contained patient information and information of oral examination and treatment. Very few of dentists in India had prior experience in solving cases related to forensic odontology.

3. Method

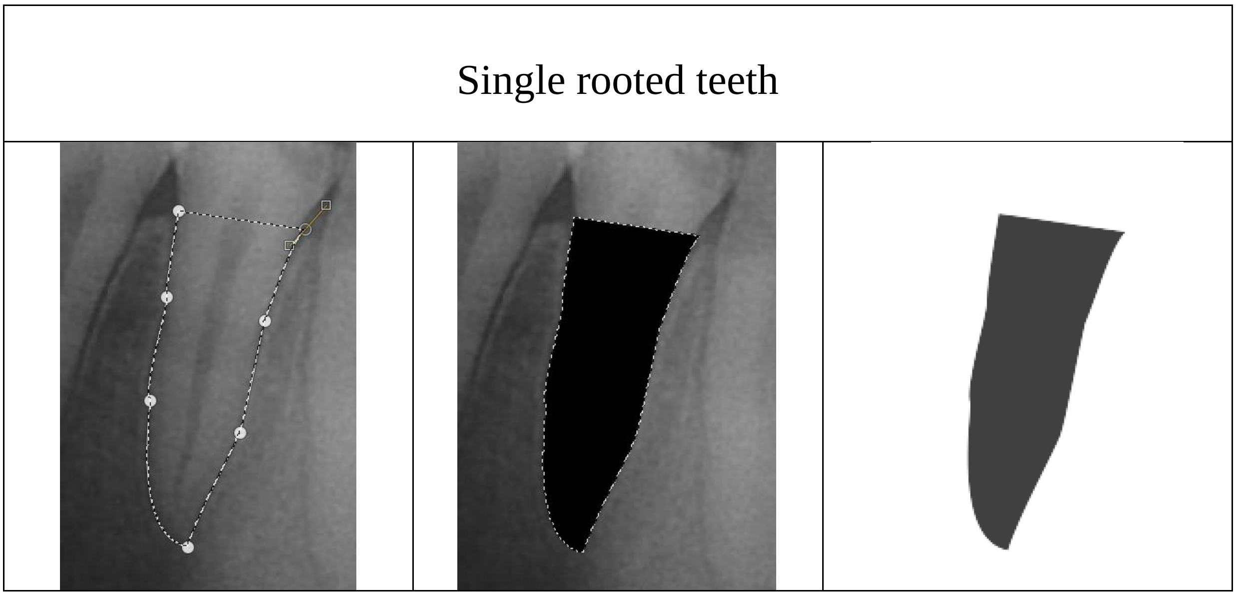
3.1. Population

Panoramic radiographs were used to conduct the research and were examined retrospectively. They were collected from the database of the Department of Oral Health Sciences, KU Leuven & Dentistry, University hospitals Leuven, Belgium. To get a representable sample, one hundred panoramic radiographs were selected, fifty originate from males between the ages of 15 and 43 years (mean 24 years) and fifty from females between the ages of 16 and 40 years (mean 27 years). Based on the symmetry between the left and right side of the jaws, only teeth from the right side were examined. Four teeth out of each quadrant were selected. These teeth represent the different tooth element, namely the (central) incisor, the canine, the (first) premolar and the (first) molar. These eight teeth had to be present in all panoramic radiographs. Further on, the roots of these teeth had to be fully developed (closed apices) and broken through in the dental arch. No presence of periodontal bone loss and absence of superimposition of the roots or other oral structures were required. The radiographs were of good image quality.

3.2. Data collection

3.2.1. Tracings

To get a representation of the 2 dimensional shape of the empty alveolar sockets the radiographs were imported in GNU Image Manipulation Program or GIMP (free and open-source software). Contours of the considered tooth roots were traced according to the following protocol (*Fig. 4*):



Multiple rooted teeth

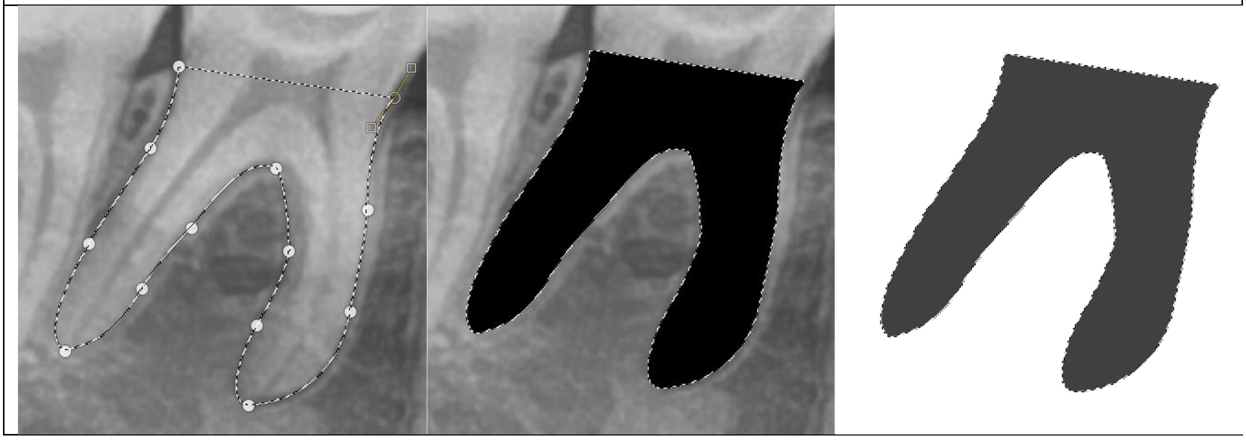
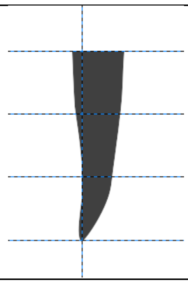


Fig. 4: *The panoramic radiograph is uploaded in GIMP. The scale is set on 200% and the brightness and contrast are adapted until the PDL of the root is clearly visible. Then in a new layer with the aid of the Path-tool the tracings were made, using seven landmarks. Starting distal at the cementum-enamel-junction (CEJ) going towards the apex using two point, respectively at 1/3 and 2/3 of the length of the root. Then going back up towards to the mesial side of the CEJ, again using two point respectively at 2/3 and 1/3 of the length of the root. In case of multiple rooted teeth, the same principle is used, but including an additional landmark which was placed at the most occlusal point of the furcation. Five extra points are necessary, going from the distal apex towards the furcation and then back towards the mesial apex. The Path-tool makes it possible to trace the curvature of the root parts in between of the landmarks. Next the path is selected, this is also an option of the Path-tool and then filled in using the Bucket-tool.*

3.2.2. Measurements

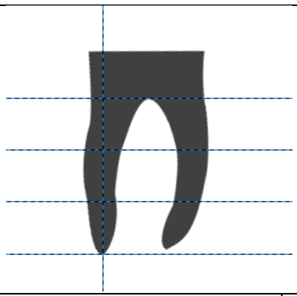
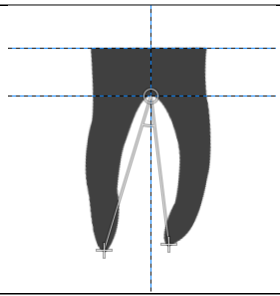
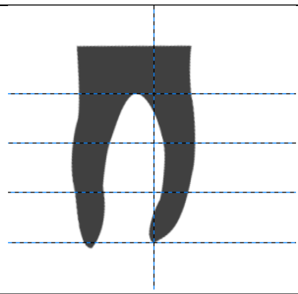
On the obtained tracing, a number of measurements were carried out. First the tracing should be rotated, so that the line connection both CEJ (mesial and distal) landmarks is parallel to the horizontal plane. For the single rooted teeth, horizontal guideline were placed at the line connection both CEJ landmarks, at the most apical root point and at 1/3 and 2/3 of the root length. A vertical guideline was placed at the most apical root point. Using the Measure-tool four linear measurements were taken per single rooted tooth, in between the placed guidelines (*Fig. 5*). For the multiple rooted teeth, horizontal guidelines were placed at the line connecting both CEJ landmarks, at the most occlusal point of the furcation at 1/3 and 2/3 of the roots length and at the most apical root point of both roots. And vertical guidelines were placed at the most apical point of the roots and most occlusal point of the furcation. This was the preparatory work, that made it possible to take linear measurements as well as the angle of the furcation.

Single rooted teeth



Surface	S	Surface of the root
Width	W	Root width at the CEJ
Length	L	Distance from CEJ perpendicular to apex
Width at 1/3	W1/3	Root width at 1/3 of the distance from CEJ to apex
Width at 2/3	W2/3	Root width at 2/3 of the distance from CEJ to apex

Multiple rooted teeth

Surface	S	Surface of the root
Width	W	Root width at CEJ
Length	Lf	Distance from CEJ perpendicular to furcation
Distance apices	Dapex	Distance from mesial to distal apex
Angle furcation	A	Angle from apex of the mesial root to furcation to apex of the distal root
Mesial width	Wm	Root width of mesial root at the height of the furcation
Mesial length	Lm	Length from mesial width perpendicular to apex mesial root
Mesial width 1/3 length	Wm1/3	Root width at 1/3 of the distance from mesial width to apex
Mesial width 2/3 length	Wm2/3	Root width at 2/3 of the distance from mesial width to apex
Distal width	Wd	Root width of distal root at the height of the furcation
Distal length	Wl	Length from distal width perpendicular to apex mesial root
Distal width 1/3 length	Wd1/3	Root width at 1/3 of the distance from distal width to apex
Distal width 2/3 length	Wd2/3	Root width at 2/3 of the distance from distal width to apex

Fig. 5: *Landmarks, guidelines and measurements performed on the tracings and this for the single as well as for the multiple rooted teeth.*

For the single rooted teeth four and for multiple rooted teeth twelve linear measurements were registered (*Fig. 5*). The areas of the roots were calculated using the Magic wand-tool. This tool makes it possible to select the entire tracing based on grey scale values. The value of the selected area was displayed in the Histogram-dialog. All these data were processed in Excel file (Microsoft Excel 2010). The unit of the measurements were in pixels, with dots per inch (DPI) equals to 96

In a second part of the research a pairwise superimposition and comparison of the root tracings was carried out in order to find the percentage of area overlap. Using GIMP two roots were placed on top of each other and then rotated until the maximal overlap was found. Only teeth within a certain interval were compared with each other. This interval was determined on the base of the linear and dimensional measurements. The single rooted teeth interval (SRTI) included all single rooted measurements (*Fig. 5*), which fell in an interval of plus and minus 10 percent of the values of the tooth to which the comparison is made, was determent. Except for the length, which was within the interval plus and minus five percent. The reason for integrating a smaller interval for the length, was related to the relative dimension of this linear measurement compared to the other measures (often more as twice as big as the other linear measurements). Moreover it was necessary to increase the possibility for similar dimensions and thus shape of the roots, because where W1/3 and W2/3 were measured depended on the value of the length. The single rooted teeth were pairwise superimposed and compared when all five, four out of five and when no measurements fell within the SRTI. The multiple rooted teeth interval (MRTI) was based on a different selection process. Six measures providing a so accurate as possible representation of the shape of the root were selected, namely: the width at CEJ, the length of the mesial root, the length of the distal root, distance from CEJ to furcation, the angle between the apices and the surface. By the multiple rooted teeth a comparison was made when all six, five out of six, four out of six and when no measurements were within plus and minus ten percent of the measurements of the tooth to which the comparison is made.

3.2.3. Control

To check the intra and inter observer reliability tracings and measurements were redone, as prescribed, by the same and a new observer after 4 weeks. Four panoramic radiographs were selected randomly, but specified on sex (two radiographs that derived from males and two from females). The new observer received a copy of the established data collection protocol and a quick introduction to the different tools of GIMP.

4. Results

4.1. Overall results

For each tooth position the number of radiographs on which a tracing was possible differed. (*table 1*). Especially for the tooth elements in the maxilla it was often difficult to produce a tracing.

Maxilla	Total	Male	Female
Central incisor	95	46	49
Canine	97	49	48
First premolar	77	37	40
First molar	51	23	29

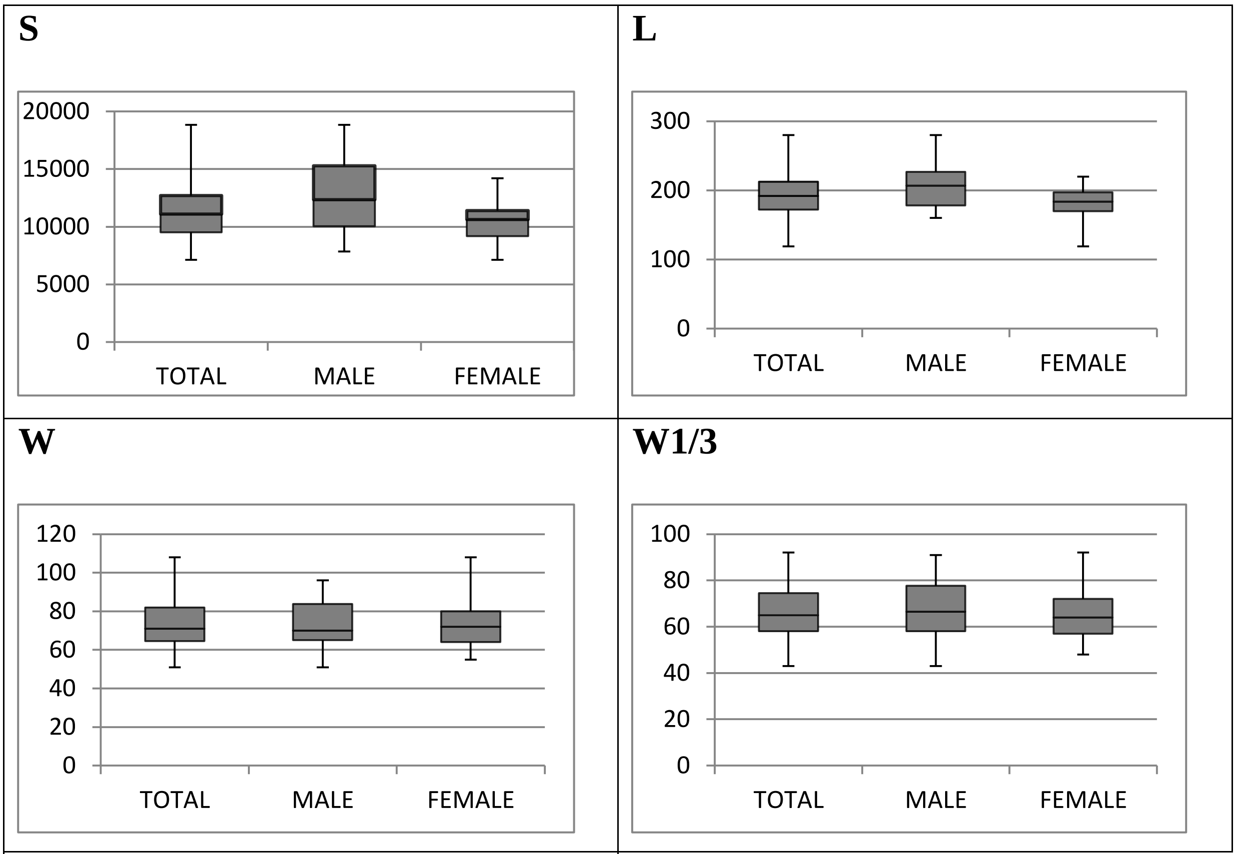
Mandible	Total	Male	Female
Central incisor	100	50	50
Canine	100	50	50
First premolar	100	50	50
First molar	100	50	50

Table 1: *Number of tracing per tooth element and separately by sex.*

Overall the values of the measurements performed on the male teeth were larger than those from the female teeth. The size difference between these values were not equal for each tooth element or between the measurement performed on the same element. For example, there was a big difference in length between male and female teeth for central maxillary incisor, but little to no difference in width. While for the maxillary canine there was a difference in both length and width. Following, is an overview of the results of the measurements, the superimposition and the control, and this per tooth element. *See appendix*, for tables with detailed representation of processed measurements per tooth element.

4.2. The maxillary central incisor

4.2.1. Measurements



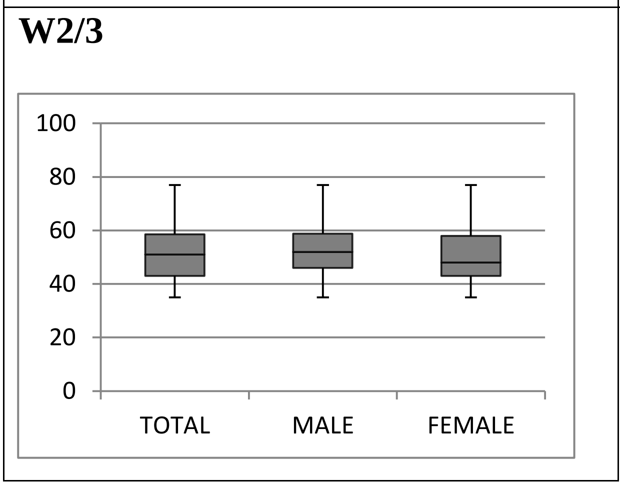


Fig. 6: *Measurement of maxillary central incisor reported as Box-Plots.*

The tracings derived from males were larger than the those from females. The reason for the larger surfaces laid in the difference in length of the tracing, while there was less variation between males and females in the width of the tracing and this at all three levels of the length. See *appendix A*, for table with detailed representation of processed measurements of the maxillary central incisor.

4.2.2. SRTI

5 out of 5:
When 5 out of 5 measures were considered, 206 pairwise superimpositions/comparisons were within the SRTI. On average 2,17 equal pairwise superimpositions were observed, with 21 tracings who had no match and the maximum amount of matches was 7.

4 out of 5:
When 4 out of 5 measures were considered, 419 pairwise superimpositions/comparisons were within the SRTI. On average 4,41 equal pairwise superimpositions were observed, with 12 tracings who had no matches and the maximum amount of matches was 11.

0 out of 5:
When 0 out of 5 measures were considered, 2922 pairwise superimpositions/comparisons were within the SRTI. On average 30,75 equal pairwise superimpositions were observed. The minimum amount of matches for a tracing was 12 and the maximum amount of matches was 69.

4.2.3. Pairwise superimposition and comparison

4.2.3.1. Per SRTI

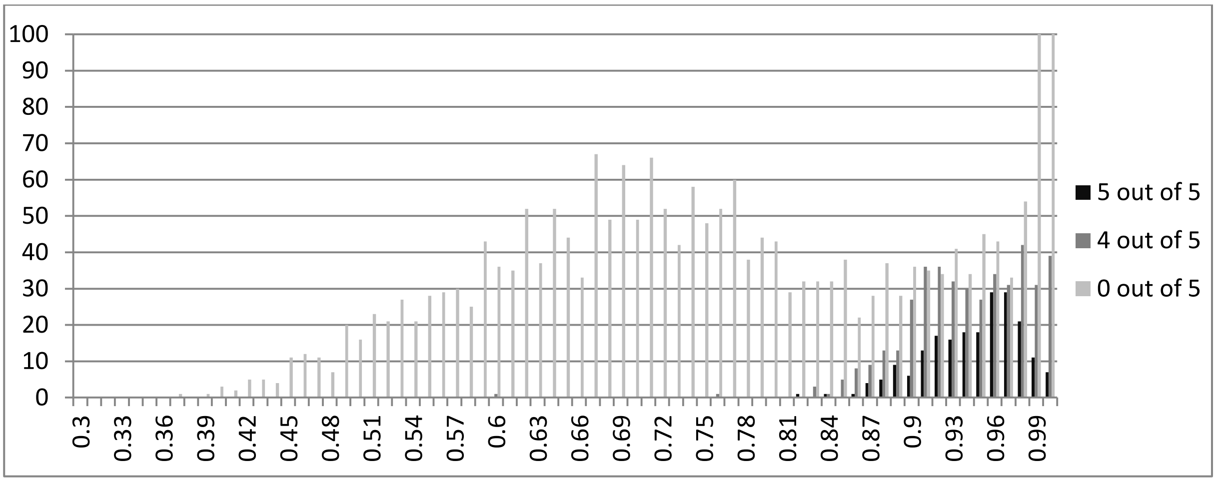


Fig. 7: *distribution of percentage of overlap for the maxillary central incisor.*

5 out of 5:
The average percentage of area overlap of these tracings was 94,01% (SD 0,03), with the lowest percentage 81,17% and the highest percentage 100% (result of one tracing falling completely within the other). *(Fig. 7)*

4 out of 5:
The average percentage of area overlap of these tracings was 93,62% (SD 0,05), the lowest percentage was 59,78% and the highest percentage was 100%. *(Fig. 7)*

0 out of 5:
The average percentage of area overlap of these tracings was 81,50% (SD 0,17), the lowest percentage was 36,93% and the highest percentage was 100%. *(Fig. 7)* An overlap of 100% was the case for 802 matches and an overlap of 99% for 121 matches. Note: value of y-axis only goes until 100.

4.2.3.2. Overall consideration

The amount of matches increased when less measures fell in the SRTI, from 206 matches when 5 out of 5 measures fell in the SRTI, to 419 matches when 4 out of 5 and 2922 matches when 0 out of 5 measures fell within the SRTI. The percentage of overlap decreased when less measures fell in the SRTI, respectively from 94,01% to 93,62% to 81,50%. While the standard deviation increased, respectively from 0,03 to 0,05 to 0,17. The maximum percentage of overlap was equal in all three situation, while there was a large deviation in value of minimum percentage of overlap, namely 81,17% for 5 out of 5, 59,78% for 4 out of 5 and 36, 93 for 0 out of 5.

4.2.4. Control

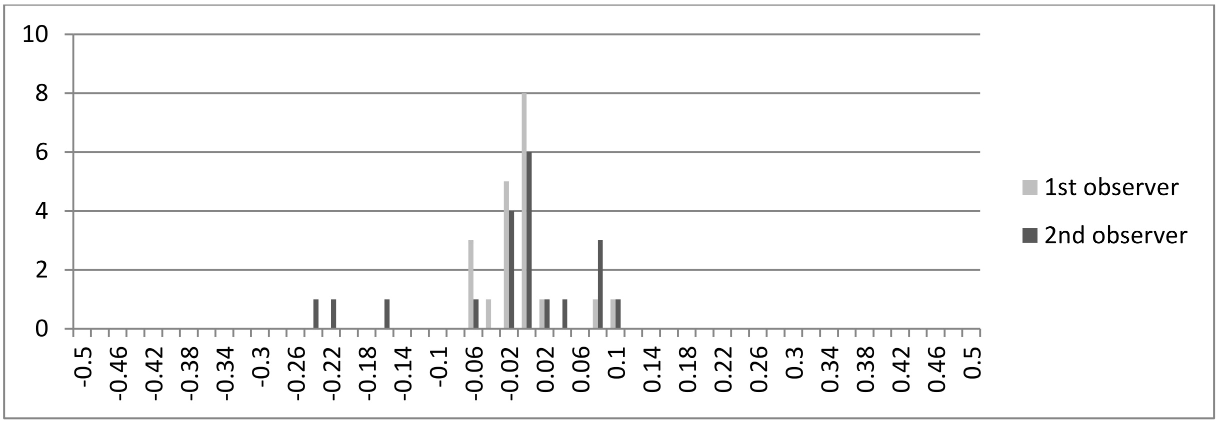


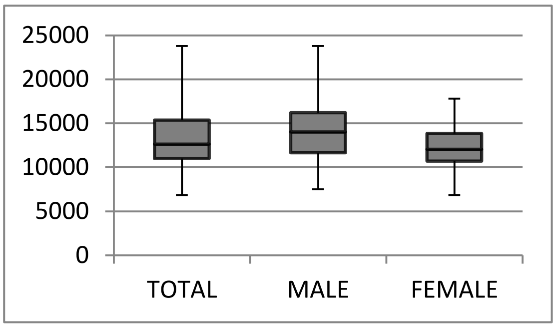
Fig. 8: *The amount of deviation of the all measurements of the maxillary central incisor.*

Both observers were able to trace all four maxillary central incisors. Less deviation in the intra observer (first observer) measurements were observed compared to inter observer (second observer) measurements. For both observers the deviation was smaller than 10 percent. The average percentage of deviation between original an control and this of all measurements, was 3,27% (SD 0,04) for the first observer and 6,03% (SD 0,09) for the second observer. The average deviation was larger for the surface than for the linear measurement, for the first observer respectively 6,56% and 2,45% and for the second observer respectively 9,35% and 5,20%. The linear measurements with the least deviation between the original and the control was W2/3 (1,18%) for the first observer and W1/3 (0,97%) for the second observer.

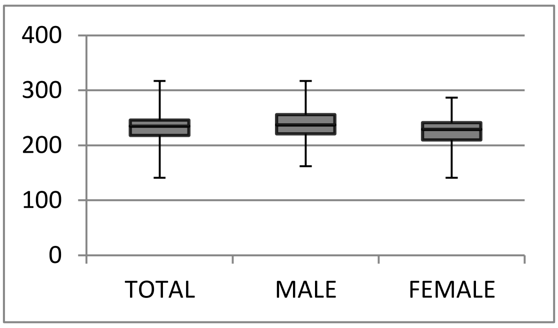
4.3. The maxillary canine

4.3.1. Measurements

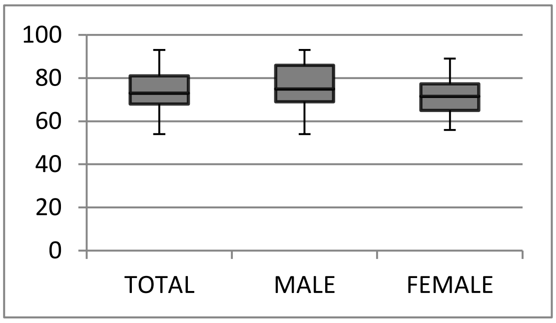
S



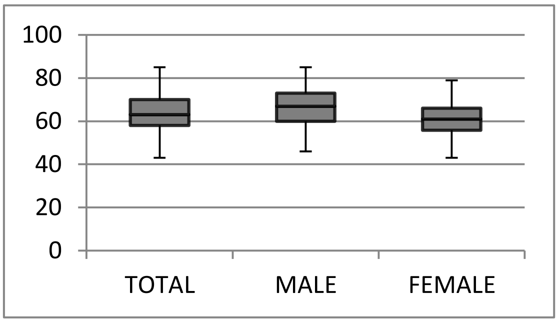
L



W



W1/3



W2/3

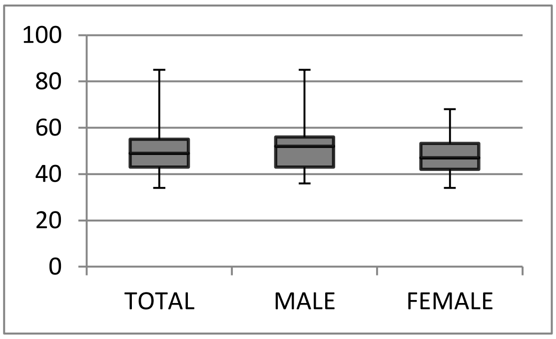


Fig. 9: *Measurement of maxillary canine reported as Box-Plots.*

The reason for the bigger surfaces in the male tracings found its origin in the difference in the value of the width, mostly the width at the height of the CEJ and at 1/3 of the length, while the values of W2/3 had less deviation between male and female tracings. The length was also slightly larger. See *appendix B*, for table with detailed representation of processed measurements of the maxillary canine.

4.3.2. SRTI

5 out of 5:
When 5 out of 5 measures were considered, 288 pairwise superimpositions/comparisons were within the SRTI. On average 2,97 equal pairwise superimpositions were observed, with 26 tracings who had no match and the maximum amount of matches was 16.

4 out of 5:
When 4 out of 5 measures were considered, 662 pairwise superimpositions/comparisons were within the SRTI. On average 6,82 equal pairwise superimpositions were observed, with 5 tracings who had no matches and the maximum amount of matches was 16.

0 out of 5:
When 0 out of 5 measures were considered, 2728 pairwise superimpositions/comparisons were within the SRTI. On average 28,12 equal pairwise superimpositions were observed. The minimum amount of matches for a tracing was 7 and the maximum amount of matches was 65.

4.3.3. Pairwise superimposition and comparison

4.3.3.1. Per SRTI

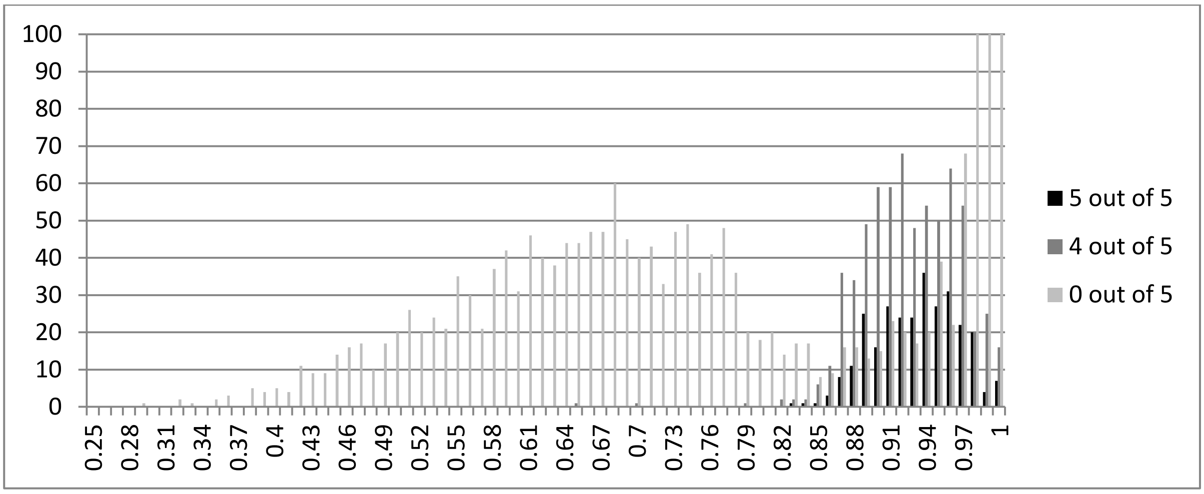


Fig. 10: *distribution of percentage of overlap of the maxillary canine.*

5 out of 5:
The average percentage of area overlap of these tracings was 92,74% (SD 0,03), with the lowest percentage 82,18% and the highest percentage 100%. *(Fig. 10)*

4 out of 5:
The average percentage of area overlap of these tracings was 92,09% (SD 0,04), the lowest percentage was 62,94% and the highest percentage was 100% . *(Fig. 10)*

0 out of 5:
The average percentage of area overlap of these tracings was 81,53% (SD 0,18), the lowest percentage was 28,74% and the highest percentage was 100% *(Fig. 10).* An overlap of 100% was the case for 761 matches, an overlap of 99% for 244 matches and an overlap of 98% for 110 matches. Note: value of y-axis only goes until 100.

4.3.3.2. Overall consideration

The amount of matches increased when less measures fell in the SRTI, from 288 matches when 5 out of 5 measures fell in the SRTI, to 662 matches when 4 out of 5 and 2728 matches when 0 out of 5 measures fell within the SRTI. The percentage of overlap decreased when less measures fell in the SRTI, respectively from 92,74% to 92,09% to 81,53%. While the standard deviation increased, respectively from 0,03 to 0,04 to 0,18. The maximum percentage of overlap was equal in all three situation, while there was a large deviation in value of minimum percentage of overlap, namely 82,18% for 5 out of 5, 62,94% for 4 out of 5 and 28,74% for 0 out of 5.

4.3.4. Control

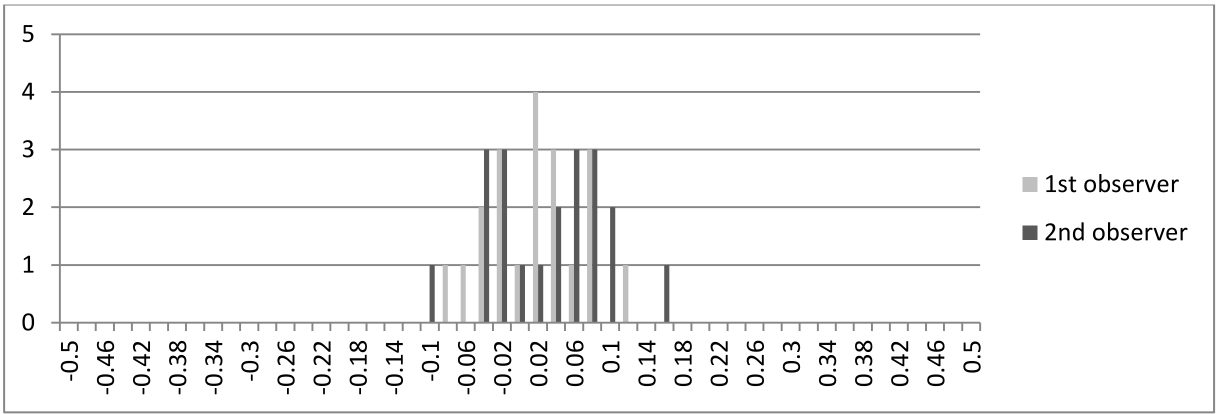


***Fig. 11**: The amount of deviation of the all measurements of the maxillary canine.*

Both observers were able to trace all four maxillary central incisors. The average percentage of deviation between original an control and this of all measurements, was 4,12% (SD 0,05) for the first observer and 5,52% (SD 0,06) for the second observer. The average deviation was larger for the surface than for the linear measurement, for the first observer respectively 6,58% and 3,51% and for the second observer respectively 8,52% and 4,77%. The linear measurements with the least deviation between the original and the control was W (2,74%) for the first observer and L (3,45%) for the second observer.

4.4. The maxillary first premolar

4.4.1. Measurements

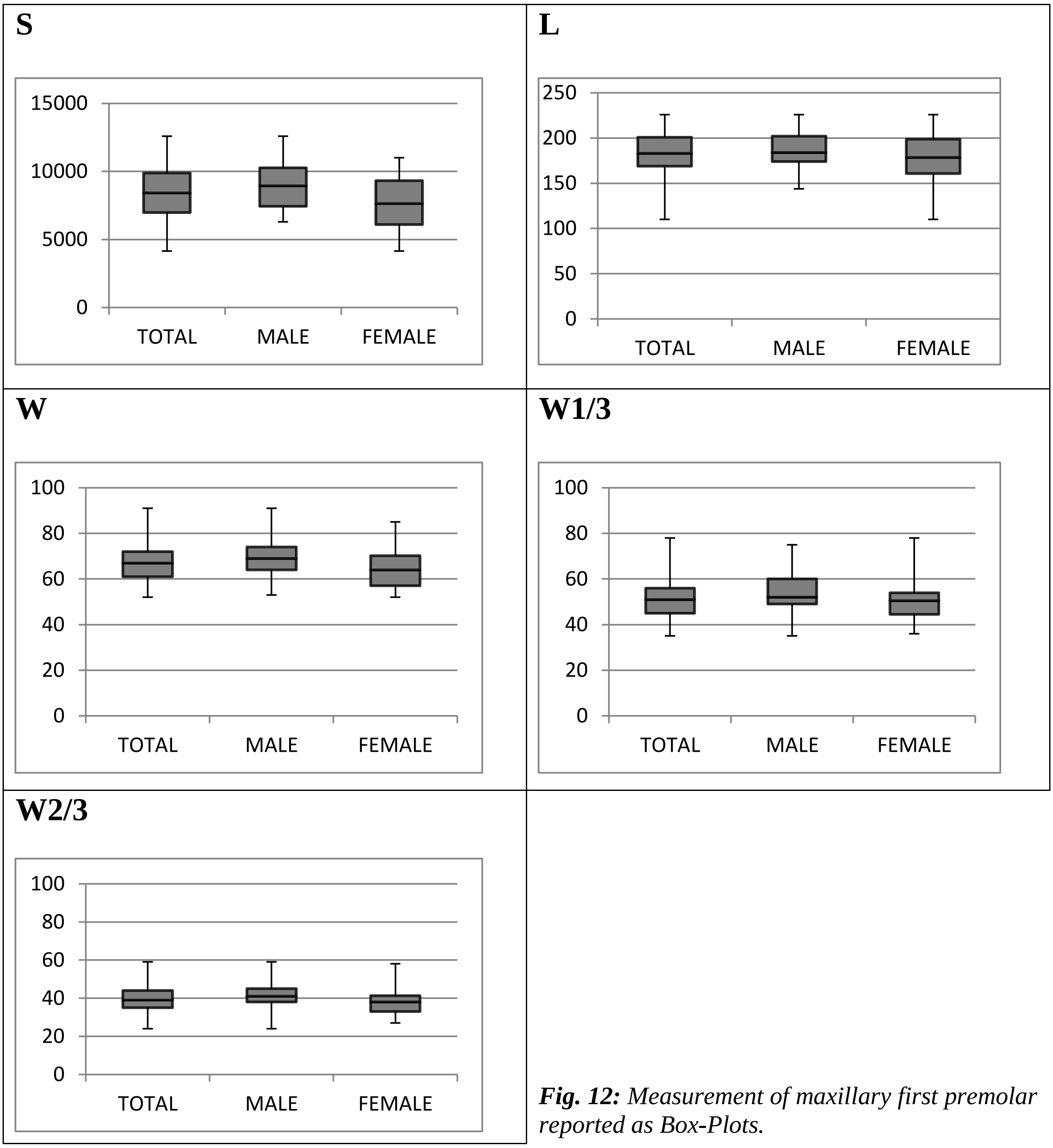


Fig. 12: *Measurement of maxillary first premolar reported as Box-Plots.*

The dimensional differences between the male and female tracings laid in the width and this at all three levels of the length. The maximum length was the same, but a larger number of male teeth have a larger value for the length compared to the female tracings. See *appendix C*, for table with detailed representation of processed measurements of the maxillary first premolar.

4.4.2. SRTI

5 out of 5:
When 5 out of 5 measures were considered, 71 pairwise superimpositions/comparisons were within the SRTI. On average 0,92 equal pairwise superimpositions were observed, with 36 tracings who had no match and the maximum amount of matches was 3.

4 out of 5:
When 4 out of 5 measures were considered, 248 pairwise superimpositions/comparisons were within the SRTI. On average 3,22 equal pairwise superimpositions were observed, with 10 tracings who had no matches and the maximum amount of matches was 10.

0 out of 5:
When 0 out of 5 measures were considered, 1482 pairwise superimpositions/comparisons were within the SRTI. On average 19,25 equal pairwise superimpositions were observed. The minimum amount of matches for a tracing was 8 and the maximum amount of matches was 43.

4.4.3. Pairwise superimposition and comparison

4.4.3.1. Per SRTI

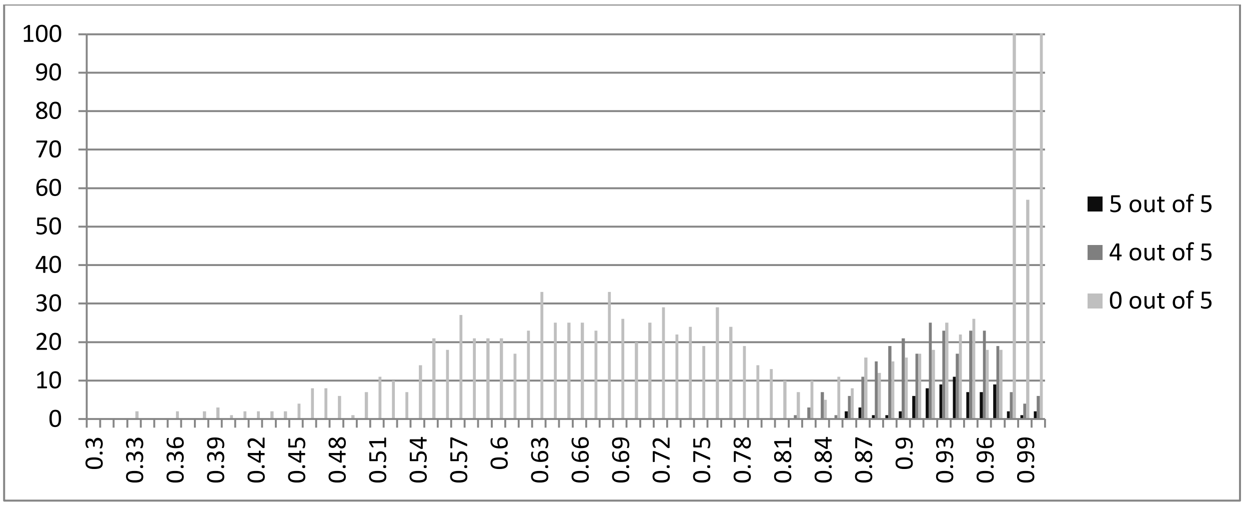


Fig. 13: *distribution of percentage of overlap of the maxillary first premolar.*

5 out of 5:
The average percentage of area overlap of these tracings was 93,14% (SD 0,03), with the lowest percentage 85,26% and the highest percentage 100%. *(Fig. 13)*

4 out of 5:
The average percentage of area overlap of these tracings was 92,75% (SD 0,04), the lowest percentage was 81,01% and the highest percentage was 100% . *(Fig. 13)*

0 out of 5:

The average percentage of area overlap of these tracings was 81,36% (SD 0,18), the lowest percentage was 32,39% and the highest percentage was 100% *(Fig. 13).* An overlap of 100% was the case for 372 matches and an overlap of 98% for 108 matches. Note: value of y-axis only goes until 100.

4.4.3.2. Overall consideration

The amount of matches increased when less measures fell in the SRTI, from 71 matches when 5 out of 5 measures fell in the SRTI, to 248 matches when 4 out of 5 and 1428 matches when 0 out of 5 measures fell within the SRTI. The percentage of overlap decreased when less measures fell in the SRTI, respectively from 93,14% to 92,75% to 81,36%. While the standard deviation increased, respectively from 0,03 to 0,04 to 0,18. The maximum percentage of overlap was equal in all three situation, while there was a large deviation in value of minimum percentage of overlap, namely 85,26% for 5 out of 5, 81,01% for 4 out of 5 and 32,39% for 0 out of 5

4.4.4. Control

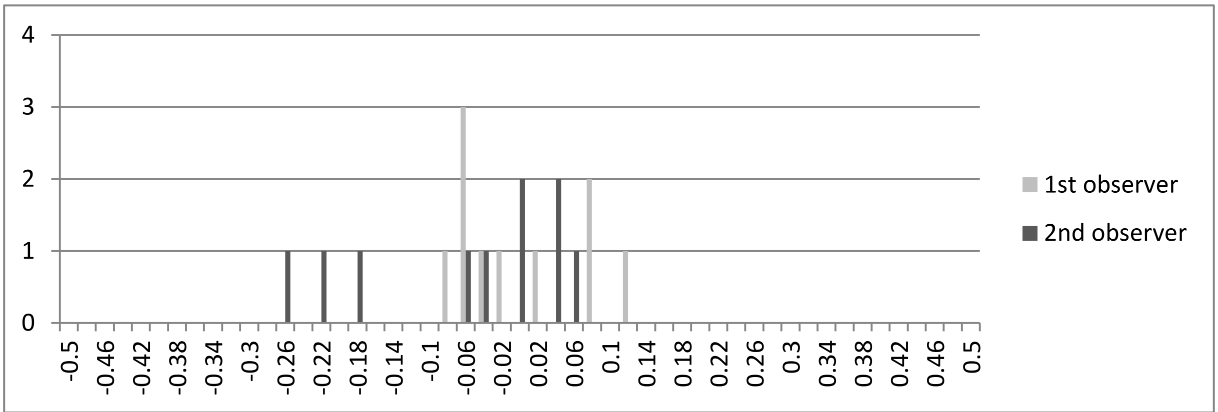


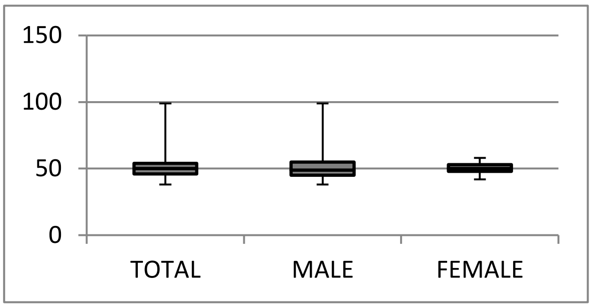
Fig. 14: *The amount of deviation of the all measurements of the maxillary first premolar.*

Both observers were able to trace two of the four maxillary first premolars, which is the same amount than the original. The average percentage of deviation between original an control and this of all measurements, was 6,17% (SD 0,07) for the first observer and 9,27% (SD 0,09) for the second observer. The average deviation was largest for W1/3 and W2/3 and this for both observers. For the first observer the average deviation of the surface was 6,34% and for the linear measurement 6,12%. The second observer had an average deviation of the surface of 11,25% and for the linear measurements 9,27%. The measure with the least deviation was the W (4,68%) for the first observer and the L (4,78%) for the second observer.

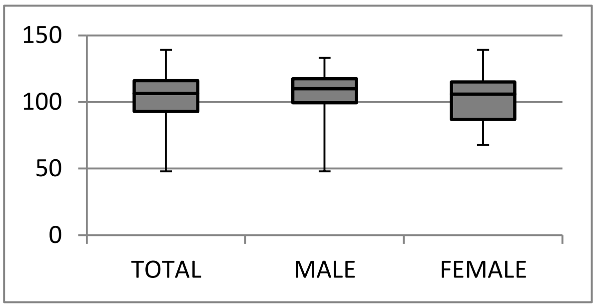
4.5. The maxillary first molar

4.5.1. Measurements

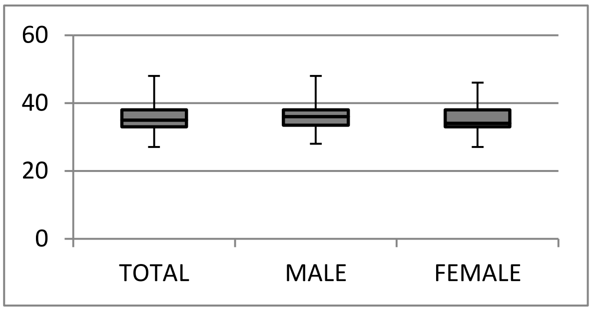
Wm



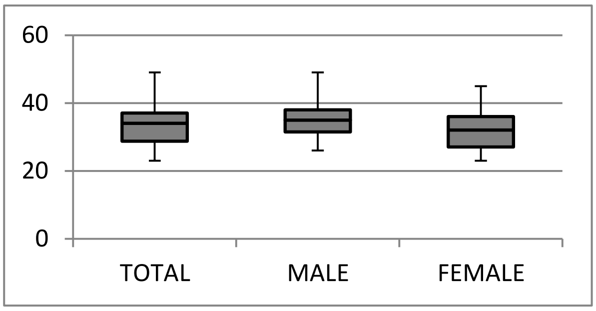
Lm



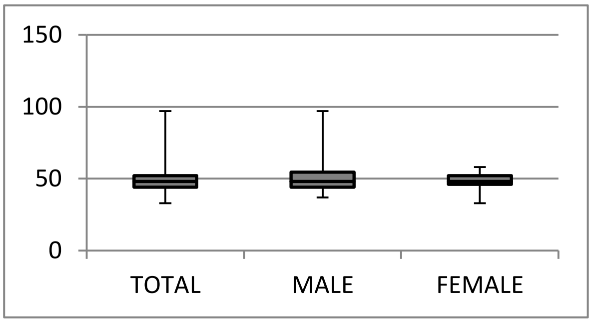
Wm1/3



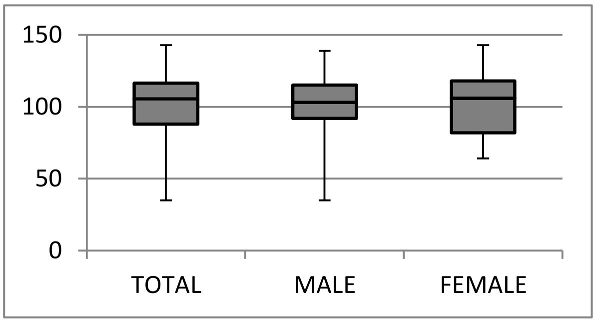
Wm2/3



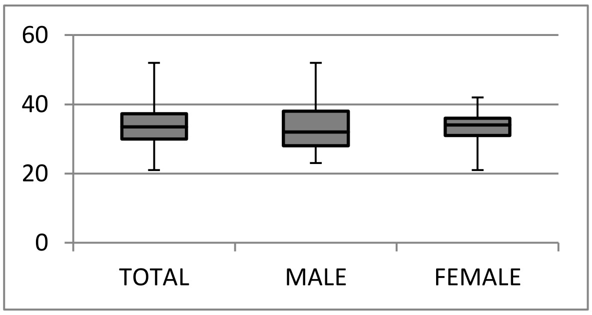
Wd



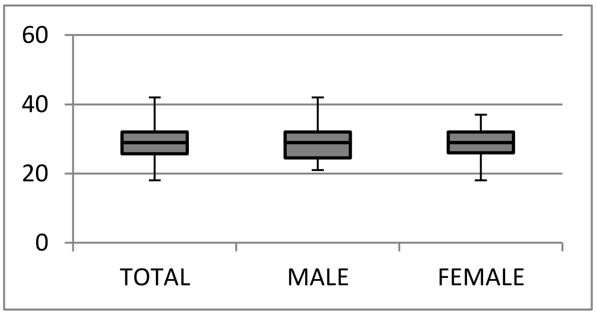
Ld



Wd1/3



Wd2/3



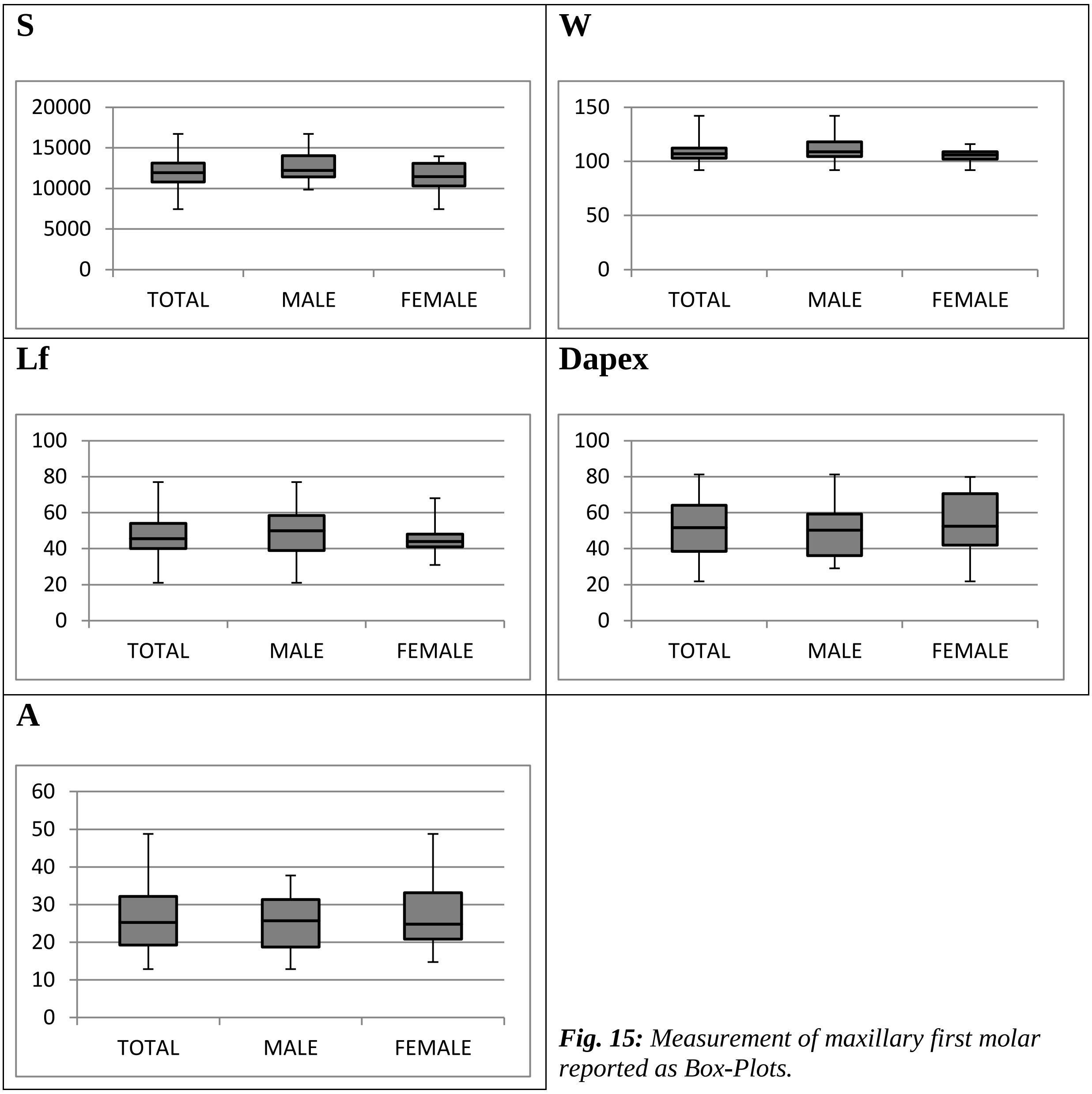


Fig. 15: *Measurement of maxillary first molar reported as Box-Plots.*

By the maxillary first molar the dimensional differences between the larger male and smaller female tracings were mostly located at the W and the Lf. When the values of both mesial and distal root were compared, relatively similar values between the males and females were found. However the angle and the distance between the apices was slightly larger for the female tracings, making the female roots more divergent than the male ones. See *appendix D*, for table with detailed representation of processed measurements of the maxillary first molar.

4.5.2. MRTI

6 out of 6:

When 6 out of 6 measures were considered, 19 pairwise superimpositions/comparisons were within the MRTI. On average 0,36 equal pairwise superimpositions were observed, with 37 tracings who had no match and the maximum amount of matches was 2.

5 out of 6:
When 5 out of 6 measures were considered, 57 pairwise superimpositions/comparisons were within the MRTI. On average 1,09 equal pairwise superimpositions were observed, with 21 tracings who had no matches and the maximum amount of matches was 5.

4 out of 6:
When 4 out of 6 measures were considered, 229 pairwise superimpositions/comparisons were within the MRTI. On average 4,40 equal pairwise superimpositions were observed, with 5 tracings who had no matches and the maximum amount of matches was 10.

0 out of 6:
When 0 out of 6 measures were considered, 236 pairwise superimpositions/comparisons were within the MRTI. On average 4,54 equal pairwise superimpositions were observed. The minimum amount of matches for a tracing was 1 and the maximum amount of matches was 27.

4.5.3. Pairwise superimposition and comparison

4.5.3.1. Per MRTI

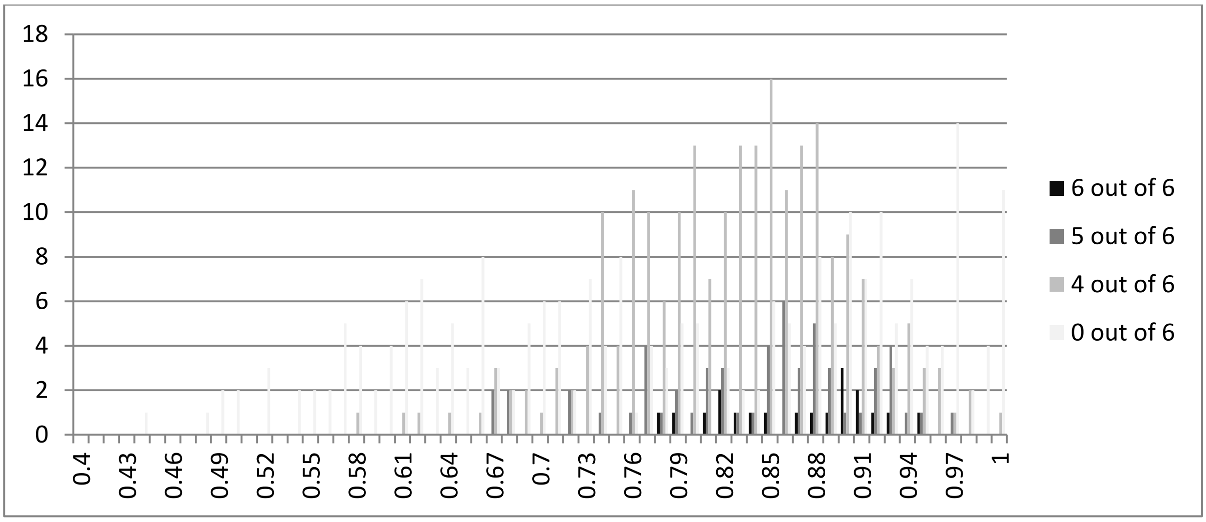


Fig. 16: *distribution of percentage of overlap of the maxillary first molar.*

6 out of 6:
The average percentage of area overlap of these tracings was 86,41% (SD 0,05), with the lowest percentage 77,62% and the highest percentage 94,68%. *(Fig. 16)*

5 out of 6:
The average percentage of area overlap of these tracings was 83,40% (SD 0,07), the lowest percentage was 66,10% and the highest percentage was 96,26% . *(Fig. 16)*

4 out of 6:
The average percentage of area overlap of these tracings was 82,13% (SD 0,07), the lowest percentage was 57,93% and the highest percentage was 99,60%. *(Fig. 16)*

0 out of 6:
The average percentage of area overlap of these tracings was 78,27% (SD 0,15), the lowest percentage was 43,72% and the highest percentage was 100%. *(Fig. 16)*

4.5.3.2. Overall consideration

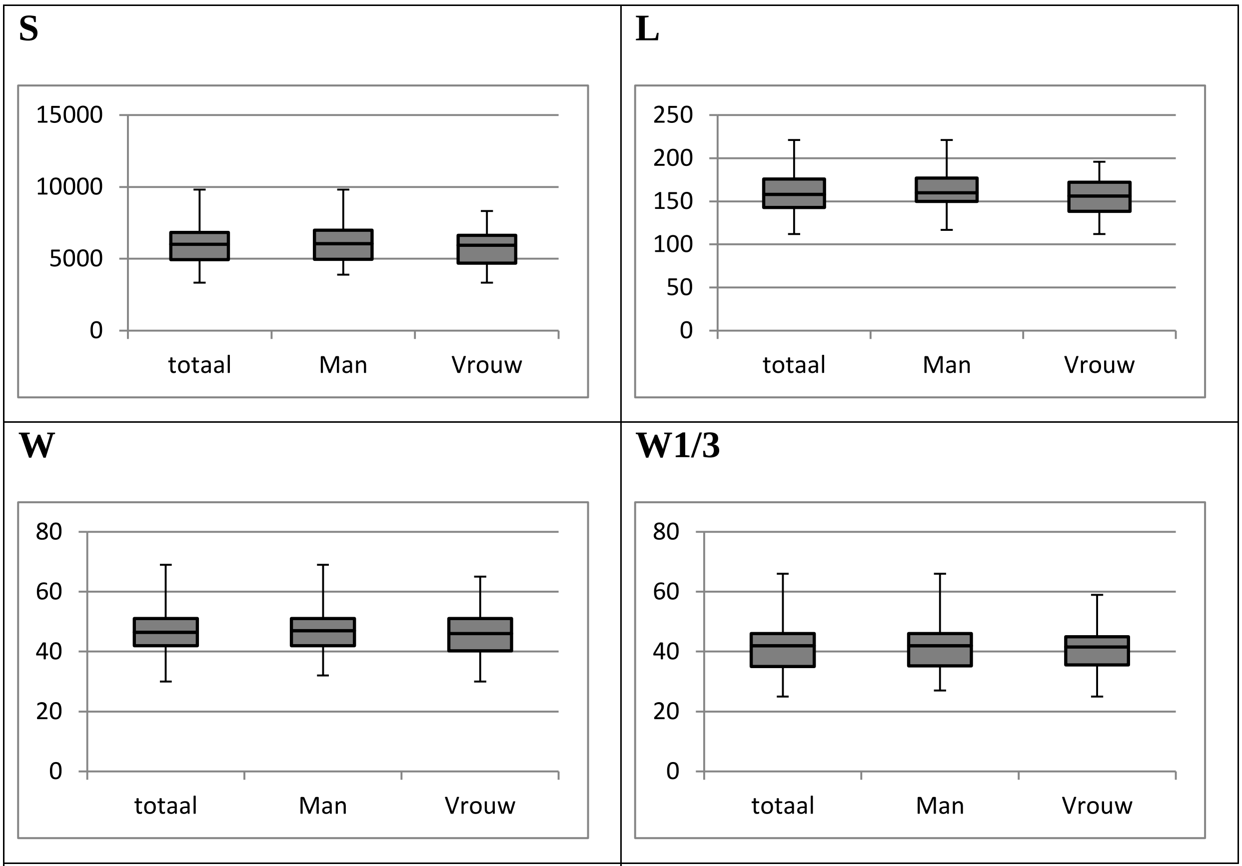
The amount of matches increased when less measures fell in the MRTI, from 19 matches when 6 out of 6 measures fell in the MRTI, to 57 matches when 5 out of 6, to 229 matches when 4 out of 6 and 236 matches when 0 out of 6 measures fell within the MRTI. The percentage of overlap decreased when less measures fell in the MRTI, respectively from 86,14% to 83,40% to 82,13% and to 78,27%. While the standard deviation increased, respectively from 0,05 to 0,07 (for both 4 and 5 out of 6 measures in the MRTI) to 0,15. The maximum percentage of overlap increased when less measures fell in the MRTI, namely 94,68% for 6 out of 6, 96,26% for 5 out of 6, 99,60% for 4 out of 6 and 100% for 0 out of 6. There was a larger deviation in value of minimum percentage of overlap, namely 77,62% for 6 out of 6, 66,10% for 5 out of 6, 57,93% for 4 out of 6 and 43,72% for 0 out of 6.

4.5.4. Control

For the four panoramic radiographs, both observers were not able to trace a single maxillary first molar. While in the original data one of the four maxillary first molars was traces and measurements were carried out.

4.6. The mandibular central incisor

4.6.1. Measurements



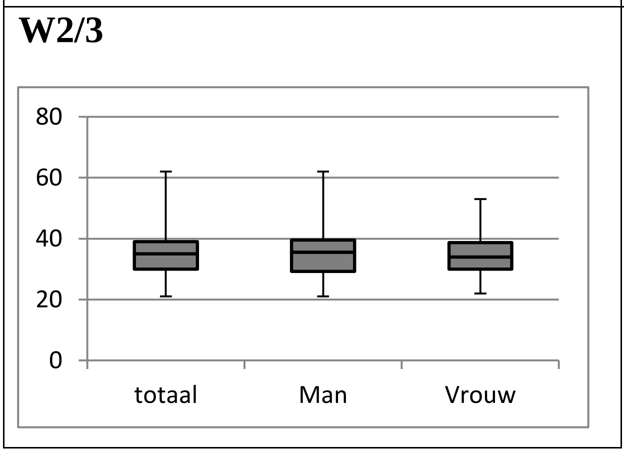


Fig. 17: *Measurement of mandibular central incisor reported as Box-Plots.*

The dimensions between the male and female tracings were relatively similar. The length from the male tracings was slightly larger and the values of the width, at the three levels of the length, were about the same between male and female tracings. See *appendix E*, for table with detailed representation of processed measurements of the mandibular central incisor.

4.6.2. SRTI

5 out of 5:
When 5 out of 5 measures were considered, 217 pairwise superimpositions/comparisons were within the SRTI. On average 2,17 equal pairwise superimpositions were observed, with 29 tracings who had no matches and the maximum amount of matches was 10.

4 out of 5:
When 4 out of 5 measures were considered, 481 pairwise superimpositions/comparisons were within the SRTI. On average 4,81 equal pairwise superimpositions were observed, with 10 tracings who had no matches and the maximum amount of matches was 16.

0 out of 5:
When 0 out of 5 measures were considered, 3083 pairwise superimpositions/comparisons were within the SRTI. On average 30,83 equal pairwise superimpositions were observed, the minimum amount of tracings was 12 and the maximum amount of matches was 76

4.6.3. Pairwise superimposition and comparison

4.6.3.1. Per SRTI

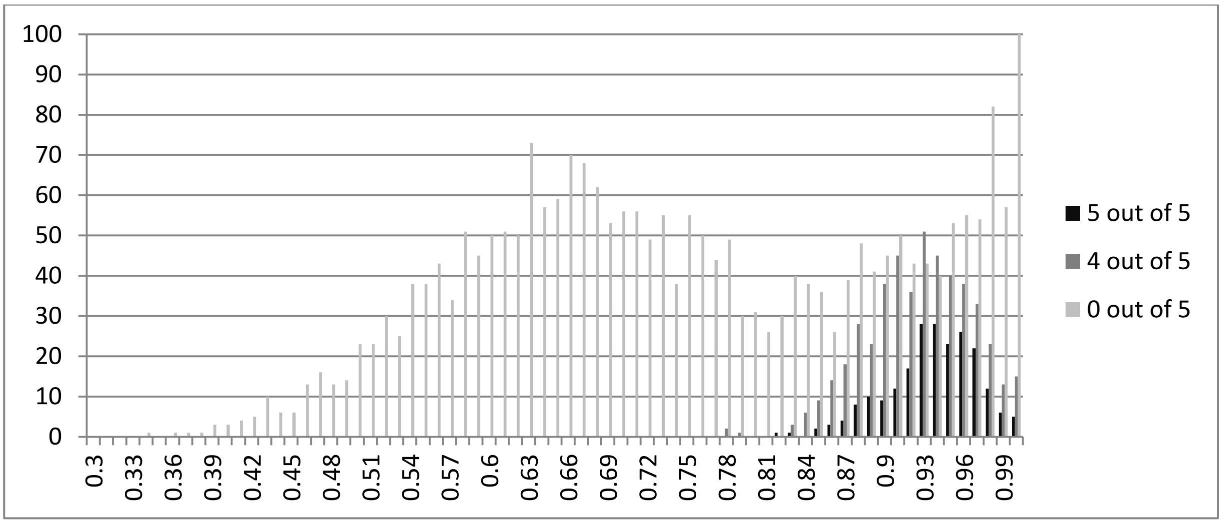


Fig. 18: *distribution of percentage of overlap of the mandibular central incisor.*

5 out of 5:
The average percentage of area overlap of these tracings was 93,17% (SD 0,03), the lowest percentage was 81,89% and the highest percentage was 100%. *(Fig. 18)*

4 out of 5:
The average percentage of area overlap of these tracings was 92,09% (SD 0,04), the lowest percentage was 77,55% and the highest percentage was 100%. *(Fig. 18)*

0 out of 5:
The average percentage of area overlap of these tracings was 79,34% (SD 0,17), the lowest percentage was 33,87% and the highest percentage was 100%. *(Fig. 18)* An overlap of 100% was the case for 684 matches. Note: value of y-axis only goes until 100.

4.6.3.2. Overall consideration

The amount of matches increased when less measures fell in the SRTI, from 217 matches when 5 out of 5 measures fell in the SRTI, to 481 matches when 4 out of 5 and 3083 matches when 0 out of 5 measures fell within the SRTI. The percentage of overlap decreased when less measures fell in the SRTI, respectively from 93,17% to 92,09% to 79,34%. While the standard deviation increased, respectively from 0,03 to 0,04 to 0,17. The maximum percentage of overlap was equal in all three situation, while there was a large deviation in value of minimum percentage of overlap, namely 81,89% for 5 out of 5, 77,55% for 4 out of 5 and 33,87% for 0 out of 5

4.6.4. Control

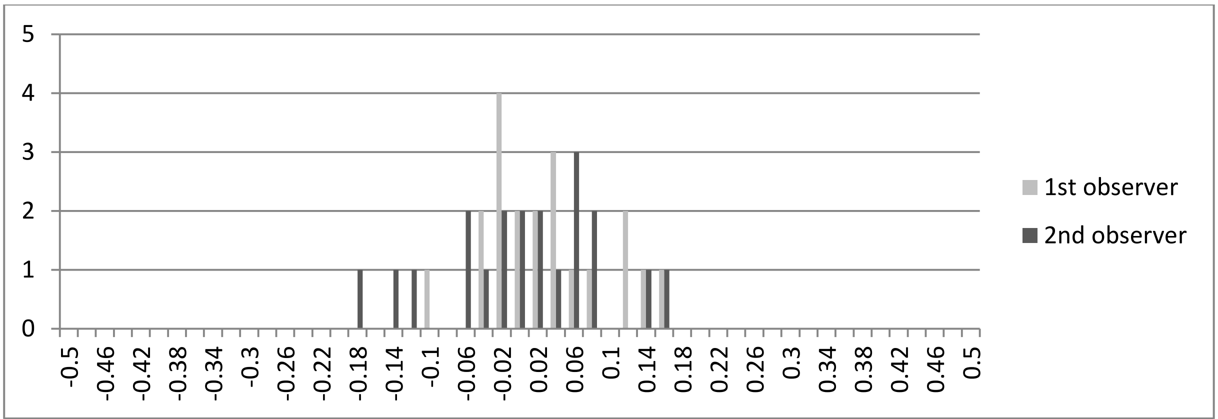
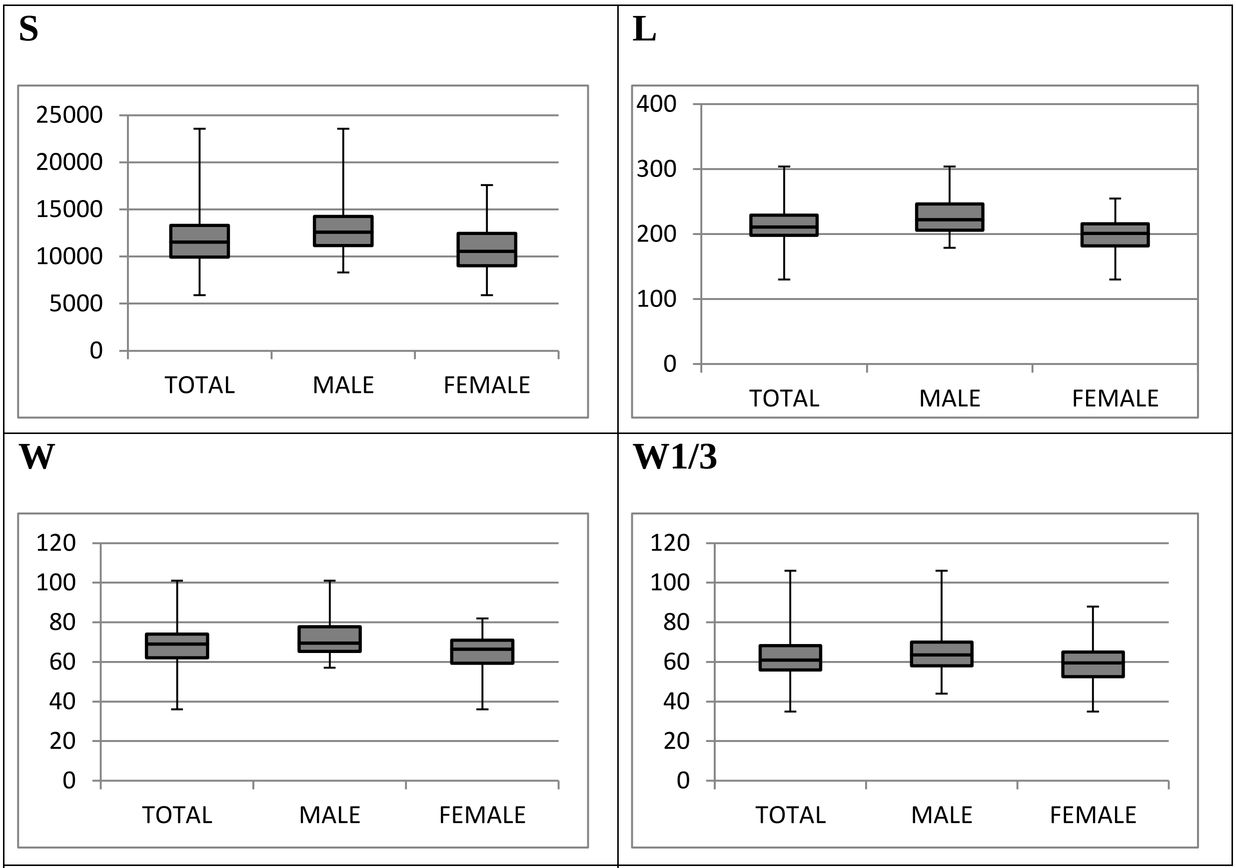


Fig. 19: *The amount of deviation of the all measurements of the mandibular central incisor.*

Both observers were able to trace all four mandibular central incisors. Less deviation in the intra observer measurements were observed compared to inter observer measurements. The average percentage of deviation between original an control and this of all measurements, was 5,27% (SD 0,07) for the first observer and 6,96% (SD 0,09) for the second observer. The average deviation was larger for the surface, 6,84% for the first observer, while the average deviation of the linear measurements 4,88% was. For the second observer the deviation of measures for the surface was 7,24% and for the linear measures 6,88%. The measurements with the least deviation between the original and the control was W1/3 (3,79%) for the first observer and W (3,84%) for the second observer. The measurements with the biggest deviation was for the first observer the S (6,84%) and for the second observer the W2/3 (13,49%).

4.7. The mandibular canine

4.7.1. Measurements



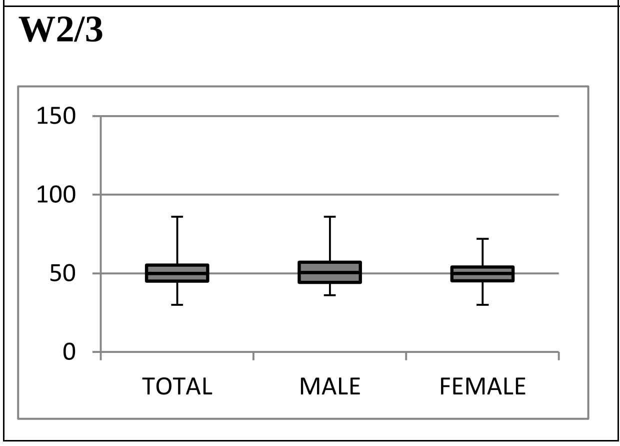


Fig. 20: *Measurement of mandibular canine reported as Box-Plots.*

The values of all the tracings were larger than the female ones. The difference was mainly located in the length. The width and this at all three levels of the length was also bigger for the males, but the difference however was less distinct than for the length. See *appendix F*, for table with detailed representation of processed measurements of the mandibular canine.

4.7.2. SRTI

5 out of 5:
When 5 out of 5 measures were considered, 235 pairwise superimpositions/comparisons were within the SRTI. On average 2,35 equal pairwise superimpositions were observed, with 33 tracing that had no match and the maximum amount of matches was 10.

4 out of 5:
When 4 out of 5 measures were considered, 479 pairwise superimpositions/comparisons were within the SRTI. On average 4,79 equal pairwise superimpositions were observed, with 11 tracings that had no match and the maximum amount of matches was 16.

0 out of 5:
When 0 out of 5 measures were considered, 2691 pairwise superimpositions/comparisons were within the SRTI. On average 26,91 equal pairwise superimpositions were observed, the minimum amount of tracings was 11 and the maximum amount of matches was 89.

4.7.3. Pairwise superimposition and comparison

4.7.3.1. Per SRTI

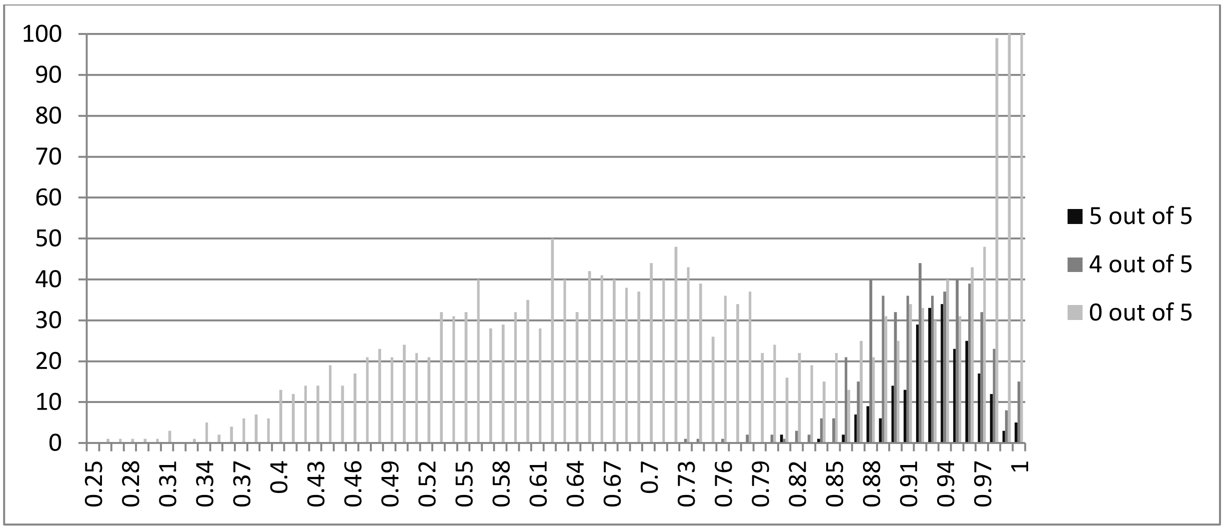


Fig. 21: *distribution of percentage of overlap of the mandibular canine.*

5 out of 5:
The average percentage of area overlap of these tracings was 92,85% (SD 0,03), the lowest percentage was 80,15% and the highest percentage was 100%. *(Fig. 21)*

4 out of 5:
The average percentage of area overlap of these tracings was 91,59% (SD 0,04), the lowest percentage was 72,59% and the highest percentage was 100%. *(Fig. 21)*

0 out of 5:
The average percentage of area overlap of these tracings was 79,74% (SD 0,19), the lowest percentage was 25,12% and the highest percentage was 100%. *(Fig. 21)* An overlap of 100% was the case for 609 matches and an overlap of 99% for 241 matches. Note: value of y-axis only goes until 100.

4.7.3.2. Overall consideration

The amount of matches increased when less measures fell in the SRTI, from 235 matches when 5 out of 5 measures fell in the SRTI, to 479 matches when 4 out of 5 and 2691 matches when 0 out of 5 measures fell within the SRTI. The percentage of overlap decreased when less measures fell in the SRTI, respectively from 92,85% to 91,59% to 79,74%. While the standard deviation increased, respectively from 0,03 to 0,04 to 0,19. The maximum percentage of overlap was equal in all three situation, while there was a large deviation in value of minimum percentage of overlap, namely 80,15% for 5 out of 5, 72,59% for 4 out of 5 and 25,12% for 0 out of 5.

4.7.4. Control

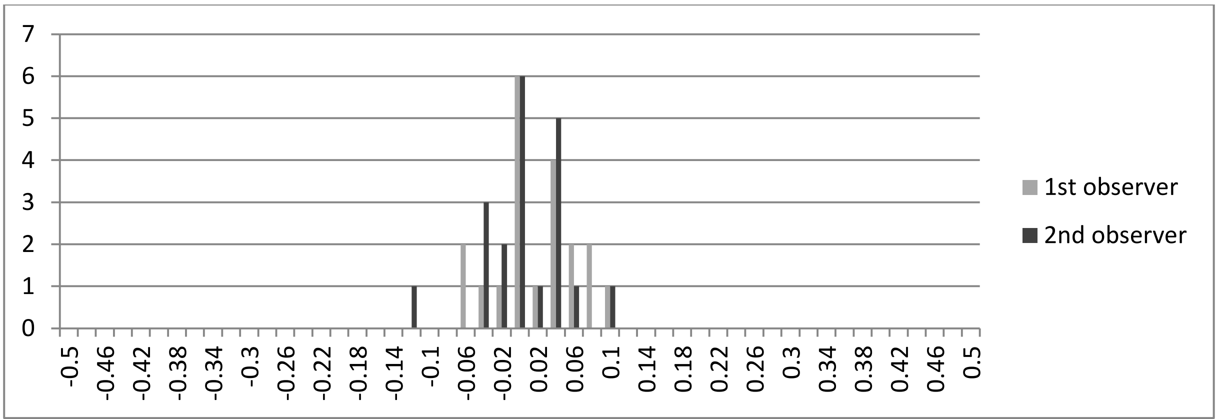


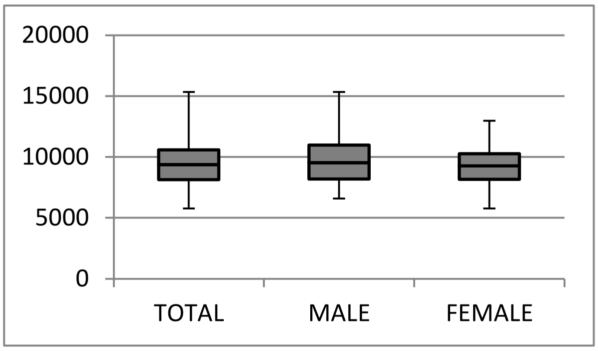
Fig. 22: *The amount of deviation of the all measurements of the mandibular canine.*

Both observers were able to trace all four mandibular canines. The second observer did slightly better than the first observer. The average percentage of deviation between original an control and this of all measurements, was 3,74% (SD 0,04) for the first observer and 3,38% (SD 0,05) for the second observer. The average deviation was larger for the surface than for the linear measurement, for the first observer respectively 5,82% and 3,22% and for the second observer respectively 4,40% and 3,12%. The linear measurements with the least deviation between the original and the control was W (2,16%) for the first observer and L (1,35%) for the second observer. The linear measurement with the most deviation between the original and the control was for the first observer the W2/3 (3,72%) and for the second observer the W1/3 (4,00%).

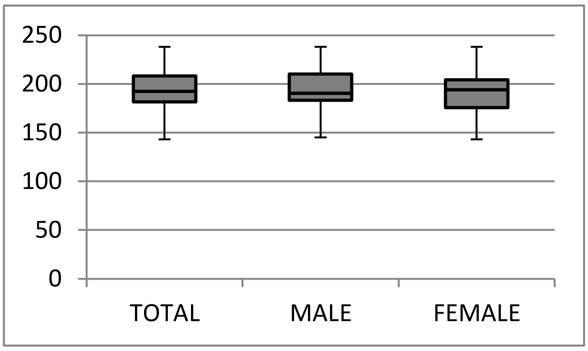
4.8. The mandibular first premolar

4.8.1. Measurements

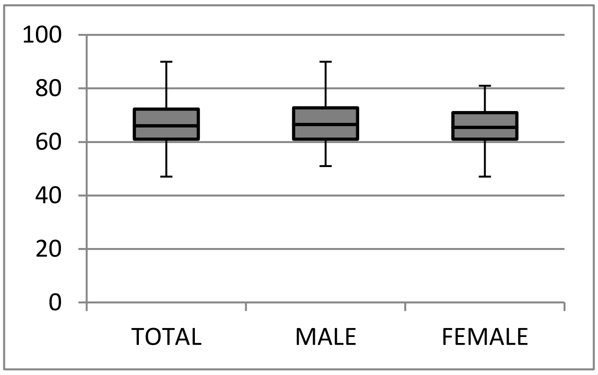
S



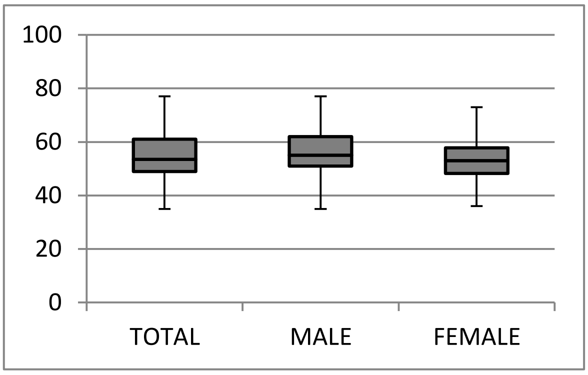
L



W



W1/3



W2/3

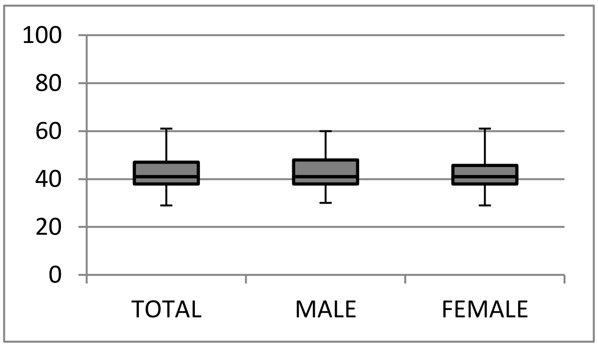


Fig. 23: *Measurement of mandibular first premolar reported as Box-Plots.*

The dimensions of the measurements were similar between male and female tracings. The male tracings were slightly bigger and this for all five measures. The difference between the minimum and maximum value of all measurements were similar between the male and female tracings and this also for all measures. See *appendix G*, for table with detailed representation of processed measurements of the mandibular first premolar.

4.8.2. SRTI

5 out of 5:
When 5 out of 5 measures were considered, 266 pairwise superimpositions/comparisons were within the SRTI. On average 2,66 equal pairwise superimpositions were observed, with 29 tracing that had no match and the maximum amount of matches was 11.

4 out of 5:
When 4 out of 5 measures were considered, 677 pairwise superimpositions/comparisons were within the SRTI. On average 6,77 equal pairwise superimpositions were observed, with 6 tracing that had no match and the maximum amount of matches was 16.

0 out of 5:
When 0 out of 5 measures were considered, 2285 pairwise superimpositions/comparisons were within the SRTI. On average 22,85 equal pairwise superimpositions were observed, the minimum amount of matches was 7 and the maximum amount of matches was 78.

4.8.3. Pairwise superimposition and comparison

4.8.3.1. Per SRTI

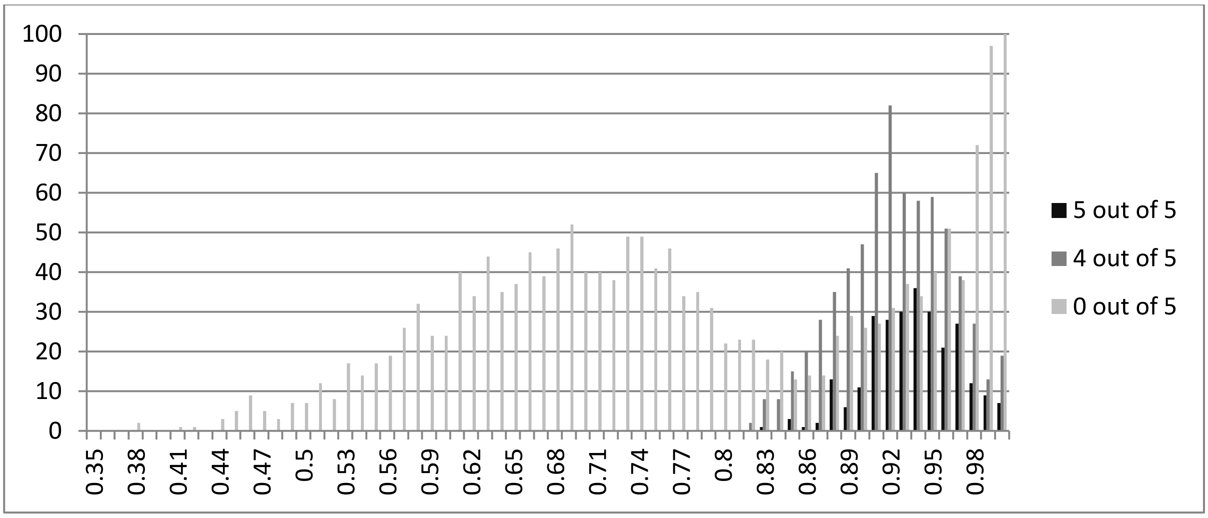


Fig. 24: *distribution of percentage of overlap of the mandibular first premolar.*

5 out of 5:
The average percentage of area overlap of these tracings was 93,16% (SD 0,03), the lowest percentage was 82,91% and the highest percentage was 100%. *(Fig. 24)*

4 out of 5:
The average percentage of area overlap of these tracings was 91,81% (SD 0,04), the lowest percentage was 81,58% and the highest percentage was 100%. *(Fig. 24)*

0 out of 5:
The average percentage of area overlap of these tracings was 85,52% (SD 0,16), the lowest percentage was 37,59% and the highest percentage was 100%. *(Fig. 24)* An overlap of 100% was the case for 621 matches. Note: value of y-axis only goes until 100.

4.8.3.2. Overall consideration

The amount of matches increased when less measures fell in the SRTI, from 266 matches when 5 out of 5 measures fell in the SRTI, to 677 matches when 4 out of 5 and 2285 matches when 0 out of 5 measures fell within the SRTI. The percentage of overlap decreased when less measures fell in the SRTI, respectively from 93,16% to 91,81% to 85,52%. While the standard deviation increased, respectively from 0,03 to 0,04 to 0,16. The maximum percentage of overlap was equal in all three situation, while there was a large deviation in value of minimum percentage of overlap, namely 82,91% for 5 out of 5, 81,58% for 4 out of 5 and 37,59% for 0 out of 5.

4.8.4. Control

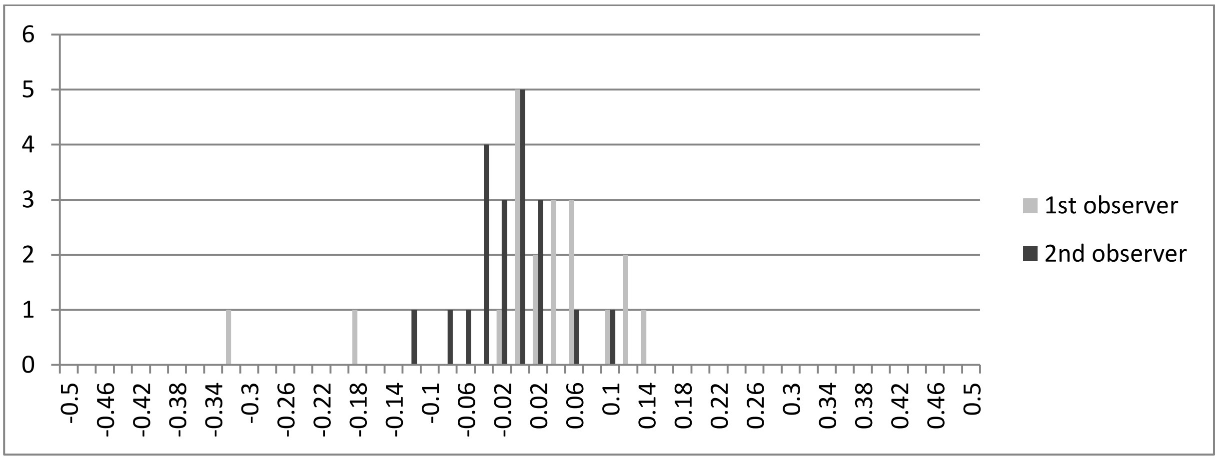


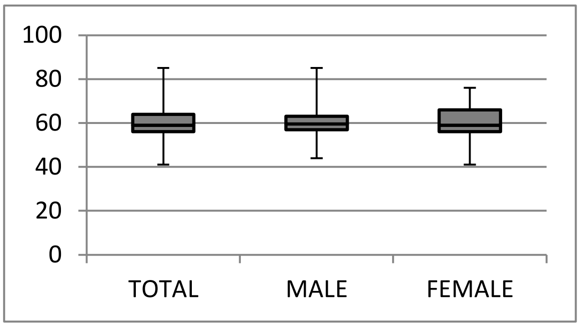
Fig. 25: *The amount of deviation of the all measurements of the mandibular first premolar.*

Both observers were able to trace all four mandibular first premolars. The second observer did better than the first observer. The average percentage of deviation between original an control and this of all measurements, was 6,32% (SD 0,10) for the first observer and 3,92% (SD 0,05) for the second observer. The average deviation of the surface was for the first observer 11,09% and for the second observer 3,49%. For the linear measurements the average deviation from the original was 5,12% for the first observer and 4,90% for the second observer. The linear measurements with the least deviation between the original and the control was the W and this for both observers, 1,50% for the first and 1,63% for the second. The linear measurement with the most deviation between the original and the control was for the first observer the L (10,17%) and for the second observer the W2/3 (8,13%).

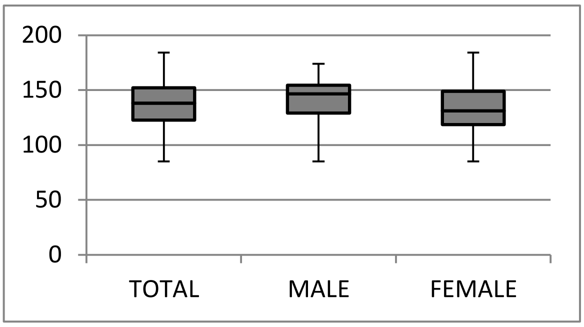
4.9. The mandibular first molar

4.9.1. Measurements

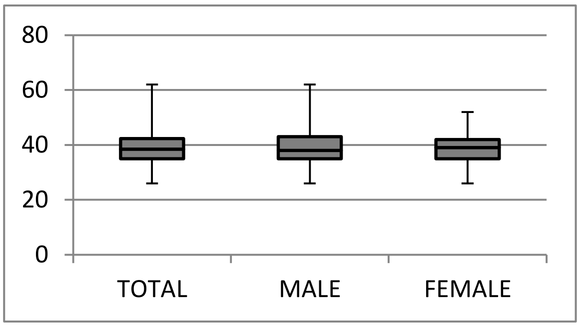
Wm



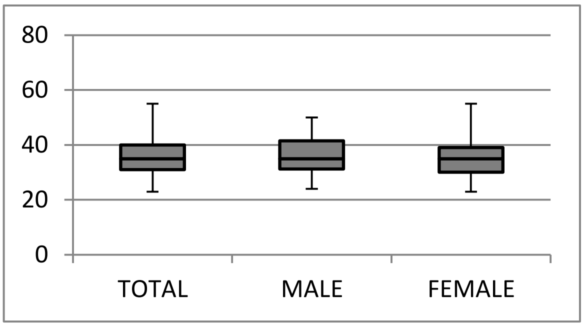
Lm



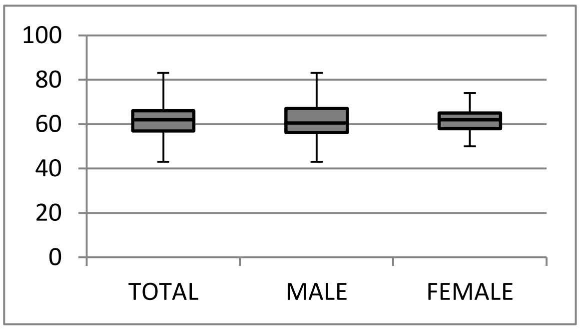
Wm1/3



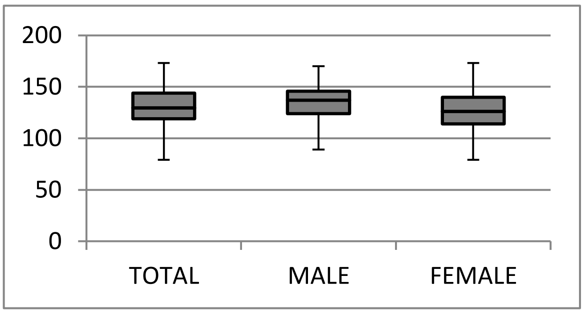
Wm2/3



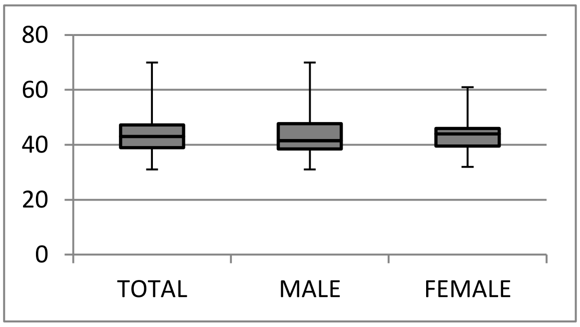
Wd



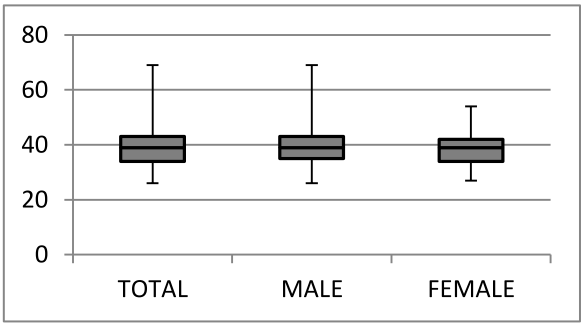
Ld



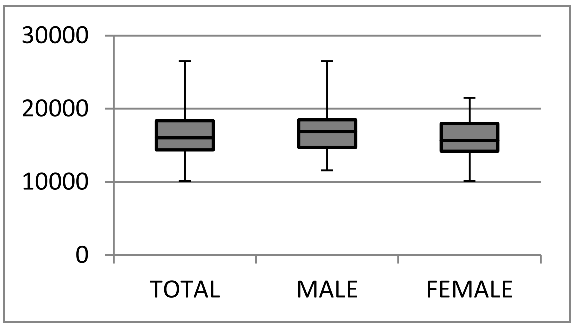
Wd1/3



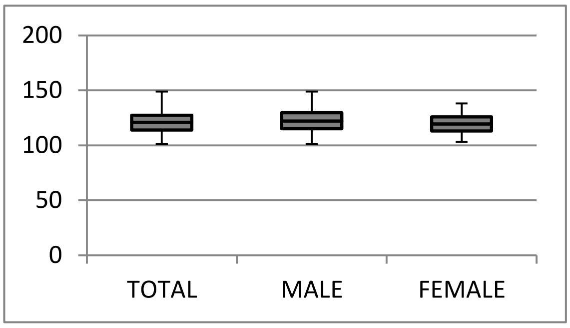
Wd2/3



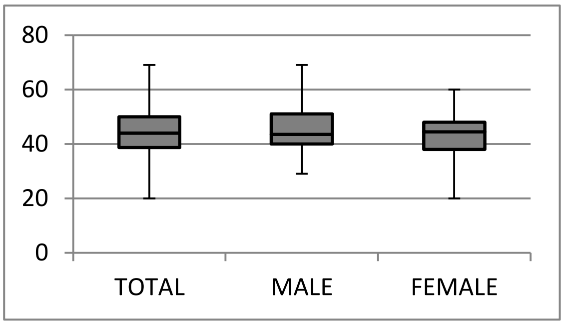
S



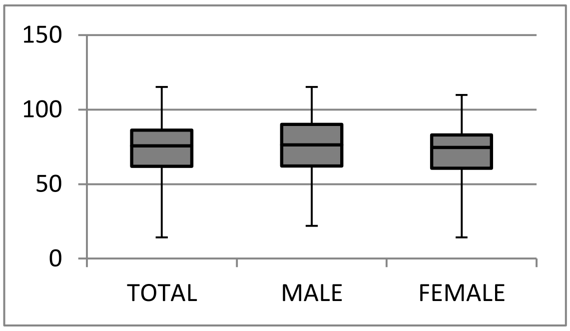
W



Lf



Dapex



A

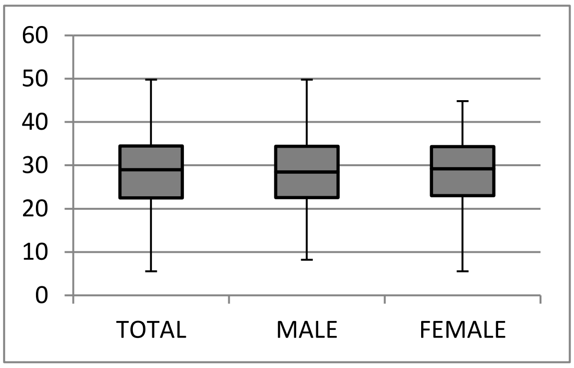


Fig. 26: *Measurement of mandibular first molar reported as Box-Plots.*

The male tracings had larger values for Lf as well as the Lm and Ld, making the total length of the male tracing longer than the female tracings. The width of the separate roots, at all levels of the length, had similar dimensions for male and female tracings. The angle and distance between both roots had relatively equal dimensions between tracings derived from males and females. There was especially a large difference between minimum and maximum value of the angle between the roots. See *appendix H*, for table with detailed representation of processed measurements of the mandibular first molar.

4.9.2. MRTI

6 out of 6:
When 6 out of 6 measures were considered, 34 pairwise superimpositions/comparisons were within the MRTI. On average 0,34 equal pairwise superimpositions were observed, with 73 tracings who had no match and the maximum amount of matches was 3.

5 out of 6:
When 5 out of 6 measures were considered, 322 pairwise superimpositions/comparisons were within the MRTI. On average 3,22 equal pairwise superimpositions were observed, with 23 tracings who had no match and the maximum amount of matches was 12.

4 out of 6:
When 4 out of 6 measures were considered, 989 pairwise superimpositions/comparisons were within the MRTI. On average 9,89 equal pairwise superimpositions were observed, with 5 tracings who had no match and the maximum amount of matches was 22.

0 out of 6:
When 0 out of 6 measures were considered, 973 pairwise superimpositions/comparisons were within the MRTI. On average 9,73 equal pairwise superimpositions were observed, the minimum amount of matches a tracing had was 1 and the maximum amount of matches was 43.

4.9.3. Pairwise superimposition and comparison

4.9.3.1. Per MRTI

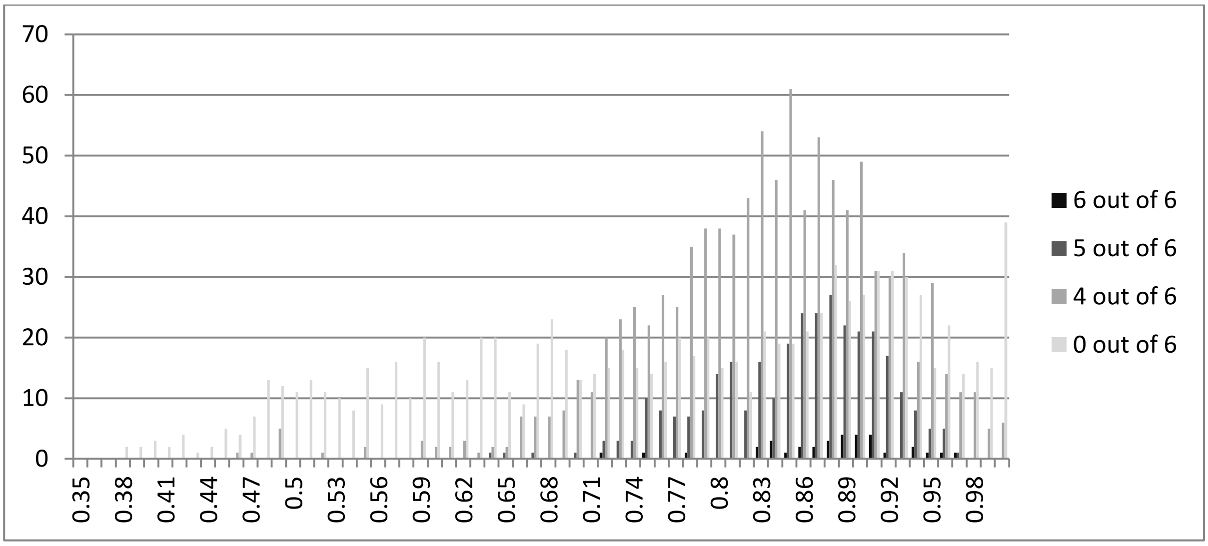


Fig. 27: *distribution of percentage of overlap of the mandibular first molar.*

6 out of 6:
The average percentage of area overlap of these tracings was 87,34% (SD 0,05), the lowest percentage was 71,70% and the highest percentage was 96,23%. *(Fig. 27)*

5 out of 6:
The average percentage of area overlap of these tracings was 85,03% (SD 0,06), the lowest percentage was 63,45% and the highest percentage was 96,59%. *(Fig. 27)*

4 out of 6:
The average percentage of area overlap of these tracings was 82,76% (SD 0,08), the lowest percentage was 45,97% and the highest percentage was 100%. *(Fig. 27)*

0 out of 6:
The average percentage of area overlap of these tracings was 76,07% (SD 0,16), the lowest percentage was 37,75% and the highest percentage was 100%. *(Fig. 27)*

4.9.3.2. Overall consideration

The amount of matches increased when less measures fell in the MRTI, from 34 matches when 6 out of 6 measures fell in the MRTI, to 322 matches when 5 out of 6, to about equal amount of matches for 4 and 0 out of 6, respectively 989 and 973 matches. The percentage of overlap decreased when less measures fell in the MRTI, respectively from 87,34% to 85,03% to 82,76% and to 76,07%. While the standard deviation increased, respectively from 0,05 to 0,06 to 0,08 to 0,15. The maximum percentage of overlap increased when less measures fell in the MRTI, namely 96,23% for 6 out of 6, 96,59% for 5 out of 6, and for both 4 and 0 out of 6 it was 100%. There was a larger deviation in value of minimum percentage of overlap, namely 71,70% for 6 out of 6, 63,45% for 5 out of 6, 45,97% for 4 out of 6 and 37,75% for 0 out of 6.

4.9.4. Control

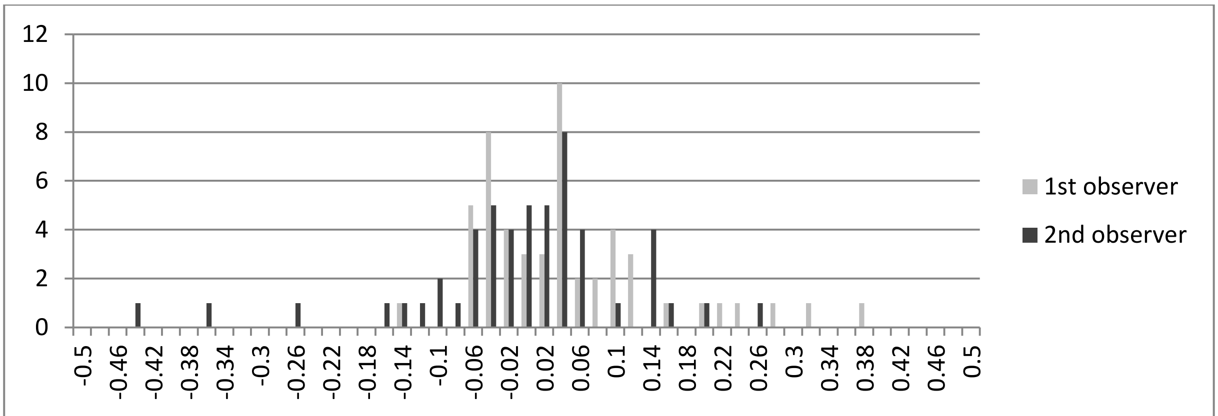


Fig. 28: *The amount of deviation of the all measurements of the mandibular first molar.*

Both observers were able to trace all four mandibular first molars. The average percentage of deviation between original an control and this of all measurements, was 7,78% (SD 0,10) for the first observer and 8,16% (SD 0,12) for the second observer. The average deviation of the surface was for the first observer 14,33% and for the second observer 6,33%. For the linear measurements the average deviation from the original was 7,23% for the first observer and 8,31% for the second observer. The linear measurements with the least deviation between the original and the control was the Lm (2,10%) for the first observer and the Ld (2,35%) for the second observer. The linear measurements with a deviation larger than 10% were for the first observer: Wm1/3 (11,09%), Wm2/3 (15,81%) and Lf (11,73%). The linear measurements with a deviation larger than 10% were for the second observer: Wm1/3 (20,70%), Wm2/3 (19,31%) and Lf (14,42%)

4.10. Comparison

4.10.1. Single rooted elements

5 out of 5	Maxillary central incisor	Maxillary canine	Maxillary first premolar	Mandibular central incisor	Mandibular canine	Mandibular first premolar
# matches	206	288	71	217	235	266
Average %	94,01	92,74	93,14	93,17	92,85	93,16
SD	0,03	0,03	0,03	0,03	0,03	0,03
Min %	81,17	82,18	85,26	81,89	80,15	82,91
Max. %	100	100	100	100	100	100

4 out of 5	Maxillary central incisor	Maxillary canine	Maxillary first premolar	Mandibular central incisor	Mandibular canine	Mandibular first premolar
# matches	419	662	248	481	479	677
Average %	93,62	92,09	92,75	92,09	91,59	91,81
SD	0,05	0,04	0,04	0,04	0,04	0,04
Min. %	59,78	62,94	81,01	77,55	72,59	81,58
Max. %	100	100	100	100	100	100

0 out of 5	Maxillary central incisor	Maxillary canine	Maxillary first premolar	Mandibular central incisor	Mandibular canine	Mandibular first premolar
# matches	2922	2728	1428	3083	2691	2285
Average %	81,50	81,53	81,36	79,34	79,74	85,52
SD	0,17	0,18	0,18	0,17	0,19	0,16
Min. %	36,93	28,74	32,78	33,78	25,12	37,59
Max%	100	100	100	100	100	100

Table 2: *data per SRTI for all 6 single rooted elements*

The chance of a tracing to have a match with all 5 measures within the SRTI, taking in account the amount of tracing it was possible to make, was 2,29%. For 4 out of 5 it was 5,45% and when no measures fell within the SRTI the chance was 28,08%.

All teeth elements followed a similar pattern. When less measures fell within the SRTI, there was an increase in amount of matches, a decrease in average percentage of overlap, an increase in SD, a decrease in minimum percentage of overlap and the maximum percentage was always 100%.

The average percentage, when all measures fell within the SRTI, was highest for the maxillary central incisor, closely followed by the mandibular central incisor and both first premolars. The canines have the lowest average percentage of overlap. When the average percentage was compared, when 5 out of 5 and 4 out of 5 measures fell within the SRTI, there were only small differences in value. For all elements combined the average difference was 0,85%, but separately for both jaws, it was 0,48% for the maxilla and 1,23% for the mandible. The minimum percentage of overlap when all 5 measures fell in the SRTI was similar to the average percentage of overlap when no measures where in the SRTI.

The maximum percentage of overlap was always 100%, making it quite common for one tracing to fall completely within the other.

4.10.2. Multiple rooted elements

6 out of 6	Maxillary first molar	Mandibular first molar
# matches	19	34
Average %	86,14	87,34
SD	0,05	0,05
Min. %	77,62	71,70
Max. %	94,68	96,23

5 out of 6	Maxillary first molar	Mandibular first molar
# matches	57	322
Average %	83,40	85,03
SD	0,07	0,06
Min. %	66,10	63,45
Max. %	96,26	96,59

4 out of 6	Maxillary first molar	Mandibular first molar
# matches	229	989
Average %	82,13	82,76
SD	0,07	0,08
Min. %	57,93	45,97
Max. %	99,60	100

0 out of 6	Maxillary first molar	Mandibular first molar
# matches	236	973
Average %	78,27	76,07
SD	0,15	0,16
Min. %	43,72	37,75
Max. %	100	100

Table 3: *data per MRTI for both multiple rooted elements*

The chance of a tracing to have a match with all 6 measures within the MRTI, taking in account the amount of tracing it was possible to make, was 0,55%. For 5 out of 6 it was 2,75%, for 4 out of 6 it was 9,49% and when no measures fell within the MRTI the chance was 9,54%.

All teeth elements followed a similar pattern. When less measures fell within the MRTI, there was an increase in amount of matches, a decrease in average percentage of overlap, an increase in SD, a decrease in minimum percentage of overlap and an increase in maximum percentage of overlap.

The high difference in amount of matches was the result of the impossibility to trace almost half of the maxillary first molars. However there is still a high similarity between the data. The average percentage is 1,20 % higher for the mandibular first molar. The minimum percentage of overlap when all measures where in the MRTI is similar to the average percentage when no measures fell within.

The increase in maximum percentage of overlap when less measures fell within the MRTI, indicate that it is quite uncommon for one tracing to fall completely within the other.

5. Discussion

It is assumed that teeth are unique, but does this also apply on the roots of the teeth? In order to find if there is enough variation in root morphology to aid in the human identification process after PMTL, we examined 100 panoramic radiographs. The root morphology of eight different tooth elements were registered radiographically and a number of measurements were performed as well as an comparison by superimposition of a portion of the tracings.

PMTL is a not to underestimated problem in the human identification process. It can occur under multiple circumstances and the risk increases with a longer PM interval, when the soft tissues can decompose for a longer time period. Already in 1992 it was reported that the root morphology could be reconstructed in a simple, inexpensive and reversible way, using a radio-opaque impression material. Using this technique additional dental information can be registered and documented. Our research was set up to assess if the root morphology is indeed unique or has at least enough variation in shape to be useful in the process of human identification.

Panoramic radiographs were used, the advantage of this type of radiographs is that all tooth positions of the same subject could be evaluated on the same radiograph at the same time and the subject is exposed to less radiation. In the meantime the roots of different radiographs get visualized with similar angulation. However panoramic radiographs also have their disadvantages. The amplification and image quality is not the same at different locations on the radiograph. Because comparisons were performed tooth position specific the deformation of the roots were similar for the compared roots. Another limitation of panoramic radiographs are the superimpositions of other skeletal structures mainly in the upper jaw. These superimpositions were the cause that for certain elements (in the upper jaw) tracings were not possible. In particular almost half of the maxillary first molars weren't traced, mainly due to superimposition of the sinus and their specific root morphology. In fact, the palatal root was often not clearly visible or was in overlap with the other roots, making it difficult to differentiate the three roots. The roots of the mandibular first premolar were traced in 3/4 of the included subjects. The main reason of the impossibility to trace these roots was the presence of a second root in superimposition with the other (root/tooth) structures. Specific root morphology caused more problems during the tracing. For example, an additional root or an eight-shaped root can give the impression of a second periodontal ligament. This gives the tracing a subjective side, because it was not always clear which PDL to trace. The control measurements illustrate this problem, because the teeth that often have an additional root, like the maxillary first premolar or mandibular first molar, showed a higher deviation in the W1/3 and W2/3 than for the other measurements. While a higher deviation in the length was seen in the elements of the upper jaw, due to superimposition of other skeletal structures. Due to an airgap between tongue and palate the PDL could not be visualized for the roots of five maxillary incisors and three maxillary, making it impossible to trace these elements.

When all measurements fell within the interval of plus and minus ten percent, there is on average a 93,07% overlap for the single rooted teeth and 86,88% for the multiple rooted teeth. However, it is only a small fraction of the teeth where all measurements fell within this interval. Depending on the tooth type around 2% for single rooted teeth and less than 1% for the multiple rooted teeth fell in the all measurements interval. In other words, when AM and PM measures are compared and all 5 are within the SRTI or all 6 within the MRTI the probability of getting a match is high. When less values from the measurements fell within the interval, the percentage of overlap dropped. The drop was around one percent when going from five to four measures in the SRTI and around twenty percent with no measures in the

SRTI. The drop was around two or three percent going from all to five and again going from five to four measures in the MRTI. From all to no measures in the MRTI, the drop was around ten percent. However, not all tracings got compared with each other, the percentage of tracings that got compared to the total amount of possible comparisons was calculated. This percentage variates between the different elements, especially between single and multiple rooted teeth. In the singe rooted teeth the percentage of tracings that got compared, was between 30% and 40% with an average of 36%. For the multiple rooted teeth, it was 21% for the maxillary and 23% for the mandibular first molar.

Depending on the considered tooth type, around 2% of the tracings of the single rooted teeth, fell in the all measurement interval. In particular the percentages for the maxillary first premolar, the mandibular central incisor and the maxillary central incisor were 1,21; 2,19; 2,31% respectively. In the current study the percentage of the maxillary first premolar (1,21%) is less reliable, because less included radiographs allowed for tracings. The highest percentage was for the maxillary canine (3,09%). Around 1% of the tracings of the multiple rooted teeth fell in the all measurements interval. The percentages for the mandibular first molar and the maxillary first molar were respectively 0,74% and 0,34%. The percentage of the maxillary first molar (0,34%) is less reliable, because less included radiographs allowed for tracings.

In forensic practice, where AM and PM tracings will be compared, there is an indication for a higher chance of a positive match, when all measurements fall in the all measurements interval. This chance is highest for the multiple rooted teeth, because they have the smallest fraction of tracings that fall in this all measures interval. However, molars are less susceptible for PMTL, therefor it will occur less in a forensic case. Teeth most susceptible for PMTL are the incisors, in particularly the maxillary central incisor. A larger fraction of the tracings of the incisors fell in the all measures interval compared to the multiple rooted teeth, however they do belong to the smallest fraction compared with other single rooted teeth.

When we take the reproducibility of the tracings in consideration, the single rooted teeth do significantly better than the multiple rooted teeth, because the control measurements show less deviation from the original. The combined data of both observers give a 4,65% deviation for the maxillary central incisor and 6,12% deviation for de mandibular central incisor. For the mandibular first molar the deviation was 7,97% and this is the highest percentage of deviation between original and control of all examined tooth elements.

One of the more obvious limitation of this research is that not all tracings got compared among each other by means of superimposition. A pre-selection of suitable cases was made based on the measures performed on the tracings. When we would have data of all tracings, the data could be processed using another grouping method, for example, all superimposition with a specific percentage of overlap. Further on it was not possible to calculate the percentage of overlap including all tracings. This percentage is probably lower, than when calculated with the superimpositions that were performed. The reason is that the fractions of tracings that were not compared, fall in the lower categories with less measurements within the SRTI/MRTI. Another problem faced with the superimposition was that smaller tracing surfaces disappeared sometimes completely in a larger one and provided 100% of overlap for these smaller element. As a consequence the real number of percentage of overlap is less than the results indicate. When the percentage of superimposition is visualized in a graph, sometimes large incline at the end of this graph (from 98% to 100% of overlap). This incline is only visible when no measures fell in the SRTI. Because there is so much difference in value of the measurement, a smaller tracing could be placed (almost) completely within a bigger tracing. Giving very high percentage of overlap for this smaller tracing even though it clearly differs from the larger tracing. This phenomenon is less seen by the multiple rooted teeth, because of their complex root structure. A last limitation is the small control group and that the control measurements are only performed by two observers. The panoramic radiographs were randomly selected and because of the small control group, there were no radiographs selected where the maxillary first molar was traced and only two radiographs where the maxillary first premolar could be traced. But in the meantime, this illustrates what can happen in a forensic practice, namely that not all random identification cases with AM panoramic radiographs will allow to perform root tracings, measures and superimposition. Luckily are these teeth (molars/premolars) least affected by PMTL. More observers would give the test more power and create a more accurate image of the applicability in a forensic case, because we would get a more clearer view of the reproducibility between different observers.

When measurements are conducted on panoramic radiographs, we see a lot of variation in root morphology. This variation gives them potential in the human dental identification process, were we rely on the differences and similarities in morphology for the identification. In the forensic practice however, they mainly use periapical radiographs for the collection of PM data and periapical radiographs are also more commonly used in a general dental practice. The advantage of a panoramic radiograph is that all teeth and multiple other skeletal structures are visualized with one picture in comparison to the much smaller periapical radiograph, though they do show more signs of distortion. The biggest disadvantage of the smaller radiographs while taking PM radiographs, is that they need to be placed similar to the AM radiograph, because another angulation can be misleading. A solution could be to use ratios of the measurements, but needs to be further examined.

Because periapical radiographs are so commonly used, both in forensic as general dental practice, a research needs to be set up to check if this variation in root morphology can also be proved on this type of radiograph. The theory, that empty alveolar sockets can be used as an identifier in the human identification process, needs to be tested. This can happen in a case study on actual forensic cases were PMTL has occurred or on skulls were the teeth are removed postmortem

PMTL is a common phenomenon that can complicate the identification process. There is enough variation in the root morphology to aid in this process. Based on measurements performed on radiographs of an empty socket and an AM panoramic radiograph, a prediction can be made regarding the possibility of a positive match or exclusion. However, image quality and inherent superimposition of anatomical structures in panoramic radiographs, strongly hamper its application on multiradicular teeth.

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7. Appendix

A. Measurements maxillary central incisor

TOTAL	S	W	L	W1/3	W2/3
Sample size	95	95	95	95	95
Mean	11424,5	73,1	192,5	66,7	51,4
Minimum	7133	51	119	43	35
25th percentile	9518,5	64,5	172	58	43
Median	11109	71	192	65	51
75th percentile	12721	82	212,5	74,5	58,5
Maximum	18846	108	280	92	77
SD	2610,5	11,0	28,8	11,5	9,6
Margin of error	525,0	2,2	5,8	2,3	1,9

MALE	S	W	L	W1/3	W2/3
Sample size	46	46	46	46	46
Mean	12525,7	73,5	204,6	68,2	52,4
Minimum	7856	51	160	43	35
25th percentile	10053,8	65	178	58	46
Median	12353,5	70	207	66,5	52
75th percentile	15287	83,8	226,8	77,8	58,8
Maximum	18846	96	280	91	77
SD	2984,8	11,4	29,5	12,0	9,8
Margin of error	862,6	3,3	8,5	3,5	2,8

FEMALE	S	W	L	W1/3	W2/3
Sample size	49	49	49	49	49
Mean	10390,8	72,8	181,2	65,3	50,4
Minimum	7133	55	119	48	35
25th percentile	9195	64	170	57	43
Median	10615	72	184	64	48
75th percentile	11413	80	197	72	58
Maximum	14213	108	220	92	77
SD	1655,5	10,8	23,2	11,0	9,35
Margin of error	463,5	3,0	6,5	3,07	2,62

B. Measurements maxillary canine

TOTAL	S	W	L	W1/3	W2/3
Sample size	97	97	97	97	97
Mean	13282,89	74,07	233,32	64,00	49,56
Minimum	6839	54	141	43	34
25th precentile	10994	68	218	58	43
Median	12652	73	235	63	49
75th precentile	15354	81	246	70	55
Maximum	23793	93	317	85	85
SD	3108,8	1,41	31?41	9,24	9,12
Margin of error	618,66	0,28	6,25	1,84	1,81

MALE	S	W	L	W1/3	W2/3
Sample size	49	49	49	49	49
Mean	14212,82	76,49	241,14	66,43	51,04
Minimum	7513	54	162	46	36
25th precentile	11650	69	221	60	43
Median	14012	75	237	67	52
75th precentile	16197	86	256	73	56
Maximum	23793	93	317	85	85
SD	3484,20	10,10	33,27	9,66	9,96
Margin of error	975,56	2,83	9,31	2,70	2,79

FEMALE	S	W	L	W1/3	W2/3
Sample size	48	48	48	48	48
Mean	12333,58	71,60	225,33	61,52	48,04
Minimum	6839	56	141	43	34
25th precentile	10720,5	65	210	55,75	42
Median	12055	71,5	229	61	47
75th precentile	13838	77,25	241	66	53,25
Maximum	17799	89	287	79	68
SD	2349,62	8,36	27,24	8,53	8,24
Margin of error	664,70	2,36	7,71	2,41	2,33

C. Measurements maxillary first premolar

TOTAL	S	W	L	W1/3	W2/3
Sample size	77	77	77	77	77
Mean	8368,94	67,10	183,00	52,04	39,42
Minimum	4165	52	110	35	24
25th precentile	6984	61	169	45	35
Median	8428	67	183	51	39
75th precentile	9884	72	201	56	44
Maximum	12582	91	226	78	59
SD	1830,71	4,95	24,16	9,71	7,12
Margin of error	408,91	1,11	5,40	2,17	1,59

MALE	S	W	L	W1/3	W2/3
Sample size	37	37	37	37	37
Mean	9032,51	69,41	187,30	53,84	40,81
Minimum	6305	53	144	35	24
25th precentile	7445	64	174	49	38
Median	8948	69	184	52	41
75th precentile	10274	74	202	60	45
Maximum	12582	91	226	75	59
SD	1715,05	9,23	22,39	9,54	7,38
Margin of error	552,62	2,97	7,21	3,07	2,38

FEMALE	S	W	L	W1/3	W2/3
Sample size	40	40	40	40	40
Mean	7755,13	64,98	179,03	50,38	38,13
Minimum	4165	52	110	36	27
25th precentile	6088,5	57	160,75	44,5	33
Median	7635	64	178,5	50,5	38
75th precentile	9318	70,25	198,75	54	41,25
Maximum	10998	85	226	78	58
SD	1735,46	8,77	26,11	9,57	6,65
Margin of error	537,81	2,72	8,09	2,97	2,06

D. Measurements maxillary first molar

TOTAL	S	W	Wm	Lm	Wm1/3	Wm2/3	Wd	Ld	Wd1/3	Wd2/3	Dapex	Lf	A
Sample size	52	52	52	52	52	52	52	52	52	52	52	52	52
Mean	12041,35	107,98	51,10	104,60	35,81	33,44	49,17	102,13	33,83	29,04	52,06	47,79	26,37
Minimum	7439	92	38	48	27	23	33	35	21	18	21,8	21	12,86
25th precentile	10803,25	103	46	93	33	28,75	44	88	30	25,75	38,55	40	19,22
Median	11954,5	107	50	106,5	35	34	48	105,5	33,5	29	51,7	45,5	25,23
75th precentile	13118	112,25	54	116	38	37	52	116,5	37,25	32	64,05	54	32,18
Maximum	16726	142	99	139	48	49	97	143	52	42	81,2	77	48,75
SD	1828,68	8,80	8,83	18,54	4,49	5,93	9,46	21,28	6,20	4,81	15,86	11,53	8,96
Margin of error	497,03	2,39	2,40	5,04	1,22	1,61	2,57	5,78	1,69	1,31	4,31	3,13	2,44

MALE	S	W	Wm	Lm	Wm1/3	Wm2/3	Wd	Ld	Wd1/3	Wd2/3	Dapex	Lf	A
Sample size	23	23	23	23	23	23	23	23	23	23	23	23	23
Mean	12733,09	110,87	52,17	105,91	36,48	35,39	51,09	101,09	34,04	29,13	48,99	50,78	24,64
Minimum	9864	92	38	48	28	26	37	35	23	21	29,1	21	12,86
25th precentile	11410,5	104,5	45	99,5	33,5	31,5	44	92	28	24,5	36,1	39	18,69
Median	12223	109	49	110	36	35	48	103	32	29	50,2	50	25,67
75th precentile	14028,5	118	55	117,5	38	38	54,5	115	38	32	59,25	58,5	31,34
Maximum	16726	142	99	133	48	49	97	139	52	42	81,2	77	37,7
SD	1887,31	10,89	12,37	19,70	4,75	5,78	12,67	22,15	7,55	5,55	14,15	14,44	7,68
Margin of error	771,31	4,45	5,05	8,05	1,94	2,36	5,18	9,05	3,09	2,27	5,78	5,90	3,14

FEMALE	S	W	Wm	Lm	Wm1/3	Wm2/3	Wd	Ld	Wd1/3	Wd2/3	Dapex	Lf	A
Sample size	29	29	29	29	29	29	29	29	29	29	29	29	29
Mean	11492,72	105,69	50,24	103,55	35,28	31,90	47,66	102,97	33,66	28,97	54,50	45,41	27,75
Minimum	7439	92	42	68	27	23	33	64	21	18	21,8	31	14,71
25th precentile	10288	102	48	87	33	27	46	82	31	26	42	41	20,8
Median	11449	106	50	106	34	32	48	106	34	29	52,4	44	24,78
75th precentile	13093	109	53	115	38	36	52	118	36	32	70,5	48	33,12
Maximum	13969	116	58	139	46	45	58	143	42	37	79,8	68	48,75
SD	1608,58	5,96	4,49	17,84	4,28	5,67	5,61	20,92	5,02	4,23	16,94	8,08	9,77
Margin of error	585,45	2,17	1,64	6,49	1,56	2,06	2,04	7,61	1,83	1,54	6,16	2,94	3,56

E. Measurements mandibular central incisor

TOTAL	A	W	L	W1/3	W2/3
Sample size	100	100	100	100	100
Mean	5962,04	46,36	158,82	41,51	34,38
Minimum	3326	30	112,00	25,00	21
25th percentile	4940,5	42	142,75	35,00	30
Median	5996,5	46,5	158,00	42,00	35
75th percentile	6838,25	51	176,00	46,00	39
Maximum	9819	69	221,00	66,00	62
SD	1310,81	8,49	22,57	7,47	6,86
Margin of error	256,91	1,66	4,42	1,46	1,35

MALE	A	W	L	W1/3	W2/3
Sample size	50	50	50	50	50
Mean	6118,78	46,66	162,38	41,94	34,38
Minimum	3894	32	117	27	21
25th percentile	4956,5	42	150	35,25	29,25
Median	6057,5	47	160	42	35,5
75th percentile	6995,75	51	177	46	39,5
Maximum	9819	69	221	66	62
SD	1363,12	7,17	22,05	8,21	7,95
Margin of error	377,83	1,99	6,11	2,28	2,20

FEMALE	A	W	L	W1/3	W2/3
Sample size	50	50	50	50	50
Mean	5805,3	46,06	155,26	41,08	34,38
Minimum	3326	30	112	25	22
25th percentile	4701,5	40,25	138,5	35,5	30
Median	5951	46	156	41,5	34
75th percentile	6637,75	51	172,25	45	38,75
Maximum	8324	65	196	59	53
SD	1250,32	7,48	22,73	7,01	5,81
Margin of error	346,56	2,07	6,30	1,94	1,61

F. Measurements mandibular canine

TOTAL	A	W	L	W1/3	W2/3
Sample size	100	100	100	100	100
Mean	11965,56	68,75	212,84	62,82	51,02
Minimum	5915	36	130	35	30
25th percentile	9930	62	198	56	45
Median	11545,5	69	211	61	50
75th percentile	13290,25	74	229	68,25	55,25
Maximum	23551	101	304	106	86
SD	3007,82	9,19	30,52	11,76	9,81
Margin of error	589,52	1,80	5,98	2,30	1,92

MALE	A	W	L	W1/3	W2/3
Sample size	50	50	50	50	50
Mean	13114,56	71,94	227,04	65,52	51,98
Minimum	8294	57	179	44	36
25th percentile	11151,25	65,25	206,25	58	44,25
Median	12593,5	69,5	222,5	63,5	50,5
75th percentile	14258,25	77,75	246,5	70	57
Maximum	23551	101	304	106	86
SD	3141,98	9,75	28,08	12,74	10,83
Margin of error	870,90	2,70	7,78	3,53	3,00

FEMALE	A	W	L	W1/3	W2/3
Sample size	50	50	50	50	50
Mean	10816,56	65,56	198,64	60,12	50,06
Minimum	5915	36	130	35	30
25th percentile	9013,75	59,25	182	52,5	45,25
Median	10536,5	66,5	201	59,5	50
75th percentile	12456,25	71	215,75	65	54
Maximum	17565	82	255	88	72
SD	2390,02	9,31	26,72	10,83	9,08
Margin of error	662,47	2,58	7,40	3,00	2,52

G. Measurements mandibular first premolar

TOTAL	A	W	L	W1/3	W2/3
Sample size	100	100	100	100	100
Mean	9538,84	66,77	193,6	54,5	42,59
Minimum	5767	47	143	35	29
25th percentile	8141	61	181,5	49	38
Median	9364	66	192,5	53,5	41
75th percentile	10591	72,25	208	61	47
Maximum	15340	90	238	77	61
SD	1812,56	10,61	20,02	8,63	7,68
Margin of error	355,25	2,08	3,92	1,69	1,51

MALE	A	W	L	W1/3	W2/3
Sample size	50	50	50	50	50
Mean	9808,04	67,44	196,24	55,4	43,08
Minimum	6598	51	145	35	30
25th percentile	8178	61	183,25	51	38
Median	9537	66,5	190,5	55	41
75th percentile	10972,75	72,75	210	62	48
Maximum	15340	90	238	77	60
SD	1993,33	8,59	20,61	9,49	8,29
Margin of error	552,51	2,38	5,71	2,63	2,30

FEMALE	A	W	L	W1/3	W2/3
Sample size	50	50	50	50	50
Mean	9269,64	66,1	190,96	53,6	42,1
Minimum	5767	47	143	36	29
25th percentile	8163,5	61	175,75	48,25	38
Median	9268,5	65,5	194	53	41
75th percentile	10254,75	71	204,25	57,75	45,75
Maximum	12974	81	238	73	61
SD	1586,35	7,86	19,43	8,03	7,25
Margin of error	439,70	2,18	5,39	2,22	2,01

H. Measurements mandibular first molar

TOTAL	S	W	Wm	Lm	Wm1/3	Wm2/3	Wd	Ld	Wd1/3	Wd2/3	Dapex	Lf	A
Sample size	100	100	100	100	100	100	100	100	100	100	100	100	100
Mean	16557,22	121,04	59,76	137,66	38,40	35,60	62,07	131,31	44,01	39,12	72,81	44,22	28,63
Minimum	10149	101	41	85	26	23	43	79	31	26	14,2	20	5,58
25th percentile	14357,5	114	56	122,75	35	31	57	119	39	34	62	38,75	22,51
Median	16034	121	59	138	38,5	35	62	129,5	43	39	75,75	44	28,97
75th percentile	18355	127,25	64	152	42,25	40	66	144	47,25	43	86,25	50	34,44
Maximum	26499	149	85	184	62	55	83	173	70	69	115,1	69	49,81
SD	3103,31	10,18	8,01	20,23	6,49	6,54	7,39	17,93	7,28	7,65	20,83	9,23	8,98
Margin of error	608,24	2,00	1,57	3,97	1,27	1,28	1,45	3,51	1,43	1,50	4,08	1,81	1,76

MALE	S	W	Wm	Lm	Wm1/3	Wm2/3	Wd	Ld	Wd1/3	Wd2/3	Dapex	Lf	A
Sample size	50	50	50	50	50	50	50	50	50	50	50	50	50
Mean	17099,9	122,66	60,2	140,92	38,98	35,92	61,72	134,54	43,6	39,96	74,69	45,3	28,93
Minimum	11563	101	44	85	26	24	43	89	31	26	22	29	8,2
25th percentile	14747,25	115	57	129	35	31,25	56,25	124	38,5	35	62,1	40	22,57
Median	16870	122	59,5	146,5	38	35	60,5	137	41,5	39	76,25	43,5	28,49
75th percentile	18496,75	129,75	63	154,5	43	41,5	67	145,75	47,75	43	90	51	34,41
Maximum	26499	149	85	174	62	50	83	170	70	69	115,1	69	49,81
SD	3446,83	11,47	8,13	19,12	7,36	6,69	8,84	15,67	8,20	8,49	21,24	9,89	9,25
Margin of error	955,39	3,18	2,25	5,30	2,04	1,85	2,45	4,34	2,27	2,35	5,89	2,74	2,56

FEMALE	S	W	Wm	Lm	Wm1/3	Wm2/3	Wd	Ld	Wd1/3	Wd2/3	Dapex	Lf	A
Sample size	50	50	50	50	50	50	50	50	50	50	50	50	50
Mean	15943,6	119,32	59,4	133,92	37,78	35,18	62,04	127,6	44,34	38,22	70,712	43,08	28,35
Minimum	10149	103	41	85	26	23	50	79	32	27	14,2	20	5,58
25th percentile	14211,75	113	56	118,5	35	30	58	114	39,5	34	60,68	38	23,00
Median	15636,5	119,5	59	131	39	35	62	126	44	39	74,6	44,5	29,21
75th percentile	17980	126	66	149	42	39	65	140	46	42	82,93	48	34,35
Maximum	21514	138	76	184	52	55	74	173	61	54	109,8	60	44,81
SD	2625,81	8,50	7,95	20,89	5,50	6,43	5,67	19,47	6,27	6,68	20,44	8,48	8,78
Margin of error	727,82	2,36	2,20	5,79	1,52	1,78	1,57	5,40	1,74	1,85	5,67	2,35	2,43