IMPACTED THIRD MOLARS: USING 3D IMAGING TO INVESTIGATE THE ETIOLOGY OF A COMMON ORAL HEALTH CONCERN

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ABSTRACT

Third molar (M3) impaction is commonly observed in dental practice. While the causes of impaction are still not clearly understood, they appear to be multifactorial. Currently, an insufficient amount of space in the jaw distal to the second molar - the retromolar (RM) region - is considered to be the most significant of these putative risk factors. However, M3 eruption is not always guaranteed by space availability in the RM region, and other factors such as delayed M3 mineralization, tooth crown size, and dental arch size are suspected to increase impaction risk. Because studies have traditionally focused on mandibular M3s and been limited to two-dimensional (2D) radiographs, this study is the first to investigate the causes of M3 impaction in both jaws, using 3D imaging, with precision and accuracy not previously possible using standard 2D dental imaging modalities. This study tests the hypothesis that not only a reduced amount of space in the RM region is observed when M3 impaction is present but also delayed M3 mineralization, larger molar and premolar crowns, and shorter dental arches. Research ethics permission (BIO#11-202) was obtained to use existing retrospective cone beam computed tomography (CBCT) images of over 500 patients aged 8 to 24 years taken and curated at the College of Dentistry, University of Saskatchewan. Anatomical landmarks were defined and a proprietary software package, Xoran-CAT (Imaging Sciences International, Philadelphia, USA) was used to measure RM regions, molar and premolar crowns, and dental arch dimensions, as well as to score M3 mineralization status. Results were assessed using independent sample t-tests. When M3 impaction was present, both short RM regions and delayed M3 mineralization occurred in both jaws, indicating that both of these are risk factors for impaction. In the presence of M3 impaction, narrower dental arches were observed only in the maxilla, while larger premolar and molar crowns were seen only in the mandible. The observation of these last risk factors in distinct jaws when M3 impaction was present, suggests that these are secondary factors in the determination of the M3 impaction condition, and that standards of M3 impaction differ between upper and lower jaws.

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I would like to dedicate my thesis to my brother, Apio Dutra Marchiori. I hope this work will contribute for advancements in the medical field. Only by advancing knowledge will we be able to overcome the barriers that currently prevent medical conditions such as the one that unfortunately affected you, Apio, to be better understood and treated.

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LIST OF ABBREVIATIONS

Abbreviation	Description
CBCT	Cone-beam computed tomography
M1	First permanent molar
M2	Second permanent molar
M3	Third permanent molar
PM1	First premolar
PM2	Second premolar
RM	Retro-molar region
Md	Mandible
Mx	Maxilla
M^3	Maxillary third molar
M_3	Mandibular third molar
TMJ	Temporomandibular joint
2D	Two-dimensional
3D	Three-dimensional
IAN	Inferior alveolar nerve
IAC	Inferior alveolar canal
LN	Lingual nerve
M-D	Mesiodistal
B-L	Buccolingual

GLOSSARY

Term	Definition
Dental crowding	Discrepancy between tooth size and arch size that results in malposition and/or rotation of teeth.
Distal	A tooth or tooth surface toward the opposite direction from the middle and front of the jaw along the curve of the dental arch.
Mesial	A tooth or tooth surface toward the middle and front of the jaw along the curve of the dental arch.
Iatrogenic	Refers to illness or injury caused by a medical examination or treatment.
Buccal	Towards the mucosa of the lip or cheek.
Lingual	Towards the tongue.
Class II of occlusion	Malocclusion in which the mandibular arch is in a posterior position in relation to the maxillary arch. This pattern is also known as distocclusion.
Quadrant	Refers to the division of the jaws into four parts, beginning at the midline of the arch and extending towards the last tooth in the back of the mouth. Each one of the four quadrants generally contains eight teeth.
Interproximal contact point	Refers to the area of two adjoining teeth that are aligned in the dental arch, where they touch each other.

CHAPTER 1
INTRODUCTION

1.1 The Third Molar Impaction Condition

The third molar (M3) is the last tooth to form (Odusanya 1991) and the most often to fail to erupt into the oral cavity (Rodu 1993). When proper eruption fails, the M3 is said to be impacted (Figure 1 and Figure 2). M3 impaction is commonly encountered in dental practice and very often associated with complications such as infections (Lysell 1988) and caries (Peterson 1998). Impacted M3s are routinely diagnosed by dentists, and it has been reported that approximately 73% of individuals aged 20 years may have at least one impacted mandibular M3 (Hugoson 1988). The reported incidence for M3 impaction in the literature is highly variable and depending on how impaction is defined, the incidence of this condition is said to be between 22.3% and 66.6% (Ganss 1993). If partially erupted M3s are considered as impacted, then up to 96% of the population may have at least one impacted tooth (Rodu 1993), representing a complication that is very commonly observed across populations (Bjork 1956, Morris 1971, Venta 1991). Even though any tooth in the maxilla (Mx) and/or mandible (Md) may become impacted (Rodu 1993), M3s are the teeth more frequently impacted in modern populations (Bishara 1983, Grover 1985), accounting for 98% of all impacted teeth (Bishara 1999). In contrast, the other most often impacted teeth are maxillary canines, mandibular first premolars, and mandibular second premolars, representing only 1.3%, 0.22%, and 0.11% of impactions, respectively (Rodu 1993). The mandibular M3 (M_3) is more frequently impacted than its maxillary counterpart (M^3) (Bishara 1983, Grover 1985, Rodu 1993), and for that reason as well as the close proximity of the M_3 to the inferior alveolar nerve, greater attention has been given to M3 impaction in the mandible. The etiology of M3 impaction has long been a controversial subject but it is generally accepted to be multifactorial in nature (Ng 1986). It has been suggested, however, that the main cause is insufficient jaw space distal[1] to the second molar (M2) (ledyard 1953, Bjork 1956, Ricketts 1972, Schulhof 1976, Graber 1981, Ganss 1993, Rodu 1993, Peterson 1998), which is an anatomical location referred to as the retromolar (RM) region.

The term impaction originates from the Latin word impactus (Durbeck 1945) and it refers to a state where one object is held by another. In the context of the dental sciences, Blum (1923) and Durbeck (1945) defined impaction as arrested tooth eruption caused by a clinically or radiographically detectable physical barrier in the eruption path, or by a tooth being malpositioned. Several other studies define an impacted tooth as one that is prevented from erupting within the expected time due to obstructions in its eruption path (Aitasalo 1972, Gensior and Strauss 1974, Ohman 1980). Bodner & Horowitz (1987) however, further consider the functionality of the tooth: they define as impacted a tooth that is prevented from erupting into a normal functional position in the oral cavity; that is, a tooth that has not reached a position that allows it to participate in the oral functions as carried out by other teeth, either due to the existence of a physical barrier preventing this tooth to erupt or for unknown reasons. **Unerupted and partially erupted M3s with severe tilts are unlikely to be functional in the oral cavity and for that reason this definition describes impaction in the present study**. Using a specific definition for impaction is important because it allows the comparison of results among studies using the same definition.

[1] Distal: A tooth or tooth surface toward the opposite direction from the middle and front of the jaw along the curve of the dental arch.

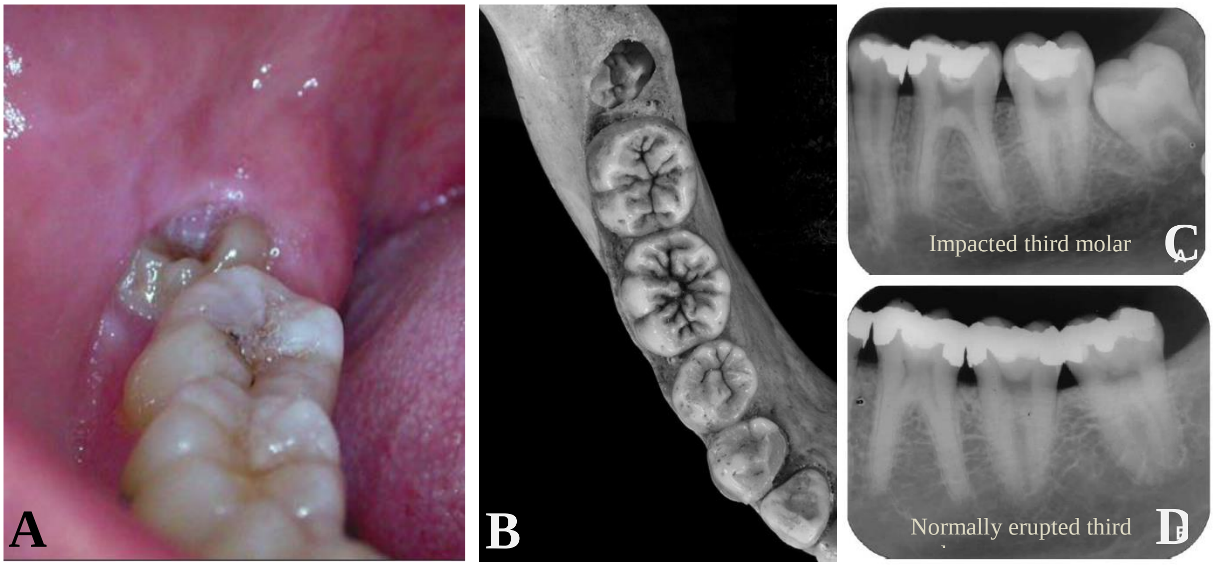


Figure 1. Impacted third molars in the mandible.

A. M_3 impacted in bone and soft tissues (Moloney 2009).
B. M_3 impacted in mandibular bone (Hillson 1996).
C. Periapical radiographic image showing an impacted M_3 (Kim 2003).
D. Periapical radiographic image showing a normally erupted M_3 (Kim 2003).

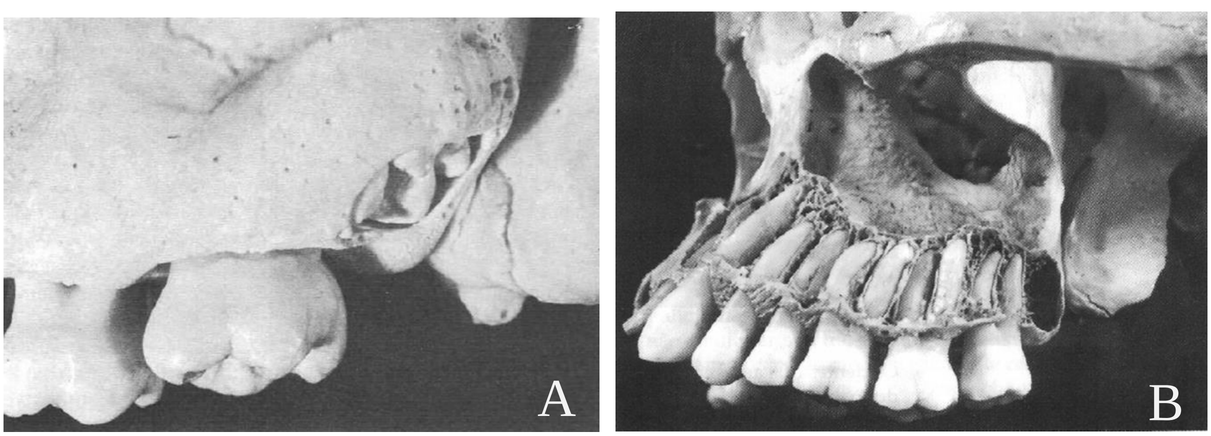


Figure 2. Impacted third molars in the maxilla.

A. M^3 impacted in bone (Bhaskar 1989).
B. Normally erupted M^3 (Madeira 2001).

1.2 Pathoses and Clinical Conditions Commonly Associated With Third Molars

One of the reasons why M3 impaction is a common oral health concern is that a number of pathoses and other relevant clinical conditions may be associated with these teeth (Figure 3). **Because of these possible associations, early prophylactic removal of these teeth is very often advised** (Fielding 1981, Fayad 2004). While the association of pathological conditions with M3s has been consistently documented by several studies (Lysell 1988, Stanley 1988, Rodu 1993, Peterson 1998, Moloney 2009), an agreement on their prevalence is still lacking. Prevalence is important since it is typically used to justify pre-emptive surgical removal of impacted and, sometimes, not yet impacted, M3s. The most frequently observed conditions are:

(1) **Dental caries**. Tooth decay and, as a result, dental caries in the adjacent M2 or in the M3 itself is also a frequent reason for removing the M3. A recent study found that caries accounted for 38% of all conditions associated with impacted M3s (Nazir 2014).

(2) **Infection**. The area of the oral cavity in which the M3 is located is populated by microorganisms from both the oral and the pharyngeal areas and an infection associated with this tooth may become a serious condition (Rodu 1993). The most common of these infectious conditions is pericoronitis (Moloney 2009). This condition accounts for approximately 25% of all pathoses associated with this tooth (Lysell 1988, Rodu 1993).

(3) **Resorption of the adjacent tooth**. Impacted teeth within the bony crypt (follicles) may, under certain circumstances, produce asymptomatic damage to adjacent normal anatomical structures such as the distal surface of the M2 roots. Resorption of the M2 is observed in 3-8% of cases of M3 impaction (Rodu 1993, Nazir 2014).

(4) **Cysts**. The cyst most commonly associated with impacted M3s is the dentigerous cyst, which is observed in about 2% (Nazir 2014) to 4% of the impacted M3s (Mourshed 1964,

Toller 1967, Lysell 1988, Stanley 1988). This cyst is formed by fluid accumulation between the reduced enamel epithelium and the crown of the unerupted M3 during its development. If this tooth fails to erupt this lesion tends to grow and it is likely to cause root resorption if located near other teeth (Rodu 1993) (Figure 3-A).

(5) **Other conditions**. Several other conditions of clinical significance such as ankylosed tooth (tooth root fused to the bone), hyperplastic dental follicles, supernumerary teeth, eruption hematoma, tumors, and other cystic processes can be found associated with M3s. However, all of them together occur in less than 4% of the cases (Stanley 1988, Rodu 1993).

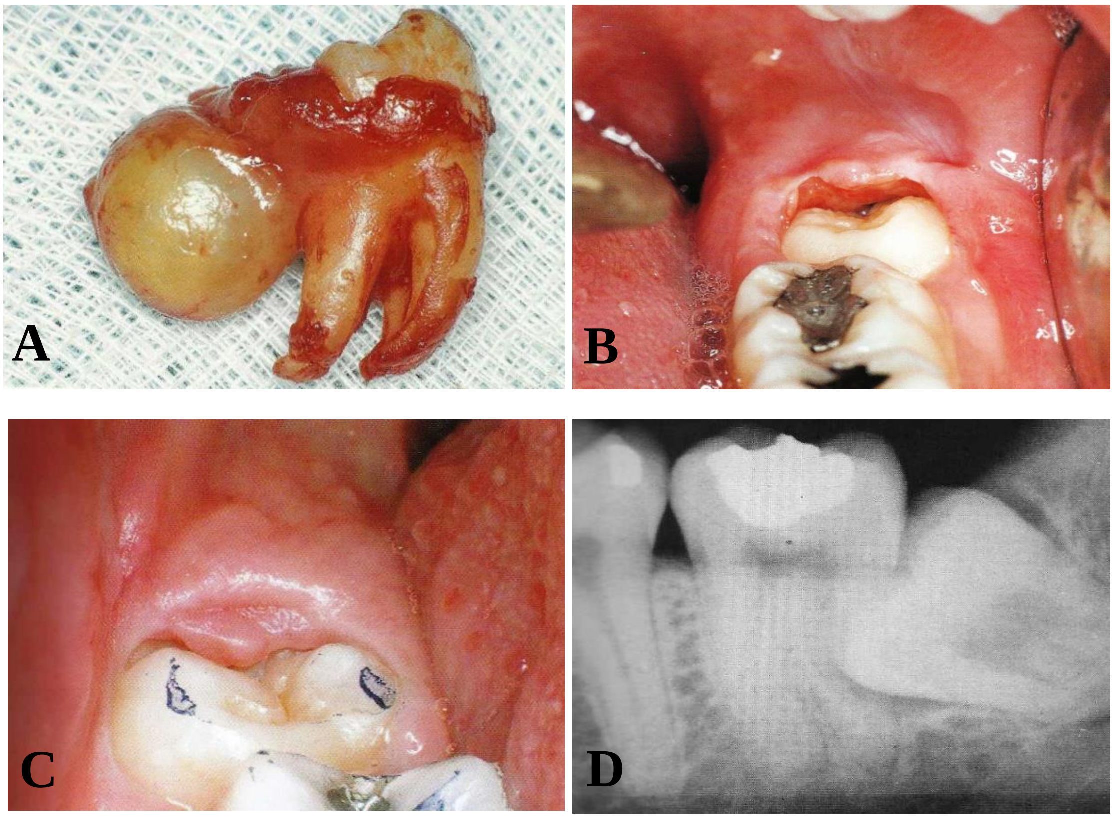


Figure 3. Clinical conditions commonly associated with third molars.

A. A posterior marginal cyst grown from the M3 follicle (Korbendau 2003).
B. Inflammation of the soft tissues surrounding the crown of the M3, characteristic of pericoronitis (Korbendau 2003).
C. A cap of soft tissue may cover partially the crown of the M3. Compression of this tissue by the opposite dentition during chewing may also result in inflammations (Korbendau 2003).
D. Root resorption of the second molar as result of an impacted M3 (Peterson 1998).

1.3 Development and Eruption of Third Molars

M3s are replacement, or successional, teeth that originate from the dental lamina (Korbendau 2003), a primitive band of ectodermal cells growing from the epithelium of the embryonic jaws into the underlying mesenchyme (Kumar 2011). The M3 bud becomes evident at around age four or five years (Korbendau 2003); M3 mineralization begins as early as age five or as late as 14 years (Garn 1962, Gravely 1965), with most M3s initiating at age eight (Banks 1934) or nine (Gravely 1965, Richardson 1980, Ragini 2003) (Figure 4). The M3 crown is usually complete between 12-15 years of age (Korbendau 2003); however mineralization continues gradually until the root is completely formed and the apex is closed. The time of M3 emergence into the oral cavity is highly variable, most often occurring from age 17 to 21 years (Korbendau 2003), or up to 24 years (Haralabakis 1957, Fayad 2004), although this tooth can occasionally erupt as late as age 32 (Venta 1991, Precious 1999). In spite of the M3's highly variable eruption time, it is always the last tooth to erupt in all populations (Odusanya 1991). **Since other teeth erupt earlier, the space in the jaws to accommodate the eruption of the M3 is very often partially or totally occupied by the other permanent teeth, and this is one reason cited for why the M3 so often becomes impacted** (Kaplan 1975, Odusanya SA 1984, Richardson 1987, Kaya 2010)**. M3 eruption may be also further compromised if M3 mineralization occurs later than normal** (Svendsen 1988). Cases of late-forming M3s are of particular interest to orthodontists because under such conditions, specific treatment plans may need to help create space in the RM region to accommodate the eruption of the M3 (Garn 1962, Gravely 1965).

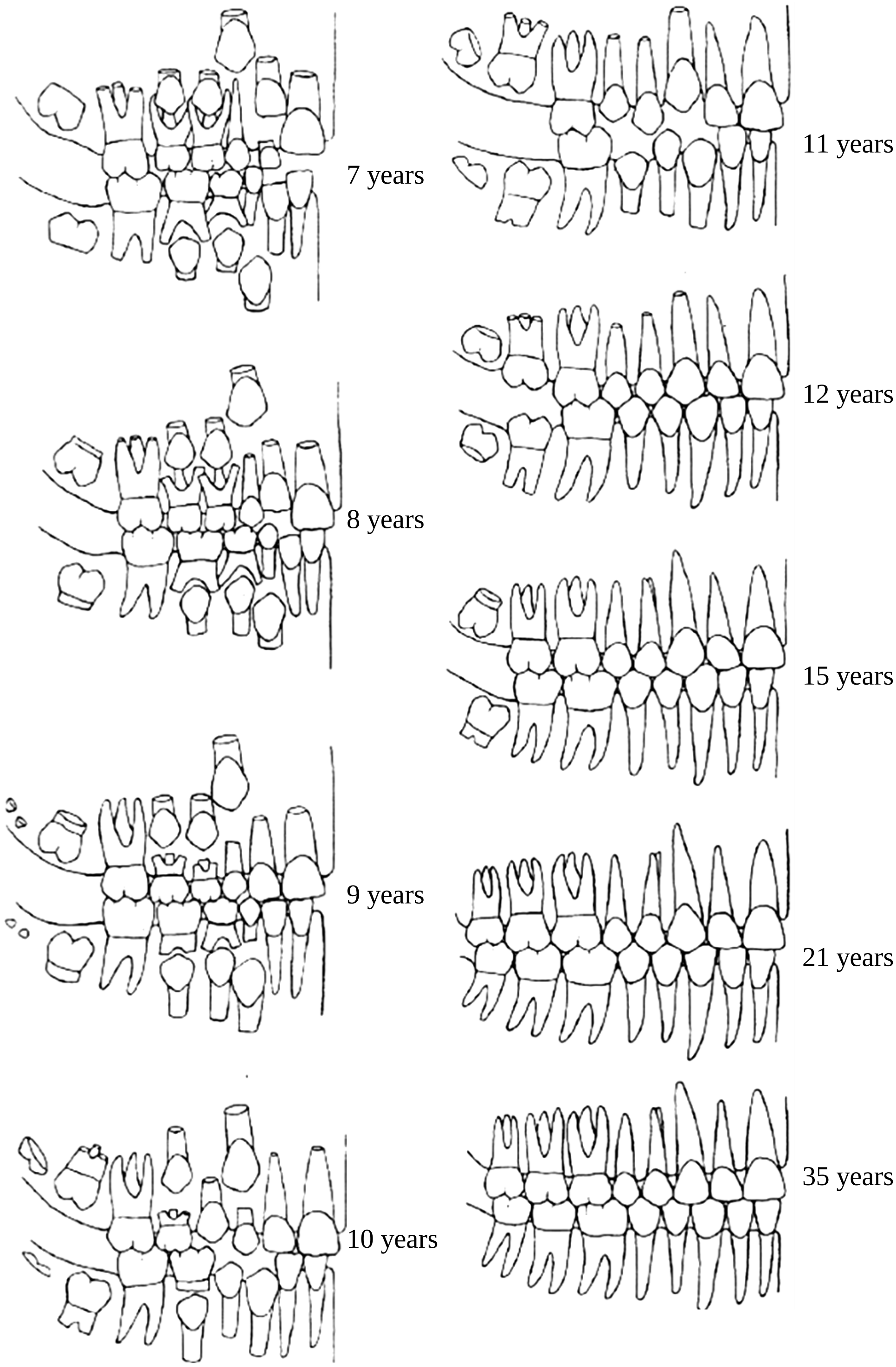


Figure 4. Development of human dentition from seventh year to maturity.
At the age nine years the third molar's cusps begin to be formed, and the mineralization process continues until the tooth is completely formed at around age 21. Figure: (American Dental Association 2006)

1.4 The causes of third molar impaction

The most common theories explaining the causes of M3 impaction relate to: inadequate space between the M2 and the distal osseous limits of the jaws (Schulhof 1976, Graber 1981); limited or insufficient skeletal growth (Richardson 1975, Richardson 1977); and increased crown size in impacted versus normally erupted teeth (Richardson 1977). Reduced jaw space may further compound the risk of impaction if M3 mineralization occurs later than normal (Svendsen 1988). Among the theories raised, **a lack of space in the RM region has been suggested as the most significant factor associated with M3 impaction** (Bjork 1956, Ricketts 1972, Schulhof 1976, Graber 1981, Ganss 1993, Rodu 1993, Peterson 1998), with the probability of impaction directly related to the amount of space available in that region (Ricketts 1976). While the exact amount of space in the RM region required for eruption of the M3 is not yet known, the length of this space must, obviously, exceed the width of this tooth crown (Venta 1991, Ganss 1993). The evidence supporting unavailability of space in the RM region as the most significant cause for impaction is derived from several studies. For instance, Kaplan (1975) showed that there was an increased probability of M3 eruption if premolars had been extracted. Similarly, the RM space was said to be reduced in 90% of the cases when M3 impaction was present compared to when this condition was not present (Bjork 1956).

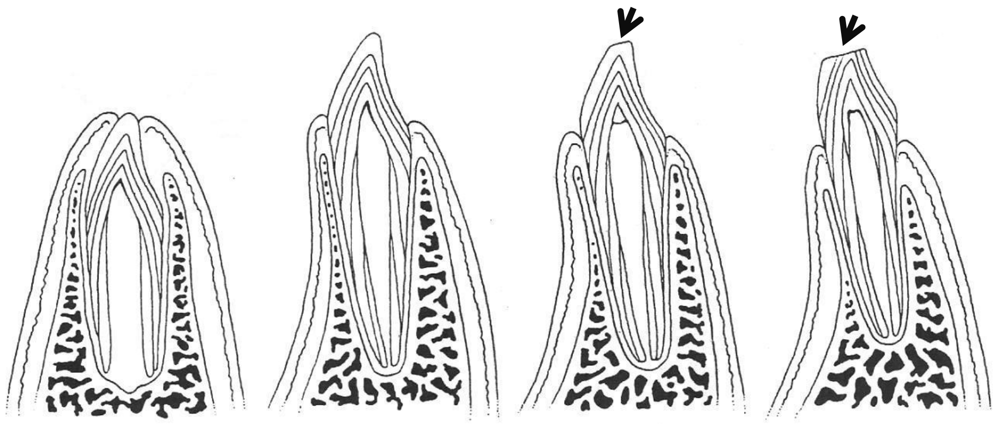
Ironically, a complete dental arch (e.g. with all teeth) often does not have the space necessary for M3 eruption. For that space to be created, a natural mesial[2] drift of teeth needs to occur gradually along the course of one's life (Rodu 1993) producing space at the back of the jaws to accommodate the eruption of the M3 (Rodu 1993). This mesial drift can occur as a result of an ingestion of an abrasive, non-refined diet which causes circumferential attrition that

[2] Mesial: A tooth or tooth surface toward the middle and front of the jaw along the curve of the dental arch.

reduces the mesiodistal[3] (M-D) width of teeth (Figure 5). Since the M3 can erupt as late as the age of 32 years (Venta 1991, Precious 1999), the occurrence of a gradual dental attrition over time may significantly create space in the jaws, which in some cases allows a later eruption of this tooth. Examples of abrasive diets are seen among Aboriginal peoples of Australia (Begg 1954), African natives (Odusanya 1986), and in skulls of ancient British populations (Rodu 1993). Varrela (1990) for example, speculated that the transition from ingestion of hard food to softer foods by modern Finns is the probable cause for changes in occlusion patterns that has limited creation of space in the jaws and thus contributed to M3 impaction. Similarly, Begg (1954) reported in Australian aborigines a normal physiological mesial drift of the M2 of more than 1 cm before time of M3 eruption. As a result, M3s erupted in a considerably more mesial position within the dental arch. Since a gradual change to softer diets has been noted in many population groups – leading to a lack of dental attrition and consequent lack of production of space in the dental arch – it has been said that M3 impaction represents a developmental condition characteristic of modern civilization (Rodu 1993). Interestingly, in addition to variations in tooth crown size caused by dental attrition, variable tooth crown size are also naturally seen among distinct individuals. (Varrela 1990, Rodu 1993). Forsberg (1988) for example, studied a group of 75 Swedish subjects and found that individuals who had M3s not totally erupted had larger tooth crowns than individuals with erupted M3s. This observation suggests that **larger tooth crowns influence the availability of space in the jaws** to accommodate all teeth, including the M3.

[3] Distal: A tooth or tooth surface toward the opposite direction from the middle and front of the jaw along the curve of the dental arch.

A



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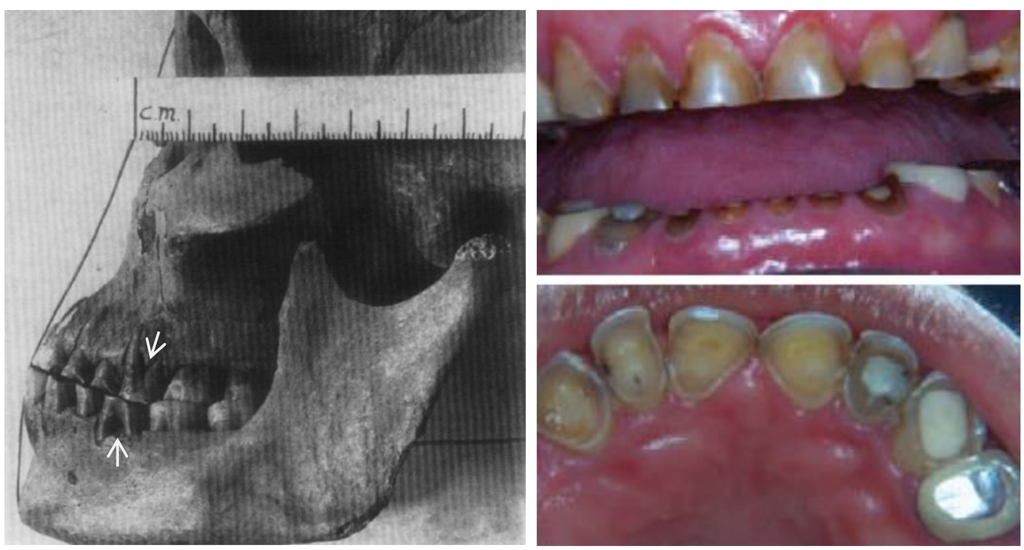


Figure 5. The role of dental attrition on development of third molar impaction.

A. The ingestion of an abrasive, non-refined diet causes natural attrition of teeth along the course an individual's life (arrows) (American Dental Association 2006).

B. Left: This figure illustrates a case of advanced degree of attrition on all teeth, especially the first permanent molar, where the attrition consumed the entire crown (arrow). As a result, teeth have migrated mesially (anteriorly) in the arch and space at the back of the jaws was created to accommodate the eruption of the M3s (Odusanya 1991).
Right: The clinical appearance of a case of advanced dental attrition (Bodner 1987).

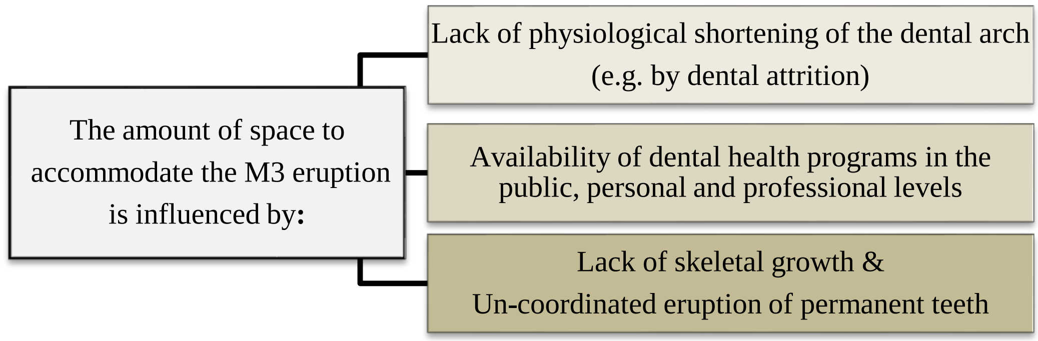


Figure 6. Factors influencing the space for third molar eruption.
Factors currently associated with creation of space in the RM region.

Interestingly, in dental arches with dimensions naturally reduced (e.g. not due to dental attrition) M3 impaction is however suspected to be more evident (Richardson 1977, Ng 1986) since in these arches space is likely to be unavailable not only for the M3 itself but also for other teeth. Today, creation of space in the RM region is additionally accepted to be influenced by other factors such as the availability of dental health programs (i.e. in the personal and public levels), the degree of skeletal development, and alterations in the sequence in which deciduous teeth are replaced by permanent teeth (Figure 6). According to Rodu (1993), programs of putting fluoride in the drinking water, for example, resulted in a significant decrease of tooth loss due to caries, which has contributed to the maintenance of complete and healthy dental arches. In cases where space in the jaws is not created naturally by skeletal growth, the M3 may not find the space for eruption without any previous tooth loss. This fact therefore implies that regardless of the occurrence of dental attrition or tooth loss, space in the RM region needs to exist for the M3 to erupt. For that reason, **non-coordination between skeletal growth and M3 maturation and time of eruption has been also associated with the M3 eruption failure** (Rodu 1993).

1.5 Clinical Management Standards of Third Molars

1.5.1 The anatomical position of the third molar: aspects of clinical importance

Before suggesting a treatment plan the dentist will first note the position of the M3 and its position relative to adjacent teeth and oral tissues. The dentist collects this information by studying clinical radiographic images ("x-rays") of the tooth and its surrounding region. For instance, in cases where the M3 is severely angled or where this tooth and the inferior alveolar canal (IAC) that contains the inferior alveolar nerve (IAN) are particularly close to each other, it is more likely that adjacent structures will be injured during the surgical procedure for removal of the M3 (Peterson 1998). For that reason, the level of difficulty of M3 extraction surgery varies considerably according to the M3 position, from relatively straightforward to extremely difficult. As a result, a classification system was created by Pell and Gregory (1933) (Figure 7) to help the oral surgeon plan M3 extraction surgery based on the type of impaction. For example, mesio-angulated M3s are generally more common in the mandible (Gupta 2011, Alsadat-Hashemipour 2013, Padhye and Dabir 2013, Nazir 2014), and are the least difficult type to remove surgically (Peterson 1998) because in this position the M_3 is more conveniently accessed during surgery. Conversely, disto-angulated M3s are generally more common in the maxilla and are the most difficult type to remove surgically (Peterson 1998). Again, the careful observation of the M3 position in relation to adjacent structures not only allows an accurate evaluation of the risks associated with the chosen treatment plan but also helps reduce the chances of complications arising from the M3 surgical removal.

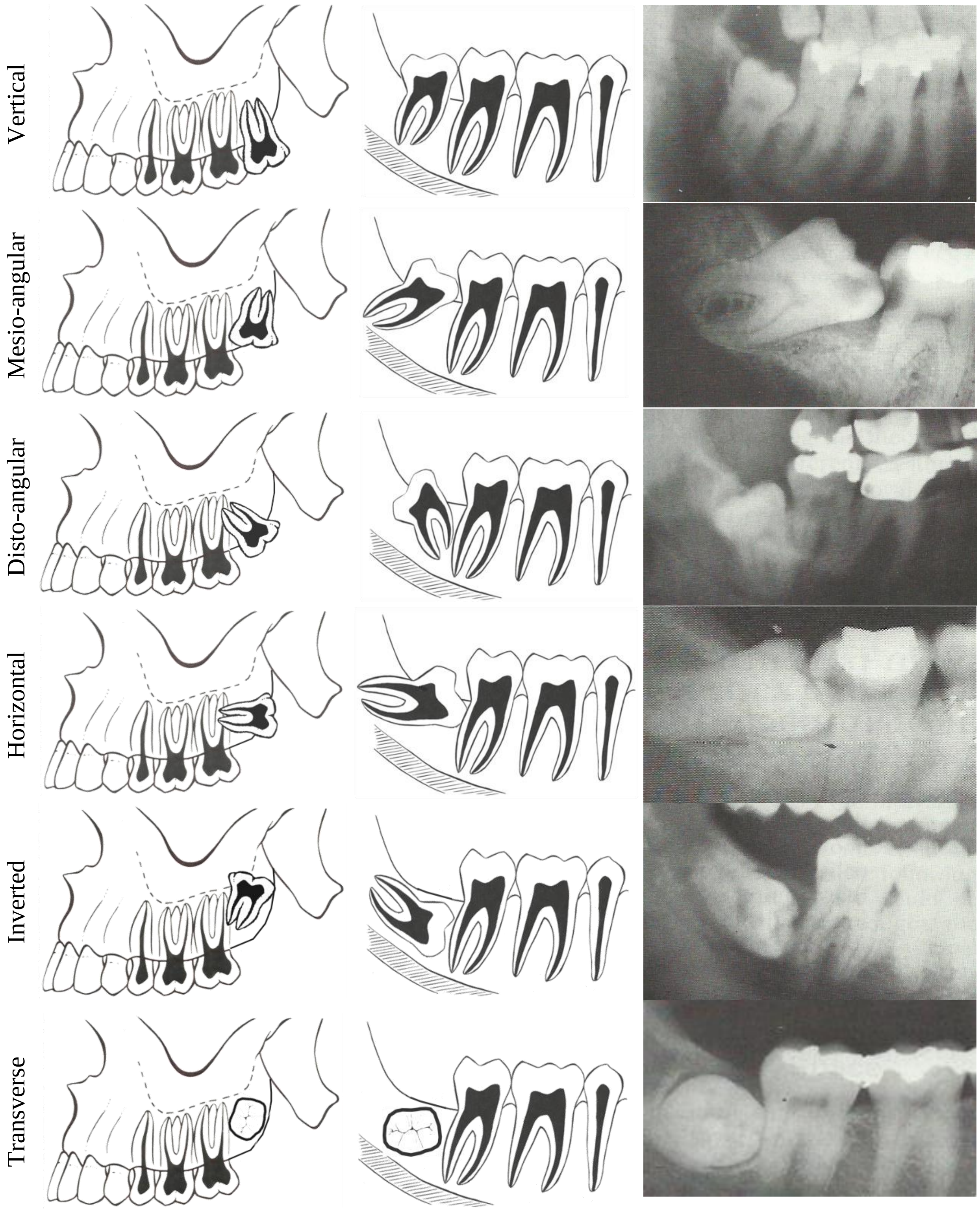


Figure 7. The position of impacted third molars.
The careful classification of the M3 position helps the surgeon to plan the proposed surgery and predict whether any extraordinary surgical approaches will be necessary. Radiograph images from Rodu (1993).

1.5.2 Current clinical management standards for third molars: surgical removal or long-term clinical monitoring?

The clinical management of impacted M3s includes: removing this tooth; opening the follicle around the M3 crown to prevent this structure from impeding the eruption of this tooth; transplanting the M3; or, under the right conditions, long-term observation (a "sit and wait" approach). As noted in detail above, the problem with impacted M3s is that they can be associated with pathoses that may affect adjacent soft and hard tissues (Moss 2007, Fisher 2010, surgeons 2011). Since the widely-held belief is that M3s put patients at high risk for such complications, **surgical removal of these teeth is a common intervention** (Bruce 1980) **and in many cases is done strictly for preventative reasons**.

Not only is the decision whether or not to surgically remove the M3 increasingly complicated and controversial (York 1998), but so is the best time to perform the surgical intervention (Fielding 1981, Chiapasco 1995). In this regard, controversy includes immediate need for surgery versus regularly monitoring M3s. Removal of these teeth at an early age usually produces fewer surgical and postoperative complications (Fielding 1981) because fewer systemic health problems exist (Ganss 1993). In addition, this surgery may be easier and relatively atraumatic in young individuals, especially if the tooth roots are not yet completely formed (Ricketts 1976). Since surgical complications are likely to increase with age (Ricketts 1976, Bruce 1980), M3 surgical removal became a procedure commonly recommended for young individuals. However, some individuals in the dental profession are starting to question this clinical approach (Friedman 2007, Kandasamy 2009) as more recent studies have suggested that no more than 12% of all impacted teeth are actually associated with pathological conditions (Friedman 2007).

1.5.3 Prophylactic removal of third molars: does it represent a public health hazard?

The risk of having M3s impacted and potentially involved with pathoses is so highly feared that prophylactic removal of M3s is the standard procedure in Canada and other Western countries (Health 2010). However, such clinical standards are starting to be questioned as recent publications have raised concerns that justification for the prophylactic removal of M3s is based on inconclusive scientific evidence (York 1998, Boughner 2013), and a more balanced clinical approach is being advocated by some individuals in dentistry (Shepherd 1994, Friedman 2007, Kandasamy 2009). So common is the removal of M3s that about 5 million of such surgeries are estimated to be performed each year in the United States (York 1998, Friedman 2007). In Saskatchewan, for example, claims for almost 13,500 M3 surgeries were processed between 2007 and 2011 by a single health insurance company at a cost of over $2.2 million Canadian dollars (Cross 2012). While the total number of M3 surgeries across Canada is not adequately reported (Health 2010), these numbers are likely to be significant since Canada's Non-Insurable Health Benefits (NIHB) program itself encourages removing M3s instead of clinically monitoring them (Canada 2009/2010, Lemchuk-Favel 2010). While removal of problematic impacted M3s is an effective and important option to help maintain good patient health, retention and long-term observation of M3s may be recommended in many patients to avoid surgery-related complications and to retain teeth that may be useful for prostheses and general dental considerations (Bruce 1980). If to maintain good oral health, individuals are required to have all their teeth checked regularly, then the burden of monitoring M3s is relatively minor – leaving surgical interventions to the most necessary cases.

1.5.4 Complications of the surgical procedure for third molar removal

While impacted M3s pose a host of risks, their surgical removal also carries risks (Sisk 1986) and at the very least involves pain or discomfort, as well as the need for a liquid diet and bed rest for 1 or more days. These risks, for instance, include damage to bone, nerves, and/or the temporomandibular joint (TMJ) (Rodu 1993). Surgical complications in particular may arise in the following conditions: extremes of age; medically compromised patients; severely angled roots; ankyloses; and increased probability of injury to adjacent structures such as nerves (Peterson 1998). In general, the complications most commonly associated with M3 surgical removal are:

(1) **Localized alveolar osteiti**s, this clinical condition (also known as “dry socket”) is characterized by severe, throbbing pain several days after the removal of a tooth and often is accompanied by halitosis (Bouloux 2007). Alveolar osteitis occurs considerably more frequent following the removal of M3s than any other tooth type (Rodu 1993). While the incidence of this condition varies from 0.3% to 26% (Bruce 1980, Goldberg 1985, Osborn 1985, Sisk 1986, Chiapasco 1993, de Boer 1995, Bloomer 2000, Bui 2003, Benediktsdottir 2004, Haug 2005), its occurrence after the removal of the M_3 is considerably higher, varying from 16.8% (Moorrees 1951) to 37.5% (Swanson 1966).

(2) **Injury of nerves,** such as the lingual (LN) or inferior alveolar nerves (IAN), occurs in 0.4% to 22% of the cases (Ziccardi 2007). Surgical removal of the M3 is the main cause of permanent injury to the IAN (Hillerup 2008). The majority of these injuries result in transient sensory disturbance in regions where these nerves’ final branches are distributed. However, permanent paraesthesia (abnormal sensation), hypoesthesia (reduced sensation), or dysaesthesia (unpleasant abnormal sensation) can occur (Costa, Fontenele et al. 2013) (Figure 8, B-C).

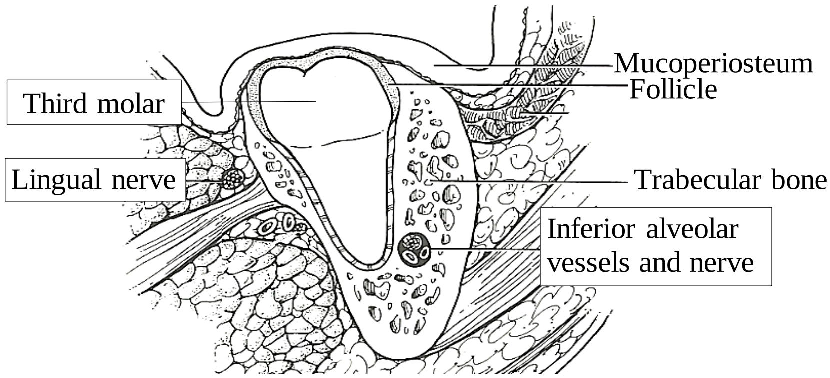
(3) **Infections**, with frequencies varying from 0.8% to 4.2% (Goldberg 1985, Osborn 1985, Sisk 1986, Chiapasco 1993, de Boer 1995, Bui 2003, Benediktsdottir 2004, Haug 2005).

(4) **Persistent bleeding**, occurring in 0.2% to 5.8% of M3 extraction surgeries (Chiapasco 1993, Bui 2003, Haug 2005), and

(5) **Mandibular fracture and iatrogenic[4] displacement of teeth**, which occur less frequently, with accurate incidence unreported by studies (Bouloux 2007).

[4] Iatrogenic: refers to illness or injury caused by medical examination or treatment.

A



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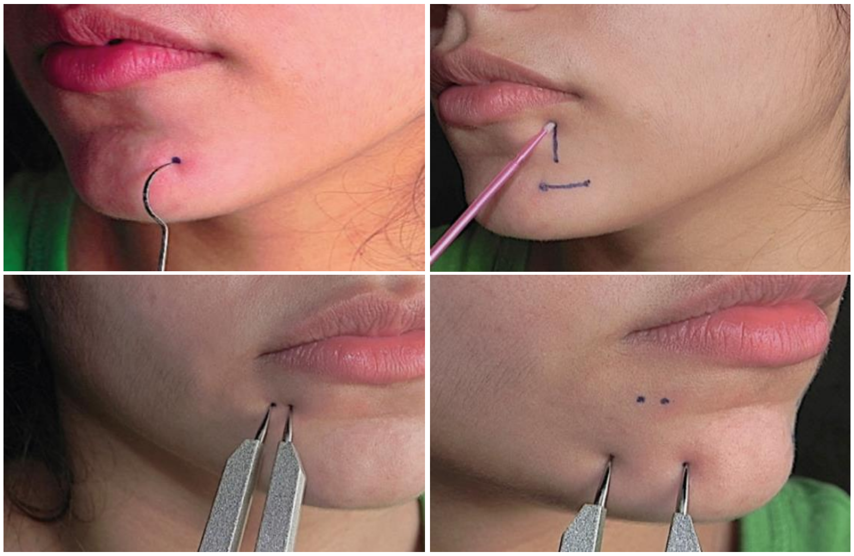

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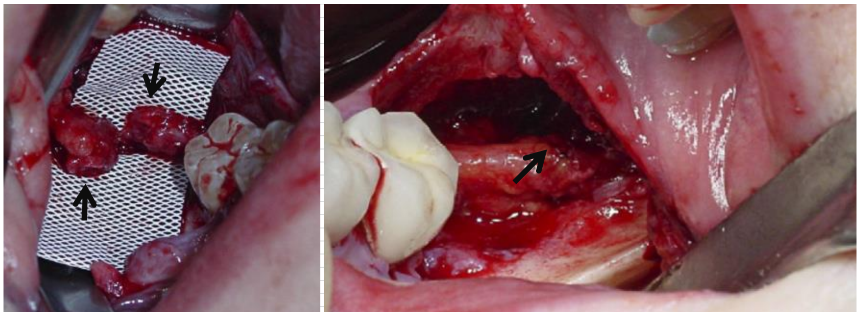


Figure 8. Nerve injury is a common complication of the third molar removal surgery.

A. Both the inferior alveolar and lingual nerves have a close anatomical relationship with the M3 and are subject to be injured during surgical procedures for removal of this tooth (Rodu 1993).
B. Injuries to the inferior alveolar nerve result in sensory disturbance in regions where this nerve's final branches are distributed. Neurosensory tests can be used to evaluate the degree of these sensory alterations (Costa 2013).
C. Left: The extremities of a sectioned lingual nerve (arrows). Right: Micro-neurosurgical repair (arrow) of the lingual nerve can be performed. However, there is no guarantee of total sensory recovery (Ziccardi 2007).

In general, the incidence of these complications varies significantly among studies, and because of that, their real risks of occurrence are not yet clear. In addition, **a lack of knowledge on the real risks posed by M3s left in place may be one of the reasons why prophylactic surgical measures are commonly adopted in dentistry** (York 1998). Such surgeries undeniably pose risks to the patient, and a more balanced approach needs to be considered to avoid or reduce the chances of complications arising from these procedures, as well as the significant inconvenience of this major oral surgery even when it is complication-free. Ultimately, the best course of clinical decision-making must be based on the most comprehensive and conclusive data available; which is why it is important to conduct investigations to provide more information and understanding about the actual risks posed by impacted M3s weighed against the actual risks of major oral surgery.

1.6 Imaging Methods to Diagnose Third Molar Impaction

In dental practice, the M3 can be evaluated by standard clinical radiographs and/or specialized imaging methods. Standard radiographs are two-dimensional (2D) images that have been commonly used to detect the presence of impacted teeth (Costa 2011). The most commonly used modalities for this purpose are intraoral (periapical and occlusal), panoramic, and lateral oblique radiographs (Abramovitch 1993). Given their common use in dental practice, the study of these images for research purposes raises few ethical concerns. Consequently, **studies of M3 impaction have traditionally relied on standard radiographic images** (Ganss 1993). However, these images carry limitations (Drage 2002, Bell 2003) since they only allow a 2D analysis of three-dimensional (3D) structures (Costa 2011) (Figure 9). In addition, these images often present distortions and/or magnification errors that cannot always be detected, measured and thus compensated for (Scarfe 1998).

Computed tomography (CT) is a type of specialized 3D imaging technology which has been increasingly adopted by dental practioners as it becomes less expensive as well as more effective at lower doses of radiation (Abramovitch 1993). Since CT was developed in 1972 (Ambrose 1973, Hounsfield 1973), 3D imaging has become increasingly more common in dental practice, including now being recommended before some surgeries including M3 removal (Engelke 1997). Furthermore, with the recent introduction of cone-beam computed tomography (CBCT) designed especially to capture the volumetric aspects of the maxillofacial region (Santos Tde 2012), CT has become an important tool to precisely determine the risks of a proposed clinical intervention (Maegawa 2003, Costa 2011). As a result, large data banks of CBCT images are available today allowing 3D studies of a large number of cases to be performed.

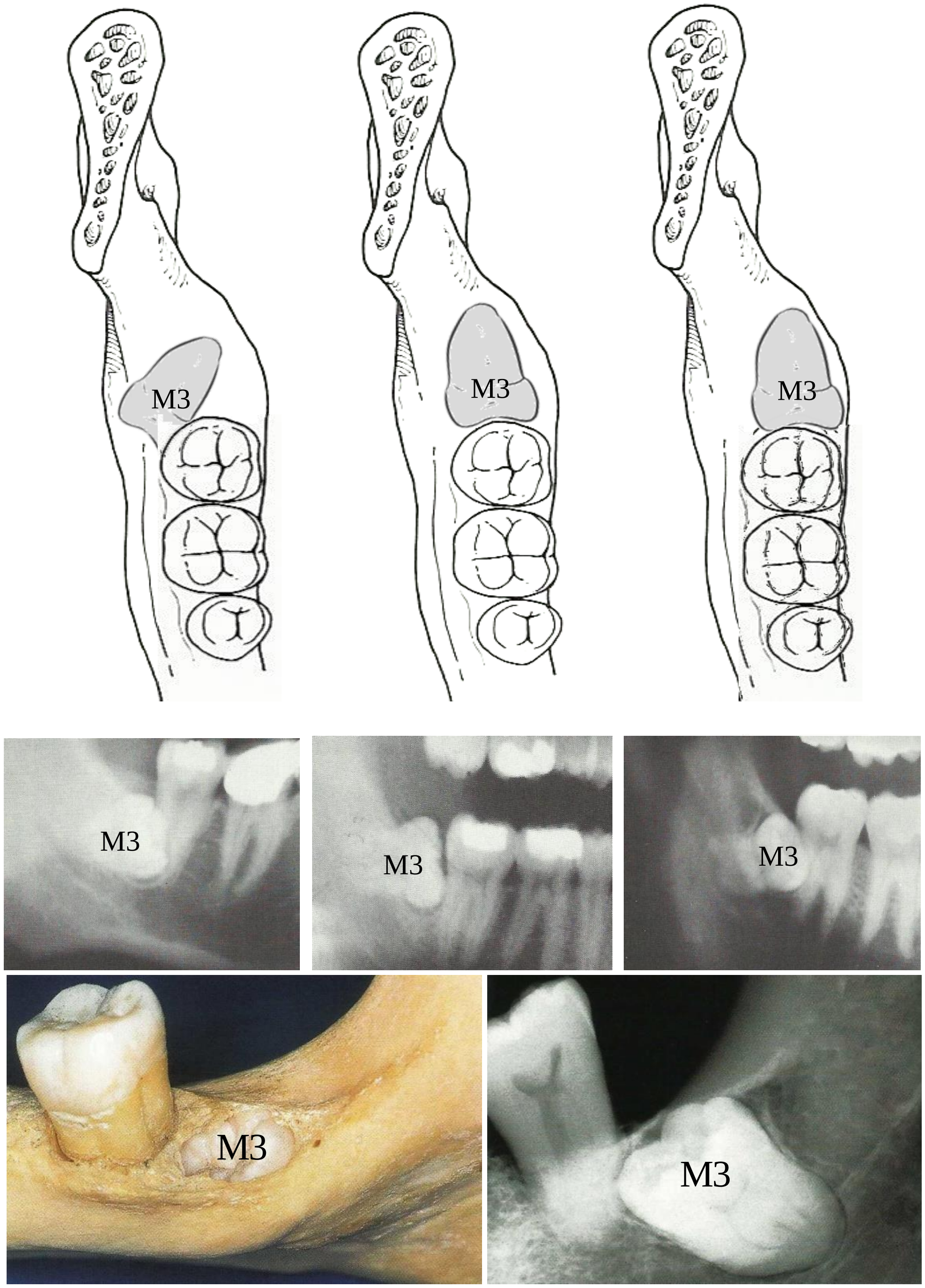


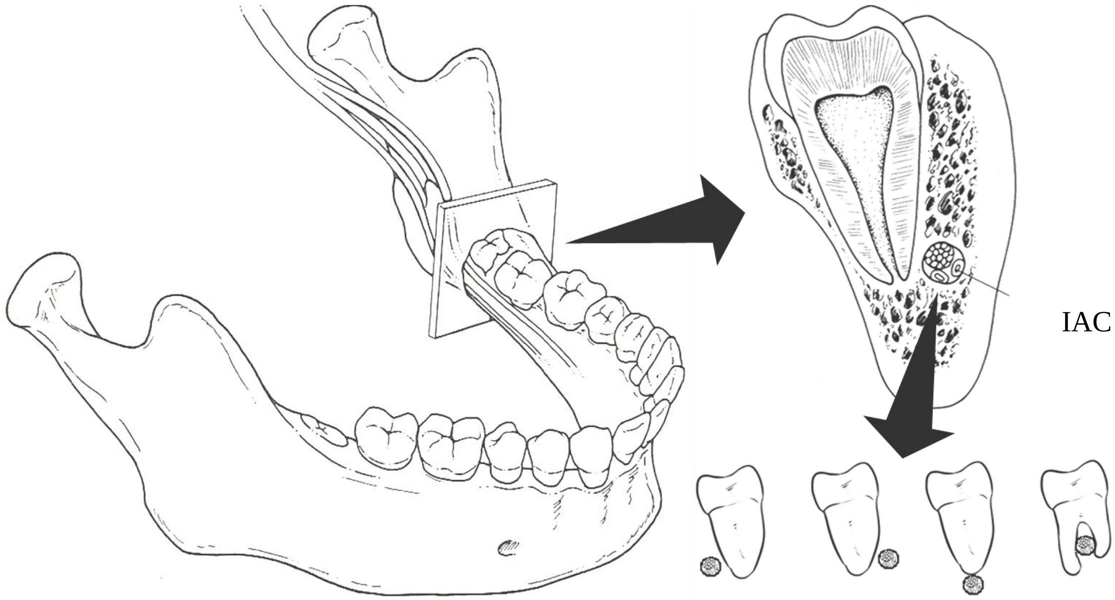
Figure 9. The limitations of standard dental radiographs.

A. Occlusal view of molars, with the ramus cut above the mandibular foramen. M3s can be positioned buccal (I), posterior (II), or lingual (III) in relation to the second molar. Image: adapted from Rodu (1993).
B. These periapical images (standard radiographs) illustrate the respective positions of the M3 as shown in “A”. The exact buccolingual position of the M3 cannot be precisely determined using these images. Image: Rodu (1993).
C. Illustrates how standard radiographs create 2D images from 3D anatomical structures. Image: Korbendau (2003).

The use of CBCT images provides a reliable view of the buccolingual (B-L)[5] relationship between the M3 root and the IAC; this relationship cannot be precisely determined with standard 2D panoramic radiographs (Ghaeminia et al., 2009) (Figure 10). For that reason, when 2D radiographic evidence of an intimate relationship between the IAC (which contains the IAN) and the M3 exists, CBCT images are a valuable resource for more accurate diagnostics to avoid possible injuries to the IAN (Flygare 2008). In addition, the software used to view and adjust the CBCT images allows measurements to be made in the three standard anatomical planes (coronal, sagittal, and axial), as well as in any customized plane of reconstruction that the observer may choose. As a result, **measurements of tooth and bone dimensions can be taken with greater precision and accuracy using CBCT scans than is possible with standard 2D radiographs** (Ghaeminia 2011). Olive and Basford (1981), for instance, found such considerable distortions and magnifications in the molar and RM regions on rotational tomograms (a type of 2D image) that they concluded that it is not possible to make useful linear measurements using these images. Given the advantages of 3D imaging resources to assess teeth and related structures (Susarla 2007, Lubbers 2011, Nguyen 2011, Santos Tde 2012), CBCT imaging was the ideal modality for the present research on M3 impaction.

[5] Buccal: towards the mucosa of the lip or cheek; lingual: towards the tongue. Buccolingual refers to a tooth or tooth surface inclined or facing either the buccal side or the lingual side of the dental arch.

A



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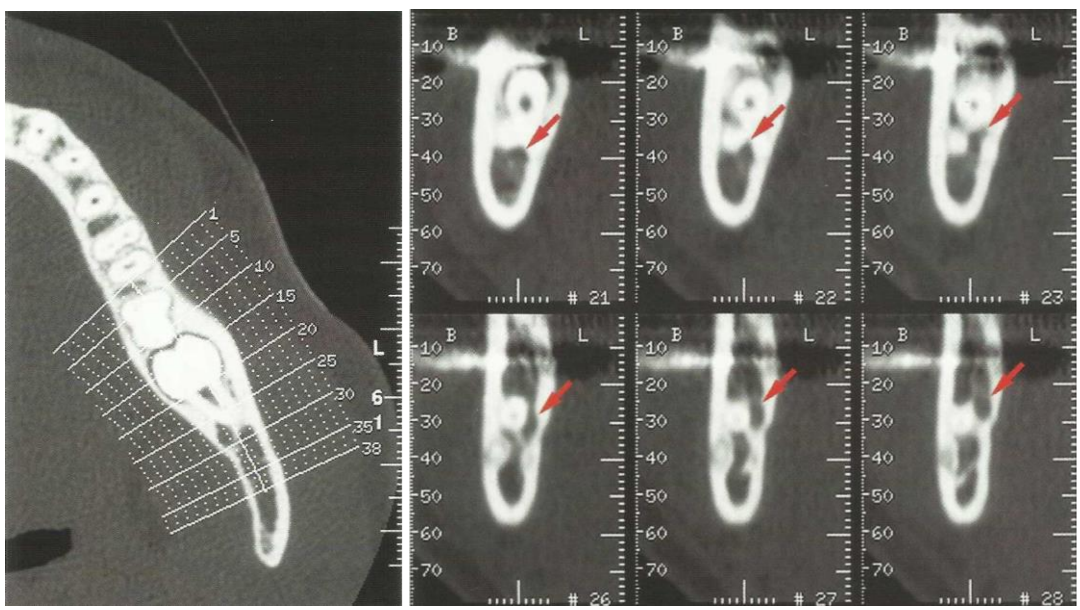


Figure 10. Three-dimensional features of CBCT images.

A. Not only the morphology of the M3's root varies considerably but also does the relationship between this root and the inferior alveolar canal (IAC). Image: Adapted from (Rodu 1993).

B. The relationship between the M3's roots and the IAC can be more accurately determined using CBCT images than when standard radiographs are used. Image: (Korbendau 2003).

1.7 The Current State of Knowledge on Third Molar Impaction

1.7.1 The Current Knowledge On Third Molar Impaction: Does It Allow Clinicians to Accurately Predict this Condition?

A lack of space in the RM region has been accepted as the main factor associated with impaction of the M3 (Bjork 1956, Bjork 1972, Richardson 1987, Venta 1991, Ganss 1993, Venta 1997, Hattab 1999, Tsai 2005, Behbehani 2006, Niedzielska 2006, Kaya 2010). However, **in some cases, availability of space in that region does not guarantee the proper eruption of the M3** (Gupta 2011), indicating that presence of space is not the only risk factor for M3 impaction. Other speculated causes include growth of the maxillofacial skeleton (Rodu 1993), delayed M3 formation (Svendsen 1988, Rodu 1993), larger tooth crowns (Begg 1954, Richardson 1977, Ng 1986, Varrela 1990, Rodu 1993, Venta 1997, Hattab 1999), and dental arches of reduced dimensions (Mills 1964, Howe 1983, Ng 1986). Therefore, for more accurate prediction methods for M3 impaction, all of these salient factors need to be considered (Hunter 1960, Hattab 1999). Ricketts and colleagues (1976), for example, investigated the RM region of seventy-four orthodontic treated cases and found a threshold value of 25 mm required for M3 eruption from the Xi point (a point located at the geographic center of the mandibular ramus) to the most distal point of the M2. They concluded that predicting M3 impaction was possible when 20 mm of space or more was available, and that the M3 would erupt properly when an adequate space of at least 30 mm was present. However, their study assessed only the RM space for mandibular M3s (M_{3s}). Since unerupted M3s can considerably change their inclination and/or orientation within the jaws with time, their eruption also depends on this inclination (Doris 1981, Flygare 2008). As a result, prediction methods based on measurements of the RM region are incomplete and thus have not proven efficient. **Even with advances in research that helped**

clarify the causes of M3 impaction, currently this condition cannot yet be predicted using jaw space alone (Gupta 2011).

Not only is M3 impaction currently impossible to predict reliably, but so are the pathoses and consequent risks associated with the impacted M3s (Fielding 1981, Fayad 2004). As a result, divergent philosophies have emerged. While some clinicians defend prophylactic surgical removal of M3s as a measure to avoid pathoses and other complications that may become associated with these teeth (Rodu 1993, Peterson 1998), others advocate that these teeth should be left in place unless their surgical removal is essential (Friedman 2007, Kandasamy 2009). Since the literature lacks sufficient data to support one approach or the other (Sisk 1986), surgical removal of M3s as a prophylactic measure has been adopted and has become a common clinical management procedure for impacted and non-impacted M3s. That is, extraction surgery is viewed as a "known" solution with the most predictable outcome and this predictability is currently used to justify the uncertainty associated with regularly monitoring M3s that are left in place. If new data become available to help guide clinical decision-making such that the "sit and wait" approach is viewed as equally reliable, then this may limit a significant number of prophylactic and potentially non-essential M3 extraction procedures.

1.7.2 Identifying the Gaps in Knowledge: Research Directions on Third Molar Impaction

With technological advances in clinically imaging dental development and morphology in all three anatomical planes (3D), it is now possible to overcome some of the barriers that once prevented greater insight into the causes of and risks posed by M3 impaction when only 2D images were used. Although understanding of the etiology of M3 impaction has been considerably advanced by previous studies, they carry some limitations that need to be considered by the present MSc research. Such limitations include:

(1) The reported prevalence of M3 impaction varies considerably among studies (Ganss 1993) especially because **of a lack of consensus about a definition for dental impaction.** A standard definition would help build a clearer picture both across Canada and globally of how often the M3 becomes impacted and/or associated with pathoses;

(2) **A lack of accurate data on the real risks of both leaving M3s in place and having them surgically removed exists** (Boughner 2013). An accurate picture of these risks - which can be generated if studies use a standard definition for impaction - would provide additional tools to help clinicians decide whether or not to extract or monitor M3s;

(3) Because the M_3 is more frequently impacted than the M^3 (Alling, 1993b; Bishara & Andreasen, 1983; Grover & Lorton, 1985), and because of the clinically important proximity of the M_3 to the LN and IAN, previous studies have focused on the impaction of M_3. As a result, **only a small number of studies compare the characteristics of M3 impaction between the maxilla and mandible** (Fayad 2004, Alsadat-Hashemipour 2013). If new studies demonstrate that the risks of M3 impaction are jaw specific, then a great number of prophylactic surgeries could be alleviated if only those M3s at high risk of complication were removed;

(4) **Previous studies on M3 impaction have relied traditionally on standard oral radiographs**. These images only allow a 2D analysis of the M3 and surrounding tissues (Costa, Bellotti et al. 2011). However, as discussed in the section 1.6, today CBCT imaging is able to provide a clear picture of the relationship between the M3 and adjacent structures, and for that reason this imaging resource was adopted by the present research project.

1.7.3 The Present Project's Contribution and the Proposed Extension of Knowledge

Availability of space in the RM region – which is currently accepted as the main cause of impaction – cannot be accurately determined in 2D images (Olive 1981) and previous studies using such images have only been able to provide relative estimates of the actual dimensions of that region of the jaws. For that reason, this project uses digital-format 3D imaging to obtain linear measurements of the space available in the jaws between the first molar (M1) or second molar (M2) and adjacent anatomical structures in the presence and absence of M3 impaction. While in some patients a short RM space may be the major risk factor for M3 impaction, in other individuals delayed M3 formation, larger tooth crowns, and/or narrower dental arches are suspected to increase the risk of that condition. Since current 3D dental imaging resources allows these factors to be more accurately observed and studied than with 2D radiographs, new studies on M3 impaction and its causes are essential to help fill the current gaps in scientific and clinical knowledge. Further studies are essential for the development of new predictive diagnostic tools for the impaction problem. For that reason, **the present MSc research project tests the hypothesis that delayed M3 mineralization, reduced RM space, larger tooth crowns, and narrower dental arches are associated with the presence of M3 impaction in maxilla and mandible**.

1.8 Overview of the Objectives of the Present Research Project

1.8.1 Objective I: Investigate the RM space in the maxilla and mandible in the presence and absence of third molar impaction

Studies support a lack of space in the RM region as the most significant factor for development of M3 impaction (Bjork 1956, Ricketts 1972, Schulhof 1976, Graber 1981, Ganss 1993, Rodu 1993, Peterson 1998). However, the information available in the literature is derived largely from 2D based-studies of the impacted M_3 while the characteristics of M^3 impaction have not been extensively explored (Fayad 2004). Since studies of the causes of M3 impaction have rarely considered both jaws, besides never using 3D image data, **the present hypothesis predicts that a reduced amount of space in the RM region is observed in both the maxilla and the mandible when M3 impaction is present.** While previous 2D-based studies have only provided relative estimates of the actual space available to accommodate the eruption of the M3, new 3D-based data will allow the dimensions of that space to be captured more accurately helping thus understand the influence of the actual existing space in the development of M3 impaction in both jaws.

1.8.2 Objective II: Investigate the timing of third molar mineralization according to the impaction status of this tooth and availability of space in the jaws

Complete mineralization of the M3 crown and roots does not necessarily mean that this tooth will erupt into the oral cavity. As noted above, for eruption to occur, a minimum amount of space must be present in the jaws. The great variability of the M3 position and path of eruption (Forsberg 1988) is therefore also reflected in this tooth's eruption time, which also varies considerably. This variability in the age of the patient when eruption occurs is also observed among different populations, ranging from 14 years in Nigerians (Odusanya 1991) to 24 years in

Greeks (Haralabakis 1957). What is not well understood, however, is if delayed M3 mineralization leads to impaction of this tooth (Svendsen 1988, Rodu 1993). However, due to a lack of longitudinal studies on M3 impaction, this association between M3 mineralization and impaction has not been intensively explored (Bjork 1956). Svendsen (1988), for instance, studied longitudinal yearly records and standard radiographs of 91 patients from before puberty until 25 years of age and concluded that late M3 mineralization in combination with early physical maturity is an etiological factor for M3 impaction. However, in that study the degree of M3 mineralization was not associated with the amount of space available in the jaws. Because CBCT images allow the M3 and its spatial position to be identified with accuracy as well as linear measurements to be done, the present project aims to test if a reduced amount of space in the jaws is evident in presence of delayed M3 mineralization in addition to testing if delayed M3 mineralization occurs in the presence of impaction as addressed by Bjork and colleagues using 2D radiographs. **The present hypothesis predicts that M3 mineralization progress is delayed when both M3 impaction and a reduced amount of space in the jaws are present.**

1.8.3 Objective III: Investigate the crown size of premolars and molars according to the third molar impaction status

Past work suggests that greater M-D crown width of post-canine teeth decreases the amount of space available in the jaws distal to the M2 to accommodate M3 development and eruption (Begg 1954, Varrela 1990, Rodu 1993). Several methods have been used in an attempt to easily and functionally measure tooth size. Most of the previous studies have applied measurements techniques on plaster models poured from alginate impressions of maxillary and mandibular dental arches (Ballard 1944, Nance 1947, Moorrees 1951, Hixon 1958, Barrett 1963, Moorrees 1964, Doris 1981, Forsberg 1988). Despite the fact that some authors consider tooth measurement techniques performed directly on plaster models a reliable method (Doris 1981), one study (Hunter 1960) reported that cast measurements were slightly larger than direct measurements made in the mouth, suggesting that plaster models may not reproduce the actual dimensions of the structures found in the oral cavity. However, one of the reasons why tooth measurements techniques on plaster models became common is that measurements taken directly from the mouth can be unwieldy, particularly in the posterior segments of the dental arches which are more difficult to access (Doris 1981). In addition, tooth crown size cannot be measured with precision and accuracy using standard 2D radiographs (Ghaeminia 2011). **The present hypothesis predicts that larger tooth crowns of premolars and molars (e.g. mesiodistal crown width) are observed when M3 impaction is present.**

1.8.4 Objective IV: Investigate the size of the dental arch according to the third molar impaction status

Impacted M3s are suspected to be more evident in individuals with dental arches of reduced dimensions (Richardson 1977, Ng 1986). However, the relationship between dental arch form and size with presence of M3 impaction has never been extensively examined (Ng 1986). This hypothesis is based on evidence that arches with dental crowding[6] tend to be narrower (Mills 1964, Howe 1983), and on the fact that narrower arches are more common in individuals with M3 impaction (Richardson 1977, Ng 1986). Bjork et al. (1956) for instance, studied mandibular growth on cephalometric profile x-ray films and they identified that a lack of increase in mandibular length associated with vertically directed condylar growth and backward eruption of the dentition are additional etiological factors for M3 impaction. That is, not only the amount of space in the RM region but also other factors associated with the growth of the

[6] Dental crowding: discrepancy between tooth size and arch size that results in malposition and/or rotation of teeth (Janson 2011).

mandible as a whole structure contribute to the risk of M3 impaction. Richardson (1977) investigated a group of 95 subjects with impacted and erupted M_{3s} and found a higher proportion of skeletal Class II[7] dental bases with shorter, narrower, and more acutely angled mandibles in the impacted group. These results therefore also connect M3 impaction to narrower mandibles. In dental arches with dimensions naturally reduced space is unlikely to be available not only for the M3 itself but also for other teeth. For that reason, in individuals with dental arches of reduced dimensions and/or with dental crowding, M3 impaction is expected to be more evident (Richardson 1977, Ng 1986). Since recent advances in 3D imaging technology have made it possible to measure tooth and arch dimensions with considerable accuracy and facility, compared with the traditionally used calipers (Ng 1986), the present study applies 3D-based imaging to investigate if the anterior-posterior and lateral-lateral dimensions – representing respectively the depth and the width - of the dental arches are reduced when M3 impaction is present. In summary, **the present hypothesis predicts that maxillary and mandibular dental arches of reduced anterior-posterior and lateral-lateral dimensions are observed in the presence of M3 impaction.** Because dental crowding can be also observed on 3D images, objective IV complementarily tests if dental crowding is more commonly present in subjects with M3 impaction, compared to when impaction is absent.

[7] Class II of occlusion (or distocclusion) – malocclusion in which the mandibular arch is in a posterior position in relation to the maxillary arch.

CHAPTER 2
RESEARCH QUESTIONS AND OBJECTIVES

Availability of space in the RM region has been accepted as the main factor determining M3 impaction. However, other factors such as delayed M3 mineralization, larger tooth crowns, and dental arches of reduced dimensions are suspected to be contributing factors. The present research project aims to further investigate the etiology of M3 impaction as well as the characteristics of the initial stages of M3 mineralization by using 3D images to obtain measurements not possible to be accurately obtained with the use of 2D images. Therefore, this study tests for the first time using CBCT-based metrics the hypothesis that **in the maxilla and the mandible, not only a reduced amount of space in the RM region is observed when M3 impaction is present but also delayed mineralization of this tooth, larger molar and premolar crowns, and dental arches of reduced dimensions.** Four distinct objectives will test whether or not each of the suggested causes of impaction contained in the above main hypothesis occurs when M3 impaction is present, as shown in Figure 11.

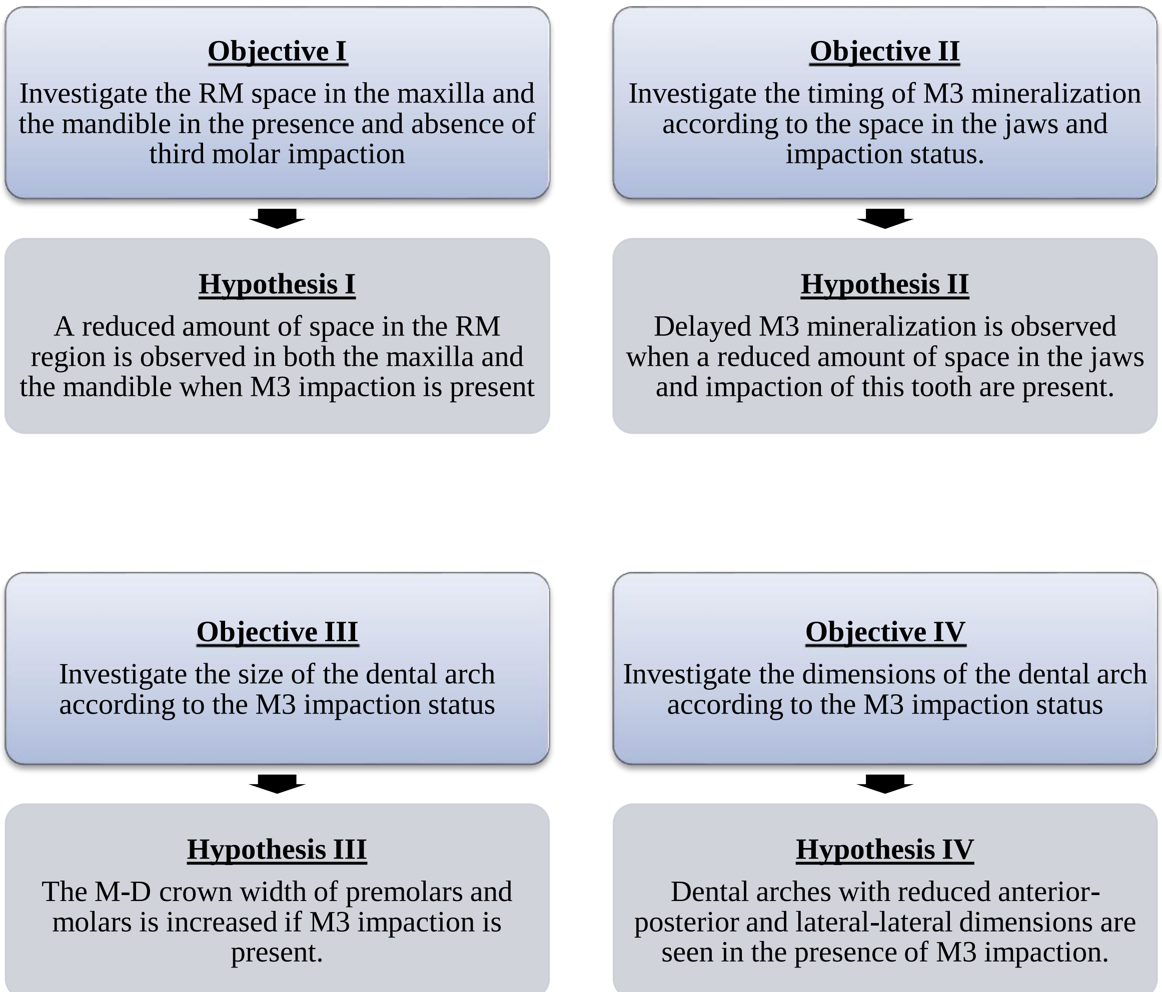


Figure 11. Overview of the hypotheses to be tested by the present study.
This present study uses 3D imaging resources to address hypotheses that, due to the limitations imposed by standard 2D radiographs, have not been intensively explored.

CHAPTER 3
MATERIALS AND METHODS

3.1 Study Materials and Ethics Permission

Ethics permission (BIO#11-202) was obtained to use existing retrospective CBCT image data sets of over 500 patients aged 8 to 24 years held at the College of Dentistry (COD), University of Saskatchewan. To investigate the M3 impaction condition and its associated causes, 213 patients were selected based on the eligibility criteria discussed in section 3.3 and de-identified data was studied as required by the research ethics permit. In addition, all CBCT scans were retrospective and done by referral by dentists for specific diagnostic purposes and therefore not done for the purpose of this study.

The initial stages of M3 mineralization are observed at around age nine years (Gravely 1965, Richardson 1980, Ragini 2003), while impaction can only be identified during later stages of this tooth formation. For that reason, patients were placed into two distinct groups (Table 1): 1) 127 subjects aged eight to twelve years, to test if the space available in the jaws is reduced if the occurrence of the initial stages of M3 mineralization is delayed; and 2) 76 subjects aged 17 to 24 years, which is the age range during which M3 eruption is expected to occur (Haralabakis 1957, Peterson 1998, Hattab 1999), to test if differences in the dimensions of the RM region, molar and premolar crowns, and the dental arch are found between the impacted and non-impacted groups. One M3 is usually expected to be present in each quadrant of the maxillary and mandibular dental arches (e.g. right and left) of a single subject. Eventually M3s can be found present in one quadrant while absent in the opposite quadrant. For that reason, right and left quadrants of the subjects included in the above two groups were studied independently from each other to address four distinct hypotheses, as described in Table 1 and Figure 12.

Group of Subjects	Age (years)	Sex				Maxilla				Mandible				Total	
		Female	Male	Total		Right	Left	Total		Right	Left	Total			
■ **Group I**	8-12	72	55	**127**	Subjects	124	122	**246**	Quadrants	120	120	**240**	Quadrants	486	Quadrants
■ **Group II**	17-24	39	37	**76**	Subjects	48	52	**100**	Quadrants	52	54	**106**	Quadrants	206	Quadrants
				213	Subjects			**346**	Quadrants			**346**	Quadrants		

Table 1. Groups of subjects studied.
While one M3 is usually expected to be present in each of the four dental arch quadrants of each subject (two in the maxilla, two in the mandible), only quadrants that met the criteria (see section 3.3) for inclusion were studied by the present project. Please note that the number of right and left quadrants included is not necessarily the same. For that reason, right and left quadrants of the subjects included in the above two groups were studied independently.

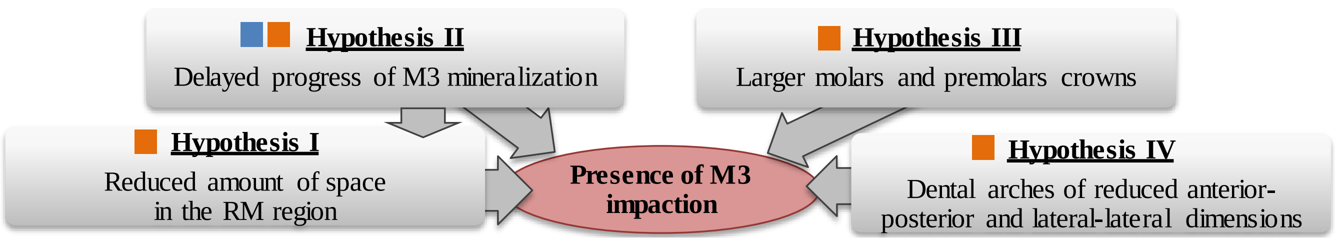


Figure 12. The hypotheses addressed by the present study.
Data collected from group II is used to test Hypotheses I, III, and IV. Hypothesis II uses data collected from both groups I and II.

- Hypothesis I predicts that the amount of space in the RM region is reduced in the maxilla and the mandible when M3 impaction is present.
- Hypothesis II predicts that the progress of M3 mineralization is delayed if a reduced amount of space in the RM region and/or impaction of this tooth are present.
- Hypothesis III predicts that the M-D crown width of premolars and molars is increased when M3 impaction is present.
- Hypothesis IV predicts that dental arches with reduced anterior-posterior and lateral-lateral dimensions are seen when M3 impaction is present.

3.2 Imaging Resources

The proprietary software package iCAT (Imaging Sciences International, Philadelphia, U.S.A.), version 3.1.62, was used to visualize and collect measurements from the CBCT image datasets. This software allows 3D multi-plane (e.g. coronal, sagittal, and axial) (Figure 13) viewing and has linear measurement tools. Therefore, anatomical features of the human jaws can be identified and studied with greater accuracy and reliability compared to standard 2D dental radiographs (Maegawa 2003, Ghaeminia 2011). For consistent reproducibility, all measurements were taken on the same plane (axial view) generated by the CBCT images rather than on the 3D surface rendering itself (Figure 14). Measurements were taken by two researchers, Denver Marchiori and Ullas Kaplor, and sets of inter- and intra-observer tests were performed in order to assure the consistency of the methodology applied and data collected (Appendix A). Statistical tests in this research project were carried out using the software packages SPSS version 21 (IBM Corporation, Armonk, New York, U.S.A.), and PAST (University of Oslo, Norway), version 2.18.

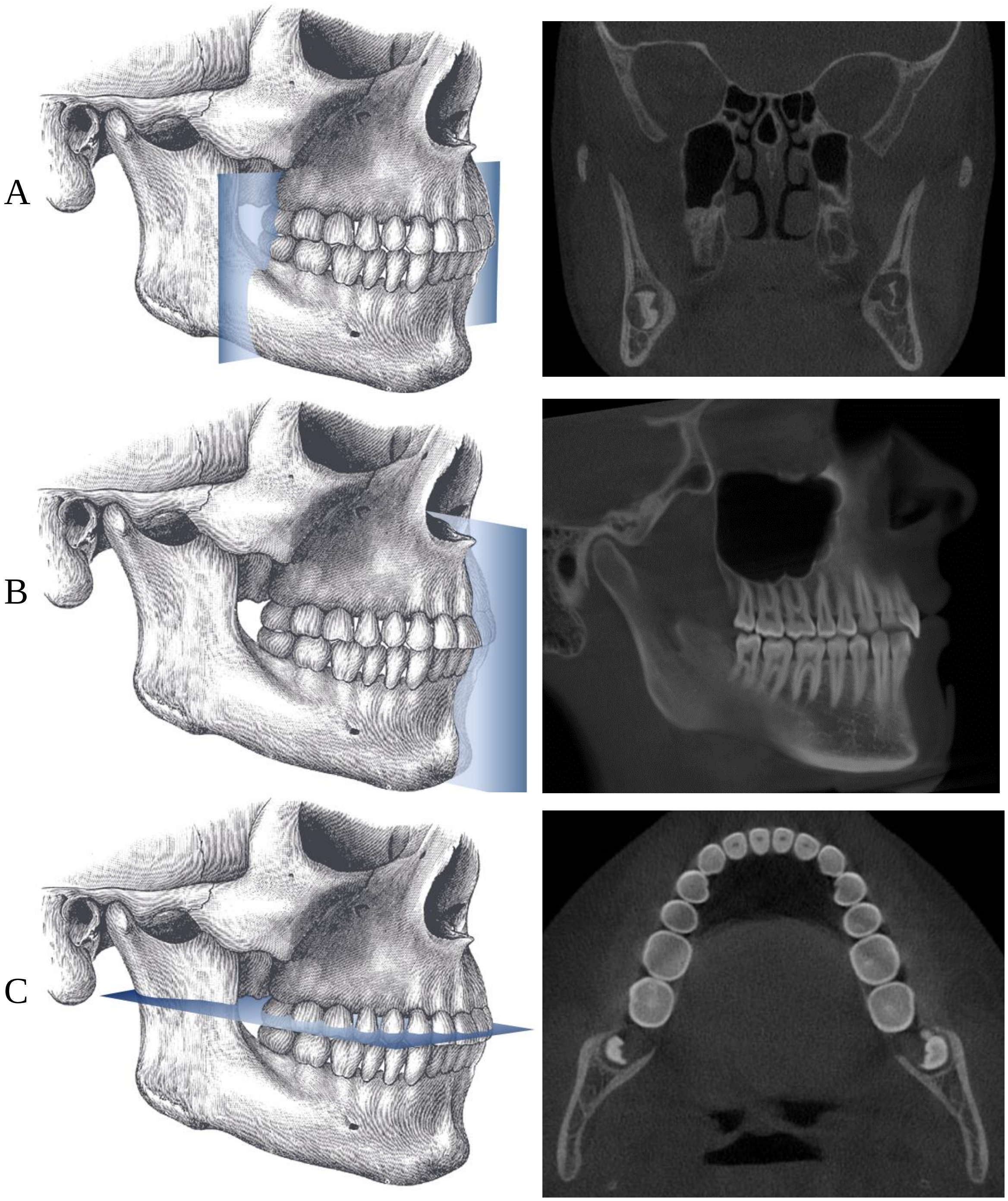


Figure 13. The three distinct plane views generated by CBCT images.
Cone-Beam Computed tomography (CBCT) images allow the study of M3s and associated anatomic features by observing these structures in three distinct anatomical views: a) coronal, b) sagittal, c) axial. Images: adapted from (Gray (1918)).

3.3 Inclusion Criteria and Sample Characteristics

Subjects were included in the present study based on the inclusion criteria described below. Summary of the cases included/excluded is shown in Table 2-3.

1. **Age**: Subjects aged 8-12 years were studied to test if the amount of space available in their RM regions was reduced when the progress of M3 mineralization was delayed. Subjects aged 17-24 were studied to test if a reduced RM region, larger tooth crowns, and dental arches of reduced dimensions were observed when impaction was present.
2. **Absence of maxillofacial defects**: Patients with cysts or any other maxillofacial lesions that could difficult measurements of the RM region were considered for exclusion.
3. **No history of extractions**: Gaps left by other extracted permanent teeth may artificially increase the space for eruption of the M3 (Kaplan RG, 1975), and for that reason subjects with extracted teeth were not included in this study.
4. **Presence of the M3**: Due to the impossibility to determine on CBCT images if an absent M3 was extracted or congenitally absent, subjects aged 17-24 years and without the M3 were excluded. However, to test if jaw space differs in the presence and absence of M3 mineralization, subjects aged 8-12 years and without forming M3s were not excluded.
5. **Absence of metallic restorations**: The presence of major metallic dental fillings often compromises the study of the CBCT images, as “streak” or “scatter” artifacts created by them will obscure adjacent structures decreasing visibility and measurement accuracy.
6. **Technical limitations**: In some occasions CBCT images are used to evaluate a specific region of a patient’s maxillofacial region and, for that reason, it may not cover both the maxilla and the mandible.

Subjects (N)		Maxilla Right quadrant (N)	Maxilla Left quadrant (N)	Mandible Right quadrant (N)	Mandible Left quadrant (N)	
133		133	133	133	133	**Exclusion criteria**
	(-)	-	-	-	-	Absence of the M3 in the quadrant.
	(-)	8	8	9	9	Region not covered by CBCT image.
	(-)	1	1	1	1	Extractions observed in the quadrant.
	(-)	9	11	13	13	Presence of metallic restorations.
	(-)	0	0	0	0	Defects of the maxillofacial skeleton
127		124	122	120	120	

Table 2. Summary of the criteria used to select subjects aged 8-12 years.
A total of 127 subjects aged 8-12 years were selected. Please note that absence of the M3 was not a criteria to select these subjects.

Subjects (N)		Maxilla Right quadrant (N)	Maxilla Left quadrant (N)	Mandible Right quadrant (N)	Mandible Left quadrant (N)	
158		158	158	158	158	**Exclusion criteria**
	(-)	86	80	90	91	Absence of the M3 in the quadrant.
	(-)	0	0	2	2	Region not covered by CBCT image.
	(-)	20	22	14	10	Extractions observed in the quadrant.
	(-)	4	4	0	1	Presence of metallic restorations.
	(-)	0	0	0	0	Defects of the maxillofacial skeleton
76		48	52	52	54	

Table 3. Summary of the criteria used to select subjects aged 17-24 years.
A total of 76 subjects aged 17-24 years were selected.

3.4 Study Methodology: Overview

Two measurements were collected from each maxillary and mandibular RM region on the CBCT images to analyze the dimensions of the space distal to the M1 and M2 available for the development and eruption of the M3. Right and left dental arch quadrants of the subjects included in the present study were studied independently. The amount of space available in the right dental arch quadrants of the subjects studied was compared using independent sample t-test to identify if that space was significantly reduced in the presence of M3 impaction and/or delayed M3 mineralization. The same methodology was applied to the left quadrant of these subjects so that the results found on the right quadrant could be confirmed. The sizes of premolar and molar crowns and the dental arch dimensions of the subjects studied here were also measured and analyzed in the presence of M3 impaction. The specific methods to test each of this study's hypotheses are discussed in details in the following sections of this chapter.

3.5 Standards for the Study of CBCT Images

Measurements were taken on the axial view generated by having the axial plane positioned parallel to the occlusal plane (of the dental arch being studied) and at the superior-inferior level of the interproximal contact point[8] of the permanent molars and premolars. This level will be hereon referred to as the **measurement level** (Figure 14 and Figure 15). The axial plane can be moved upwards and downwards in order to allow the distance between structures that are located in distinct superior-inferior levels to be linearly measured, as illustrated by Figure 14. This procedure allows the positions of structures or landmarks to be defined on the measurement level.

[8] Refers to the specific point of two adjoining teeth that are aligned in the dental arch, where they touch each other.

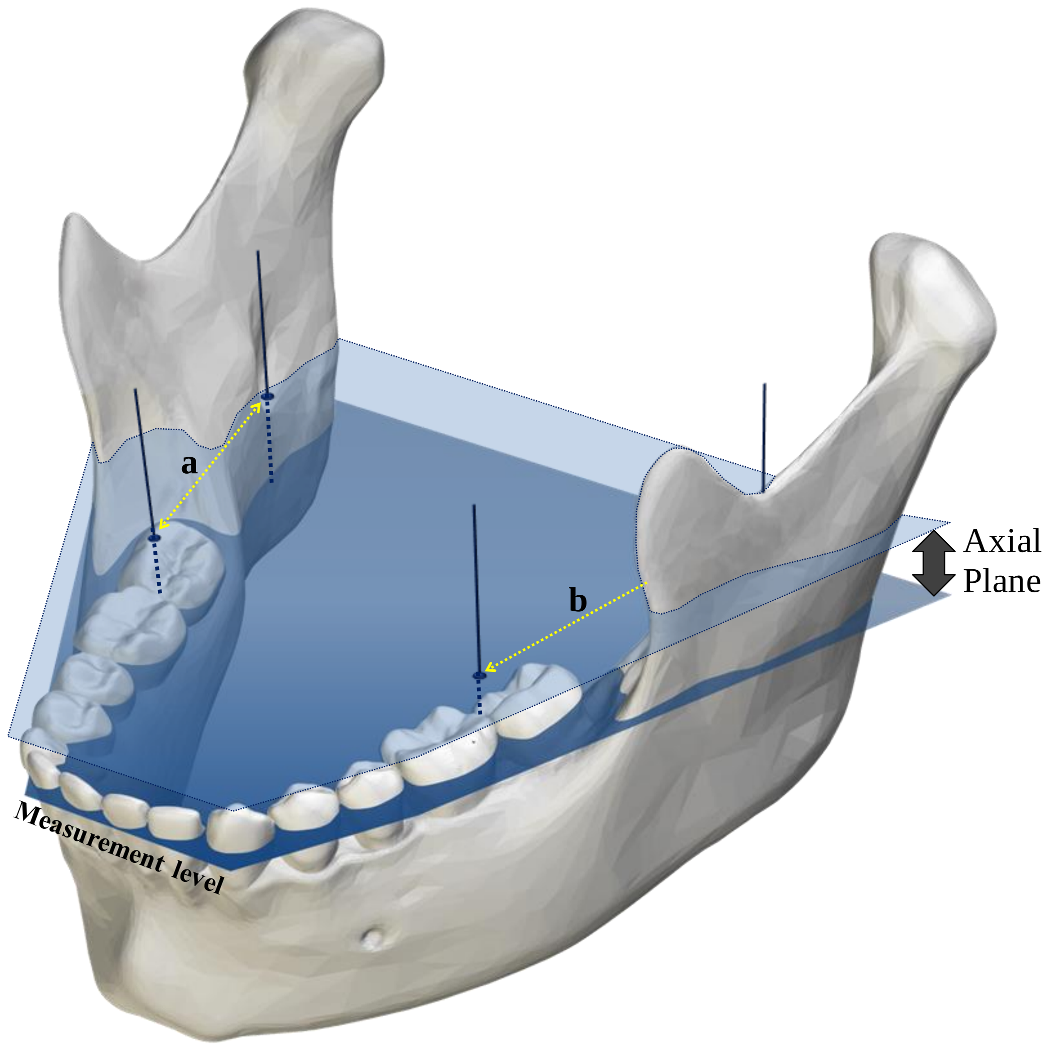


Figure 14. The use of the axial plane view to collect measurements.
The axial plane can be moved upwards and downwards in order to allow the distance between structures located in distinct superior-inferior levels to be linearly measured. In the image above, the distance between the distal M1 and the mandibular foramen is measured to illustrate the technique. This technique is applicable to measurements collected in both the maxilla and the mandible. Image: (3DCadbrowser 2014).

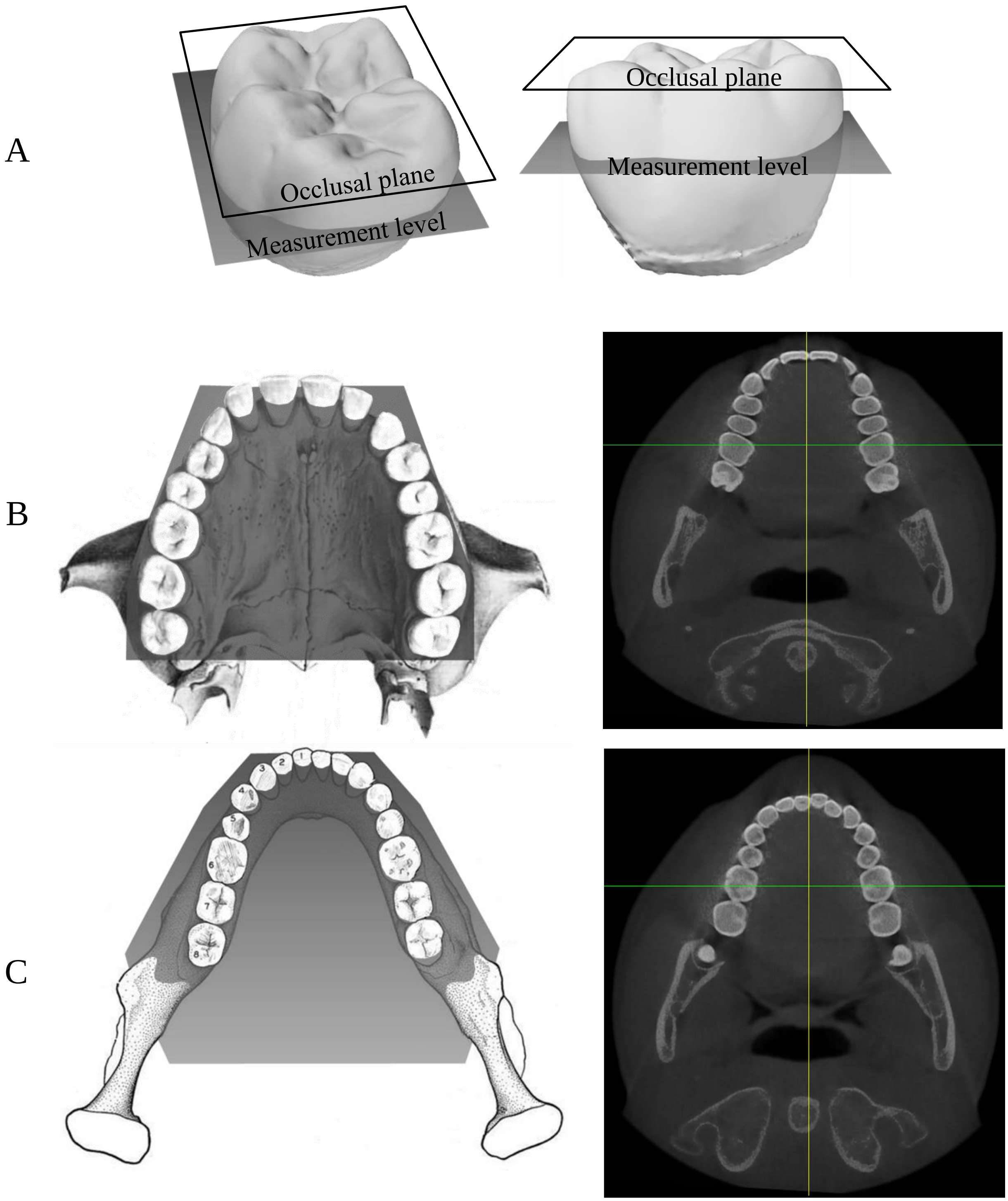


Figure 15. The superior-inferior level of the axial plane.
(**A**) Measurements were taken by positioning the axial anatomical plane parallel to the occlusal plane of the dental arch and at the superior-inferior level of the interproximal contact regions of the permanent molars, in the maxilla (**B**) and mandible (**C**). At this level, CBCT images produce axial views that allow the observation of the maximum M-D teeth crown sizes. Image A**:** 3DCadbrowser (2014); image B**:** Sobotta (2006); Image C**:** University (2014). All images are adapted.

3.6 Establishment of Landmarks on Osseous Structures

In order to collect measurements, most studies of M3 impaction have used the distal-most point of the maxillary tuberosity and the ascending ramus of the mandible as measurement landmarks. These landmarks represent the most distal limit of the jaw (Ganss 1993), and they are used because the region between the distal M2 and these landmarks is where the M3 is expected to erupt into. In this case, the space available for M3 eruption is represented by the distance between these landmarks and the M2 of the same quadrant[9]. Because of the 3D characteristics of the CBCT images, previously used landmarks could be once again adopted and reliably identified in all images studied. Although the distance between the M2 and virtually any established point on adjacent anatomical structures can be measured using CBCT images, landmarks used in classic 2D-based studies were adopted here to make it possible to compare the 3D-based data with those data obtained using 2D radiographs. **Previous measurements with standard 2D radiographs only produced estimates of the actual dimensions of the space for M3 eruption while 3D-based data allow these dimensions to be more accurately captured.** Two landmark points were set at the posterior region of the maxilla and the mandible (see below) to test for regions with greater variations in size when M3 impaction was present. If for instance, the space between the M_2 and the mandibular ramus is proportionally more variable than the space between M_2 and the mandibular foramen when M3 impaction is present, then the mandibular ramus may be a better indicator for impaction.

[9] In dentistry, quadrant refers to the division of the jaws into four parts, beginning at the midline of the arch and extending towards the last tooth in the back of the mouth. There are four quadrants in the mouth where each quadrant generally contains eight teeth.

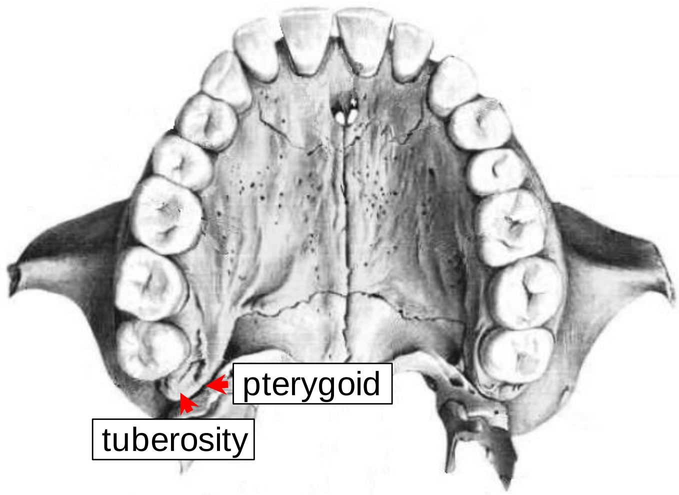
In the **maxilla**, two landmarks (Figure 16) were used for the measurements. These are:

- **Landmark 1**, or the pterygoid process of the sphenoid bone, at the point where the maxillary bone articulates with that anatomical structure, as observed on CBCT images. The limit established by the vertical plate of the pterygoid has been commonly used by previous studies (Ricketts 1976, Ganss 1993, Elsey 2000) and it is being adopted here to allow the future comparison of results among studies. This landmark point will be here on referred to as pterygoid.
- **Landmark 2,** on the distal-most point of the maxillary tuberosity surface. This landmark point will be here on referred to as tuberosity.

In the **mandible**, two landmarks (Figure 17) were used for the measurements. These are:

- **Landmark 1,** or the anterior margin of the mandibular foramen. This point will be here on referred to as foramen. The mandibular foramen contains the IAN and vessels and it was used as a landmark because no teeth are expected to form distal to this structure. Furthermore, the mandibular foramen can be easily identified on CBCT images, and is therefore a clearly reproducible and visible landmark.
- **Landmark 2,** or the mandibular ramus, where the measurement level touches the anterior border of the ascending ramus. The ascending ramus of the mandible has been used by studies on M3 impaction in the mandible (Bjork 1956, Ganss 1993) as it represents a physical barrier for proper eruption of the M_3. This landmark point will be here on referred to as ramus.

A



B

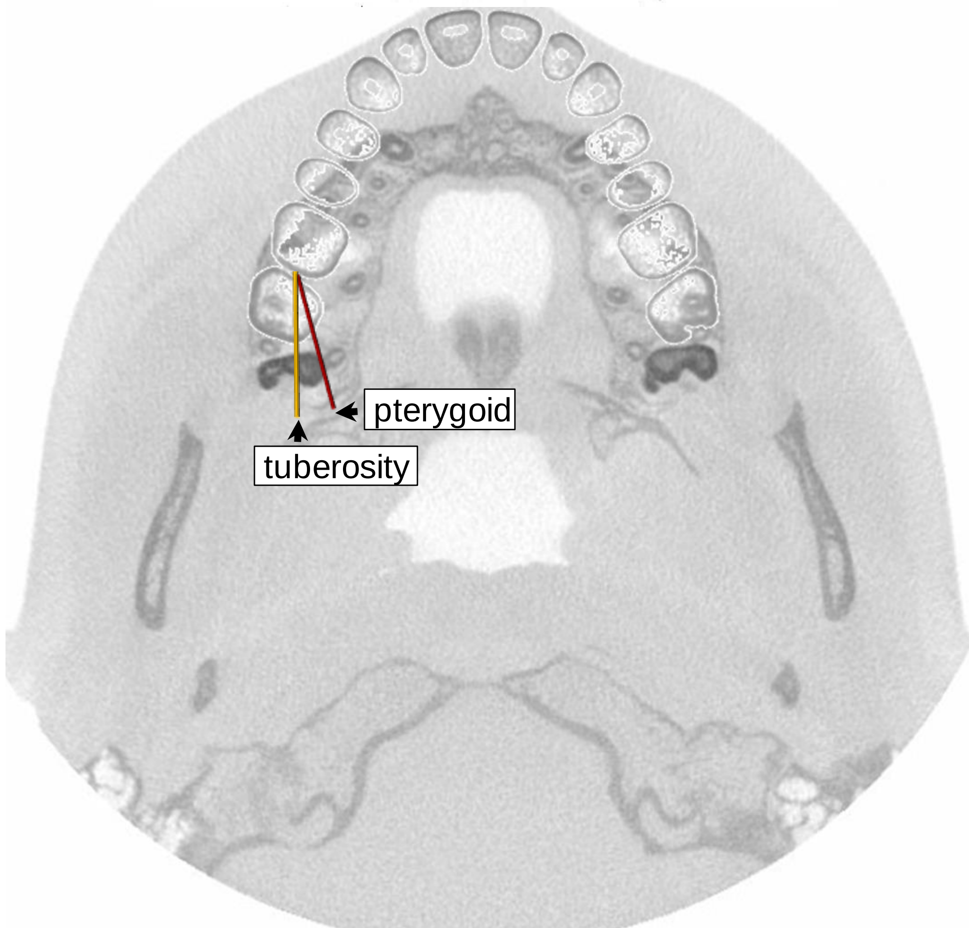


Figure 16. Landmarks in the maxilla.
The jaw space available to accommodate the development and eruption of the M3 was measured from the M1 and M2 to both landmarks shown above. Landmarks **(p)** or **pterygoid**; and **(t)** or **tuberosity** are illustrated in (**A**), a figure of the maxilla; and in (**B**), an actual CBCT image. Top image: adapted from Sobotta (2006); Bottom image: original.

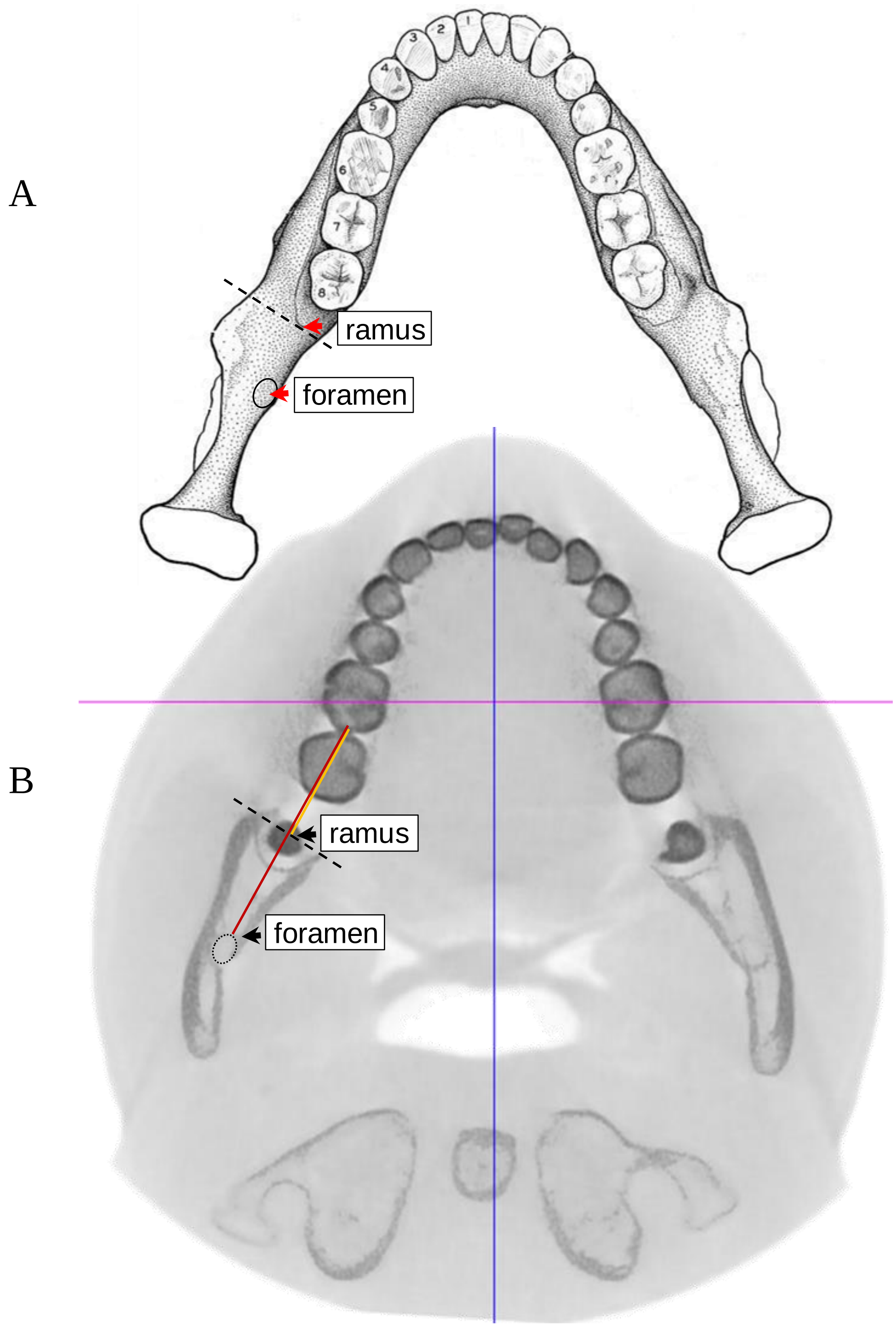


Figure 17. Landmarks in the mandible.
The jaw space available to accommodate the development and eruption of the M3 was measured from the M1 and M2 to both landmarks shown above. Landmarks **(r)** or **ramus**; and **(f)** or **foramen** are illustrated in (**A**), a figure of the mandible; and in (**B**), an actual CBCT image. Top image: adapted from University (2014). Bottom image: original.

3.7 Measurement Design for Maxilla and Mandible

To estimate the amount of space in the jaws available for the development and eruption of the M3, the distance between the M1 and/or the M2 and the landmarks 1 and 2 in both jaws was measured using the method described in section 3.5. Visual details of each measurement is illustrated in Figure 18 and Figure 19. Because M2s are still erupting and forming in most subjects aged eight to twelve years, the space for M3 eruption was measured from the M1, while in subjects aged 17 to 24 years this space was measured from both the M1 and the M2.

In the **maxilla** (Figure 18), two measurements were collected, as follows:

Measurement 1: the distance between the landmark one (pterygoid) and the:

- M1, here on referred to as **M^1-pterygoid**, or the
- M2, here on referred to as **M^2-pterygoid**.

Measurement 2: the distance between the landmark two (tuberosity) and the:

- M1, here on referred to as **M^1-tuberosity**, or the
- M2, here on referred to as **M^2-tuberosity**.

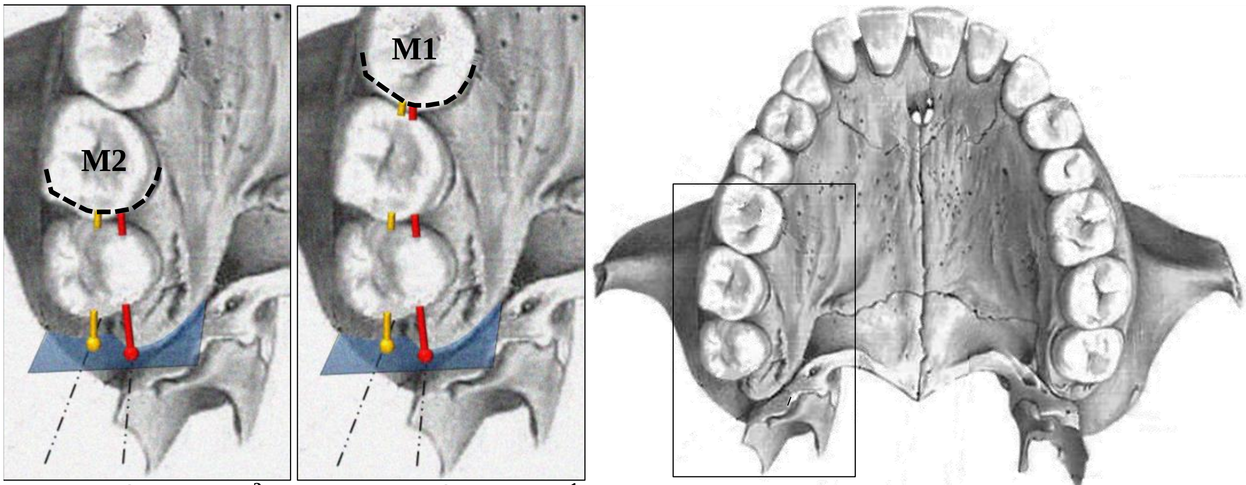
In the **mandible** (Figure 19), two measurements were collected, as follows:

Measurement 1: the distance between the landmark one (foramen) and the:

- M1, here on referred to as **M_1-foramen**, or the
- M2, here on referred to as **M_2-foramen**.

Measurement 2: the distance between the landmark two (ramus) and the:

- M1, here on referred to as **M_1-ramus**, or the
- M2, here on referred to as **M_2-ramus**.



Measures from the M^2
Subjects aged
17-24 years

Measures from the M^1
Subjects aged
8-12 and 17-24 year

■ **Measurement 1**: Distance between the distal surface of the M^1 or the M^2 and the landmark one (the point where the pterygoid process fuses with the maxillary bone, as observed on CBCT images).

■ **Measurement 2**: Distance between the distal surface of the M^1 or the M^2 and the landmark two (the distal-most point of the maxillary tuberosity convexity, as observed on CBCT images).

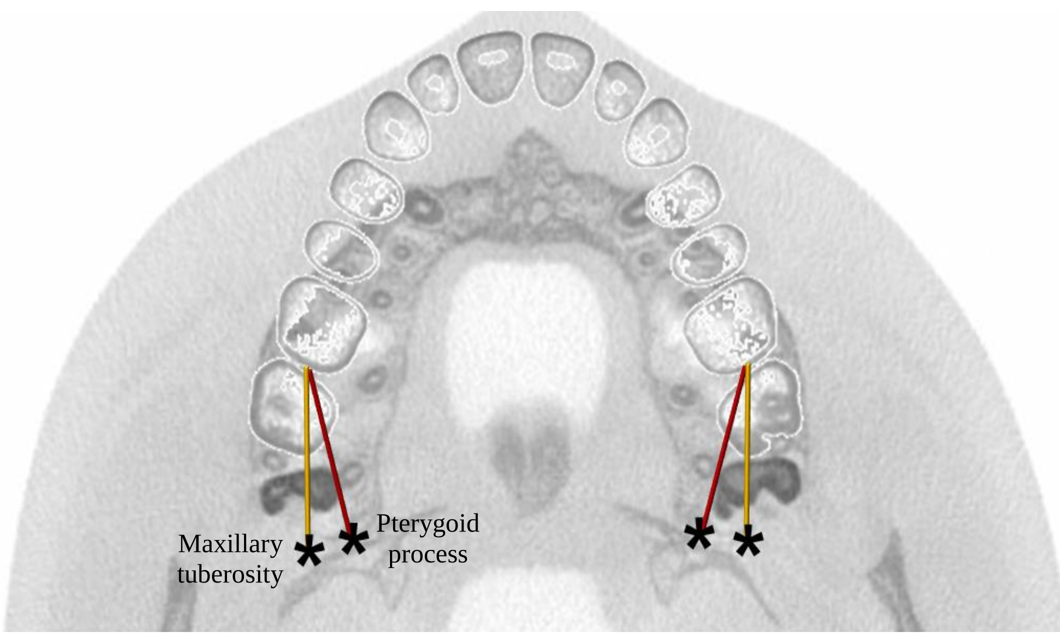
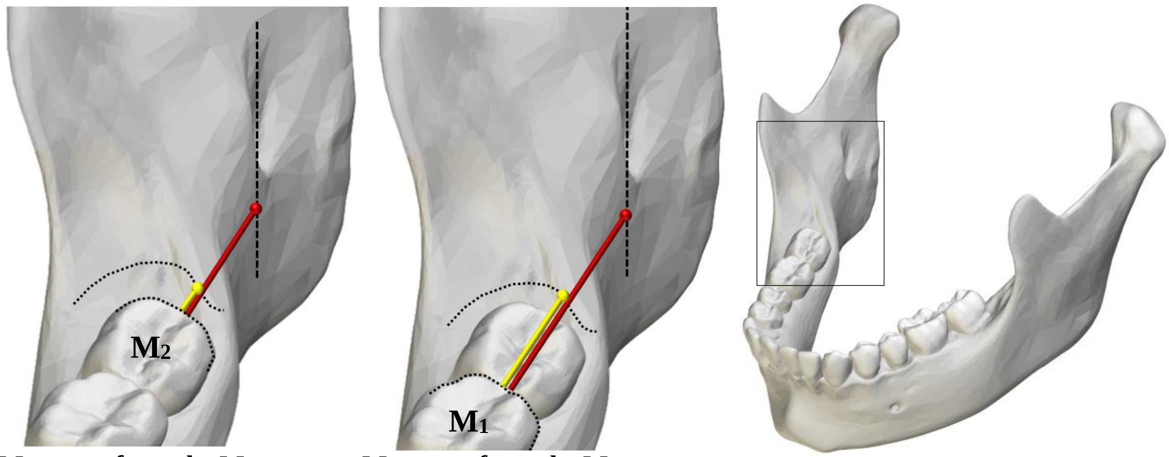


Figure 18. Measurements in the maxilla.
The amount of space to accommodate the development and eruption of the M^3 was measured in the maxilla as shown in the figures above. M^1: First molar; M^2: Second molar; M^3: Third molar. Top image: adapted from Sobotta (2006); bottom image: original.



Measures from the M_2
Individuals aged
17-24 years

Measures from the M_1
Individuals aged
8-12 and 17-24 year

Measurement 1: Distance between the distal surface of the M_1 or the M_2 to the landmark one (the anterior margin of the mandibular foramen). Although the M_1 or the M_2 are not in the same plane as the foramen, the linear distance between these two structures can be measured by moving the axial plane upwards and downwards, as described on section 3.5 of this chapter.

Measurement 2: Distance between the distal surface of the M_1 or the M_2 to the landmark two (ascending ramus of the mandible, at the level where the axial plane (positioned at the measurement level) touches the ascending mandibular ramus (this level is represented in the figure above by the dotted line on the surface of the mandibular ramus)). This measurement is taken parallel to the measurement one.

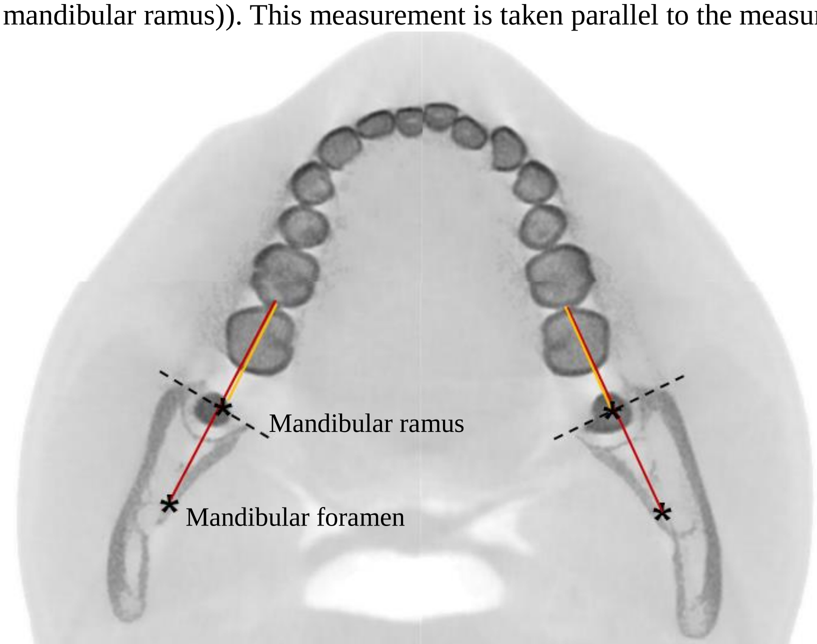


Figure 19. Measurements in the mandible.
The amount of space to accommodate the development and eruption of the M3 was measured in the mandible as shown in the figures above. M_1: First molar; M_2: Second molar; M_3: Third molar. Top image: adapted from 3DCadbrowser (2014); bottom image: original.

3.8 Methodology to Test Hypothesis I

Third molar impaction is observed when the amount of space in the jaws to accommodate the eruption of this tooth is reduced

Since M3 impaction can only be identified during the later stages of M3 formation, the group of subjects aged 17 to 24 years was studied to test if the amount of space in the RM region was reduced when this condition was present. These subjects were selected based on the criteria discussed on section 3.3 of this chapter. To address the present hypothesis, one hundred (100) M^3 and one hundred and six (106) M_3 of seventy-six subjects aged 17 to 24 years were studied on CBCT images, accounting for a total of two hundred and six (206) teeth studied (Table 1). The amount of space in the jaws distal to the M1 and the M2 was measured according to the methodology discussed in the sections 3.5, 3.6, and 3.7. Due to the distinct morphological characteristics of the maxilla and the mandible, they were studied independently and two sub-groups were created based on the impaction status of the M3: an **impacted sub-group,** and a **non-impacted sub-group**. The prevalence of M3 impaction as well as the number of M3s included in each of the above mentioned sub-groups is given in Table 5 (page 62).

Unerupted and partially erupted M3s with severe tilts were included in the impacted sub-group while those holding an erupting position vertically parallel to adjacent molars were included in the non-impacted sub-group. The amount of space in the RM region of a dental arch quadrant (e.g right or left) of subjects included in the non-impacted and impacted sub-groups were compared using independent sample t-test. Since it is possible that the same subject has M3s of distinct impaction status in opposite quadrants (e.g. right vs. left), statistical analyses were focused on quadrants (not on subjects). Therefore, results for both the right and the left quadrants are given independently from each other. The level of significance adopted was 5%.

3.9 Methodology to Test Hypothesis II

Delayed third molar mineralization is observed when a reduced amount of space in the jaws and impaction of this tooth are present

A total of 486 dental arch quadrants (of 127 subjects aged eight to twelve years (Table 1) were included in this test based on the criteria discussed on section 3.3 and the M-D length of the space between the M1 and the landmarks established at the posterior region of the maxilla and the mandible was measured. Two hundred and forty six (246) maxillary quadrants and two hundred and forty (240) mandibular quadrants met the established inclusion criteria and were studied for this test. Due to the distinct morphological characteristics of the maxilla and the mandible, they were studied independently. Following the measurements, the M3 mineralization status was studied and classified according to seven distinct stages of mineralization, adapted from the classification proposed by Dermijian and colleagues (1973) (Figure 20). **This classification system organizes the mineralization process of the M3 in seven distinct stages that can be identified with great accuracy on CBCT images**. However, for the purposes of data analysis, the seven stages were organized into four major categories:

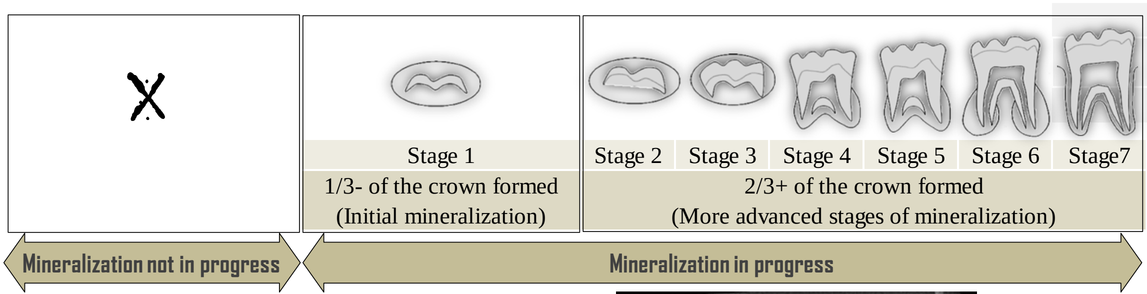
- **Mineralization not in progress**: No visible sign of M3 mineralization.
- **Mineralization in progress**: Includes cases of visible M3 mineralization, regardless of the stage of mineralization.
- **Initial mineralization**: Includes only those M3s initiating mineralization and with 1/3 or less of their crowns formed.
- **Advanced mineralization**: Includes only those M3s in relatively more advanced stages of mineralization, with at least 2/3 of their crowns formed.

The mean amount of space distal to the M1 available in the right quadrant of the dental arches of same age subjects were compared using independent sample t-test to identify if the amount of space available to accommodate the M3 formation differed significantly between the categories below. The same methodology was applied to the left quadrant of these subjects so that the results found on the right quadrant could be confirmed.

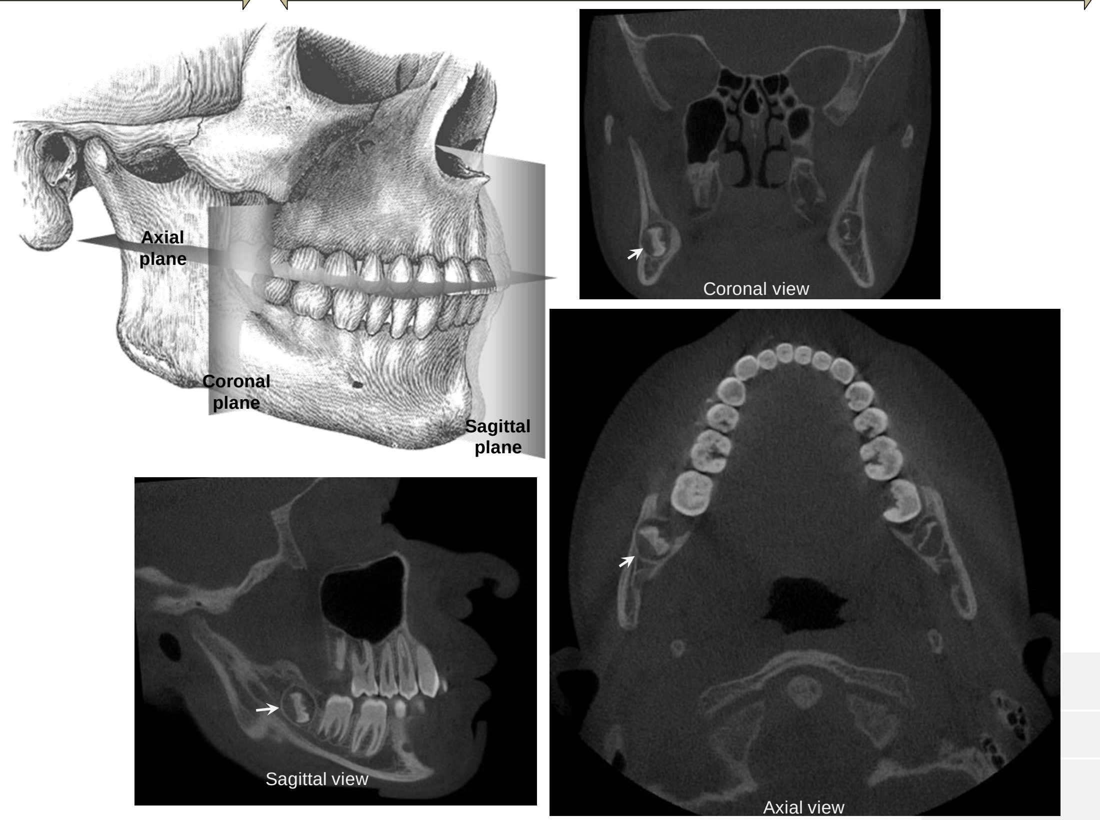
- **"Mineralization not in progress" vs. "mineralization in progress".** This test aims to identify if the amount of space at the posterior region of the jaws is significantly reduced in the presence of a late onset of M3 mineralization (e.g., when M3 mineralization is still not in progress);
- **"Initial mineralization" vs. "advanced mineralization".** This test aims to identify if the amount of space at the posterior region of the jaws is significantly reduced in the presence a delayed progress of M3 mineralization (e.g., when M3 mineralization is still in its initial stages. That is, when only 1/3 or less of the M3's crown has formed).

The present hypothesis also tests if delays in the M3 mineralization occur when this tooth is impacted. Since M3 impaction cannot be identified among those patients aged eight to twelve years, data collected from the subjects aged 17 to 24 years were also analyzed to test hypothesis I. One hundred (100) M^{3s} and one hundred and six (106) M_{3s} of seventy-six (76) subjects were therefore studied here and two sub-groups were created based on the impaction status of the M3: an **impacted** sub-group, and a **non-impacted** sub-group**.** The degree of M3 mineralization (Figure 20) was compared between the impacted and non-impacted sub-groups. Because tooth mineralization is classified according to a descriptive scale (e.g. non-parametric), Mann-Whitney tests were used for the above comparisons. The level of significance for this test was 5%.

A



B



Stage 1. First third of the tooth crown formed.
Stage 2. Second third of the tooth crown formed.
Stage 3. Last third of the tooth crown formed.
Stage 4. First third of roots formed.
Stage 5. Second third of roots formed.
Stage 6. Last third of roots formed. Apex open.
Stage 7. Roots formed and apex closed.

Figure 20. The tooth mineralization stages.

A. The mineralization process of molars was organized into seven distinct stages. The tooth mineralization classification used in this study was adapted from the system proposed by Dermijian et. al (Demirjian A, 1973).

B. The multi-angle views of CBCT images allow an accurate identification of the stage of M3 mineralization. Image a: Araújo (2010). Image b: Gray (1918). CBCT images shown here are original.

3.10 Methodology to Test Hypothesis III

Third molar impaction is observed in the presence of premolar and molar crowns of increased mesiodistal width

Fifty-eight subjects (thirty-five females and twenty-three males) were selected for this test (and also for the tests addressed by hypothesis IV) from the group of seventy-six subjects aged 17 to 24 years (Table 4). In addition to the selection criteria discussed on section 3.3 of this chapter, only subjects who had M3s of same impaction status in both the right and left quadrants of a dental arch were studied here – while subjects with only one M3 per dental arch were excluded from this test (due the impossibility to determine if the absent M3 was extracted or naturally absent). This measure allowed tooth dimensions to be determined in the total presence or absence of M3 impaction. Due to the distinct morphological characteristics of the maxilla and the mandible, they were studied independently and two sub-groups of subjects were created according to the M3 impaction status: **impacted**, and **non-impacted**.

Measurement tools of the iCAT software were used to measure the M-D width of all premolars (PM1, PM2) and molars (M1, M2, and M3). For that to be done, the axial plane of each CBCT image was positioned parallel to the occlusal plane of the dental arch under investigation and at the superior-inferior level which coincided with the interproximal contact point[10] of teeth, such that the maximum M-D crown width of premolars and molars could be observed (Figure 21). The size of each tooth in the right and left quadrants of each subject were calculated to produce an average, which was compared between the impacted and non-impacted sub-groups using independent samples t-tests to determine if each tooth studied had a larger crown in the presence of M3 impaction. The level of significance used was 5%.

[10] Refers to the area of two adjoining teeth that are aligned in the dental arch, where they touch each other.

Group of Subjects	Age range (years)	Sex				Maxilla				Mandible				Total	
		Female	Male	Total		Right	Left	Total		Right	Left	Total			
Group I	8-12	72	55	**127**	Subjects	124	122	**246**	Quadrants	120	120	**240**	Quadrants	486	Quadrants
Group II	17-24	39	37	**76**	Subjects	48	52	**100**	Quadrants	52	54	**106**	Quadrants	206	Quadrants
		35	23	**58**	Subjects were selected (out of 76)										
		19	19			**38**	of these subjects had both right and left **M^3s**.			**43**	of these subjects had both right and left **M_3s**.				
		22	21												
						13	had no impacted M^3s.			10	had no impacted M^3s.				
						25	had both M^3s impacted.			33	had both M_3s impacted.				

Table 4. Additional inclusion criteria for hypotheses III and IV.
Only subjects who had M3s of same impaction status in both the right and left quadrants of their maxillary or mandibular dental arches were studied to test the questions addressed by hypotheses III and IV. Therefore, 58 subjects were selected out of the 76 subjects included in group II. M^3: maxillary third molar; M_3: mandibular third molar.

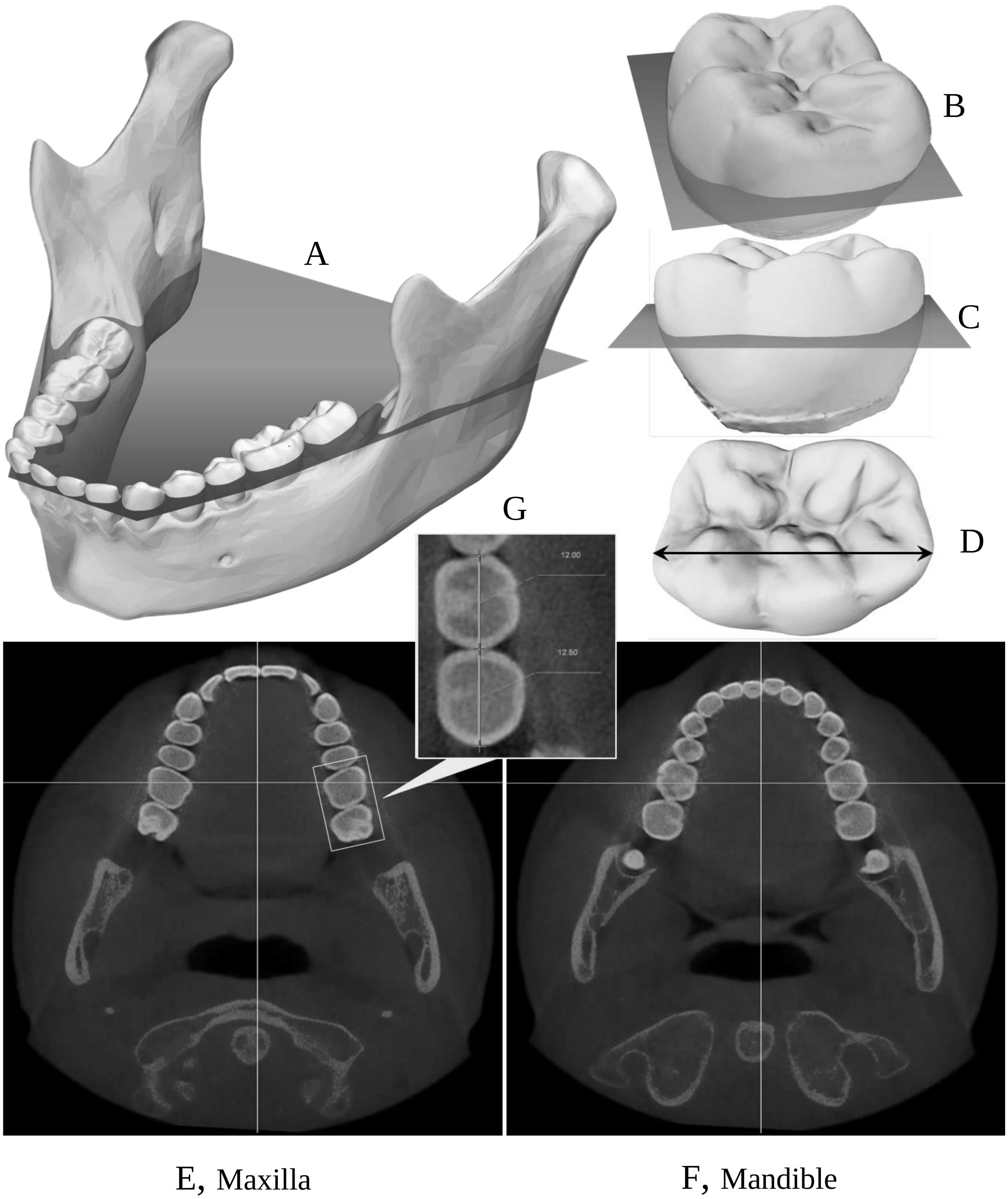


Figure 21. Tooth crown measurements.
The axial anatomical plane is positioned parallel to the occlusal plane of the dental arch under investigation (**A**) and at the superior-inferior level that corresponds to the level of the interproximal contact areas of premolars and molars (**B** and **C**). At this level, CBCT images generate axial views (**E** and **F**) that allow the observation and measurement of the maximum M-D widths of these teeth (**D** and **G**). Images A, B, C, D: 3DCadbrowser (2014). Images E, F, and G: Original.

3.11 Methodology to Test Hypothesis IV

Third molar impaction is observed in patients with dental arches of reduced anterior-posterior and lateral-lateral dimensions

Fifty-eight subjects (thirty-five females and twenty-three males) were selected for this test from the group of seventy-six subjects aged 17 to 24 years (Table 4). As also done to test hypothesis III, only subjects who had M3s of same impaction status in both the right and left quadrants of a dental arch were studied here. This measure allowed the dental arch dimensions to be determined in the total presence or absence of M3 impaction. Due to the distinct morphological characteristics of the maxilla and the mandible, they were studied independently and two sub-groups of subjects were created according to the impaction status of the M3: an **impacted** sub-group, and a **non-impacted** sub-group to serve as the control group. To guide the measurements, the tip of the buccal[11] cusps of all teeth (except the M3) was identified (Figure 22) and the dimensions of the maxillary and mandibular dental arches were obtained by measuring:

(1) The distance between the tips of the bucco-distal cups of the M2s on both quadrants of the same arch in order to obtain the width of this arch, hereon referred to as **W**.

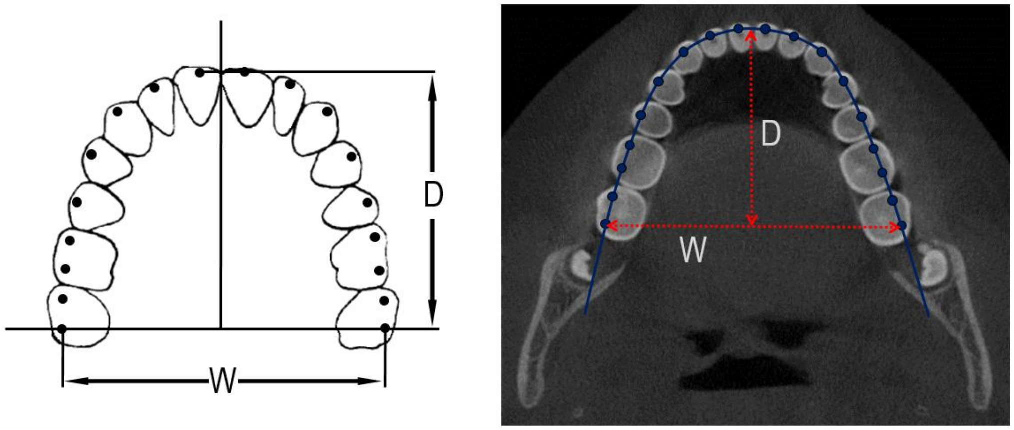
(2) On the anatomical midline, the distance between the edges of the central incisors and the line W. This measurement represents the depth of the dental arch, hereon referred to as **D**.

[11] Buccal: Refers to side of a tooth facing the cheek or lip.

Maxillary and mandibular arch dimensions were compared between the **impacted** and **non-impacted** sub-groups using independent sample t-tests to determine if, at the 5% level of significance, dental arches with reduced dimensions are seen in the presence of M3 impaction.

In addition, due to the suggestions that dental crowding is more evident in subjects with M3 impaction (Ng 1986), the presence of dental crowding, as visible on CBCT images, was also recorded in the impacted and non-impacted sub-groups to complementarily test if dental crowding is more commonly observed among subjects with M3 impaction.

A



B

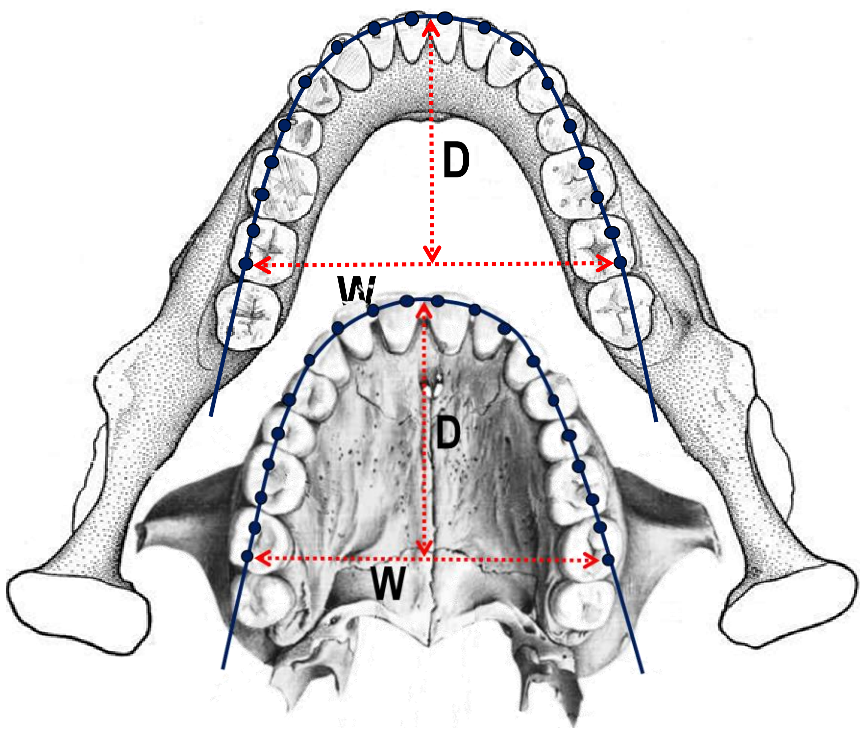


Figure 22. Dental arch measurements.
A curve passing through the tip of the buccal cusps of all teeth (except the M3) was drawn. **W** represents the distance between the tips of the bucco-distal cups of the M2s on both sides of the arch. **D** represents the distance between the central incisors and a posterior line defined by W.
A. Shows schematically how measurements were taken on CBCT images.
B. Illustrates how measurement standards apply for both the maxilla and the mandible.
Image A: on the left, from Braun (1996); on the right, Original.
Image B: mandible (University 2014); maxilla (Sobotta 2006).

CHAPTER 4
RESULTS

4.1 Hypothesis I: Findings

4.1.1 Prevalence of third molar impaction in the population studied

One hundred (100) M^{3s} and one hundred and six (106) M_{3s} of seventy-six (76) subjects aged 17 to 24 years were studied to test the hypothesis I. According to the definition of dental impaction adopted by the present project, 64% of the M^{3s} and 73% of the M_{3s} studied were impacted respectively (Table 5). Despite of a tendency for a higher prevalence of M3 impaction in the maxilla versus the mandible, these differences were not statistically significant (Chi-Square, p-value 0.29). Therefore, based on these results, **it is not possible to affirm that the prevalence of M3 impaction was higher in the mandible**. In addition, 69% of the female subjects studied had M3 impaction, with the same prevalence (69%) found among male subjects. (Table 5).

Group of Subjects	Age (years)	Sex				Maxilla				Mandible				Total	
		Female	Male	Total		Righ	Left	Total		Right	Left	Total			
Group I	8-12	72	55	**127**	Subjects	124	122	**246**	Quadrants	120	120	**240**	Quadrants	486	Quadrants
Group II	17-24	39	37	**76**	Subjects	48	52	**100**	Quadrants	52	54	**106**	Quadrants	206	Quadrants

A

	Maxilla			%	Mandible			%	Total
Non-impacted	17	19	**36**	36%	15	14	**29**	27%	**65**
Impacted	31	33	**64**	64%	37	40	**77**	73%	**141**
			100				**106**		

B

	Female	%	Male	%	Total
Non-impacted	32	31%	33	31%	**65**
Impacted	70	69%	71	69%	**141**
	102		**104**		

Table 5. Prevalence of third molar impaction in subjects aged 17-24 years.

A. Prevalence of M3 impaction in the maxilla and mandible.
B. Prevalence of M3 impaction in females and males.

4.1.2 The amount of space to accommodate the eruption of the third molar was reduced in both jaws when impaction was present

CBCT images of one hundred (100) M^{3s} and one hundred and six (106) M_{3s} of 76 subjects aged 17 to 24 years were studied to test this hypothesis. M3s were classified in two distinct sub-groups according to their impaction status: impacted and non-impacted sub-groups. In the **maxilla**, results for the entire group of subjects aged 17 to 24 years showed that these subjects had less space between either the M^1 or the M^2 and the pterygoid or the tuberosity when M3 impaction was present (all p-values $\leq .04$) (Table 6). These results shows that the amount of space to accommodate the eruption of the M3 in the maxilla was significantly reduced when this tooth was impacted, compared to when impaction was absent. In the **mandible**, similarly, results for the entire group of patients aged 17 to 24 years showed that the distance between either the M_1 or M_2 to the foramen or the ramus was significantly reduced in the impacted sub-group, compared to the non-impacted one (all p-values $\leq .01$) (Table 7). Similarly to what was observed in the maxilla, such results showed that the amount of space to accommodate the eruption of the M3 in the mandible was significantly reduced when this tooth was impacted, compared to when impaction was absent. In summary, the present 3D-based **results show that shortages of the space between the M1 or M2 and each of the established landmarks were reliably associated with presence of impaction in both jaws**.

Maxilla - amount of space (mm) in the RM region vs. impaction status of the M3.

		Non-Impacted			Impacted			d	Sig.
		N	Mean	SD	N	Mean	SD		
Quadrant	**Measurement**								
Right	M1-pterygoid	17	19.30	2.7	31	17.55	2.1	1.8	.01
	M1-tuberosity	17	18.39	2.9	31	16.92	2.1	1.5	.03
	M2-pterygoid	17	10.50	2.1	31	8.78	2.0	1.7	< .01
	M2-tuberosity	17	9.00	2.4	31	7.58	2.0	0.4	.02
Left	M1-pterygoid	19	18.91	2.2	33	17.20	1.9	1.7	< .01
	M1-tuberosity	19	17.60	2.1	33	16.55	2.1	1.1	.04
	M2-pterygoid	19	10.38	2.1	33	8.52	1.9	1.9	< .01
	M2-tuberosity	19	8.53	2.2	33	7.38	1.9	1.1	.03

Table 6. Summary of measurements from the M1 and M2 to each maxillary landmark.

Results of statistical analysis using independent sample t-test - Subjects aged 17 to 24 years. Level of significance adopted: 5%.

N: Number of quadrants studied.
SD: Standard deviation.
d: Difference of means between sub-groups.

Mandible - amount of space (mm) in the RM region vs. impaction status of the M3.

		Non-Impacted			Impacted			d	Sig.
		N	Mean	SD	N	Mean	SD		
Quadrant	**Measurement**								
Right	M1-foramen	15	34.47	2.6	37	32.17	3.0	2.4	.01
	M1-ramus	15	21.93	2.1	37	18.06	1.9	3.9	< .01
	M2-foramen	15	23.88	2.3	37	20.69	2.9	3.2	< .01
	M2-ramus	15	11.77	2.0	37	7.44	1.9	4.4	< .01
Left	M1-foramen	14	35.78	2.1	40	31.13	3.4	4.7	< .01
	M1-ramus	14	21.35	3.1	40	17.92	2.8	3.4	< .01
	M2-foramen	14	24.91	1.9	40	20.26	2.6	4.6	< .01
	M2-ramus	14	11.60	2.5	40	6.93	2.1	4.7	< .01

Table 7. Summary of measurements from the M1 and M2 to each mandibular landmark.
Results of statistical analysis using independent sample t-test - Subjects aged 17 to 24 years. Level of significance adopted: 5%.

N: Number of quadrants studied.
SD: Standard deviation.
d: Difference of means between sub-groups.

4.2 Hypothesis II: Findings

4.2.1 The proportion of third molars initiating mineralization at age nine was greater than in ages eight, ten, eleven, or twelve

In the **maxilla**, at age eight 76% (19 out 25) of the quadrants studied did not have M3s yet mineralizing. At this same age, no cases of M3s with 2/3 or more of their crowns formed were observed. At age twelve 66% (63 out of 96) of the quadrants studied had M3s with at least 2/3 or more of their crowns formed while only 19% of the quadrants (18 out 96) had M3s initiating mineralization. That is, M3s not yet mineralizing were more common at age eight while at age twelve most M3s were already in more advanced stages of mineralization (Table 8). This trend was also observed in the **mandible** where at age eight 57% (13 out of 23) of the quadrants studied had M3s that were not yet mineralizing, while in only 4% (1 out of 23) of these quadrants M3s were in more advanced stages of mineralization. At age twelve 67% (61 out of 91) of the quadrants studied had M3s with at least 2/3 or more of their crowns formed while only 10% of these quadrants (9 out 91) had M3s that were not yet mineralizing. These results show that, in both the maxilla and the mandible, most M3s at age eight had not yet begun mineralization while at age twelve most of these teeth had already 2/3 or more of their crowns mineralized (Table 8). In addition, these results showed that **the proportion of M^{3s} initiating mineralization at age nine was greater than in ages eight, ten, eleven, or twelve** (Table 8). Only one case of advanced M3 mineralization was observed among subjects aged eight or nine years in each of the jaws. Tables reporting full details regarding the status of mineralization of M3s are given in Appendix D.

Group of Subjects	Age range (years)	Sex				Maxilla				Mandible				Total
		Female	Male	Total		Right	Left	Total		Right	Left	Total		
Group I	8-12	72	55	**127**	Subjects	124	122	**246**	Quadrants	120	120	**240**	Quadrants	486 Quadrants
Group II	17-24	39	37	**76**	Subjects	48	52	**100**	Quadrants	52	54	**106**	Quadrants	206 Quadrants

Maxilla

Age	**Eight**		**Nine**		**Ten**		**Eleven**		**Twelve**		
Mineralization not in progress	19	76%	8	37%	13	30%	18	30%	18	19%	
Initial mineralization	6	24%	13	59%	15	34%	7	12%	15	15%	
Advanced mineralization	0	0%	1	4%	16	36%	34	58%	63	66%	
	25		22		44		59		96		246

Mandible

Age	**Eight**		**Nine**		**Ten**		**Eleven**		**Twelve**		
Mineralization not in progress	13	57%	12	46%	9	21%	13	23%	9	10%	
Initial mineralization	9	39%	14	54%	22	51%	18	32%	21	23%	
Advanced mineralization	1	4%	0	0%	12	28%	26	45%	61	67%	
	23		26		43		57		91		240

Table 8. Third molar mineralization in subjects aged 8-12 years.
Distribution of M3 mineralization according to the age and the jaw studied.

4.2.2 The amount of space in the jaws was reduced when third molar mineralization initiated later

In regards to measurements **M^1-pterygoid** and **M^1-tuberosity**, in patients of the same age and at the level of 5% of significance, **a reduced amount of space was found in quadrants where a delayed onset of M3 mineralization was observed** (e.g. quadrants where M3 mineralization had not yet initiated) compared to when mineralization of this tooth was already in progress. Results for this test were especially significant within ages with a comparable number of patients in both groups (e.g. group 'mineralization not in progress', and group 'mineralization in progress') or when patients of all ages from eight to twelve are grouped ($p. < .01$) (Table 9-10). As for measurements **M_1-foramen** and **M_1-ramus**, in patients of same age and at the level of 5% of significance, **a reduced amount of space was found in quadrants where a delayed onset of M3 mineralization was observed** compared to when mineralization of this tooth was already in progress. Similarly to what was observed in the maxilla, results for this test were especially significant within ages with a comparable number of patients in both groups or when patients of all ages from eight to twelve are grouped ($p. < .01$) (Table 11-12). In summary, **a delayed onset of M3 mineralization was observed in both jaws when a reduced amount of space to accommodate this tooth development was present.**

Maxilla - amount of space (mm) in the RM region vs. M3 mineralization status.

		Mineralization Not in progress			Mineralization In progress				
		N	Mean	SD	N	Mean	SD	D	Sig.
Quadrant	**Age**								
Right	8	10	7.66	1.6	3	8.52	1.5	0.9	.21
	9	4	8.21	1.3	7	8.93	0.4	0.7	.10
	10	6	8.37	1.7	16	10.79	2.8	2.4	.03
	11	8	10.60	2.4	22	12.45	2.4	1.8	.03
	12	8	12.87	2.6	40	14.43	2.8	0.2	.08
	All	36	9.65	2.8	88	12.63	3.2	3.1	< .01
Left	8	9	8.06	1.2	3	8.56	1.9	0.5	.30
	9	4	8.02	0.7	7	8.88	0.4	0.9	.01
	10	7	7.73	3.3	15	11.34	2.2	3.6	< .01
	11	10	10.41	2.2	19	12.67	2.5	2.3	.01
	12	10	12.46	2.6	38	14.15	2.6	1.6	.08
	All	40	9.82	2.6	82	12.78	3.0	3.0	< .01

Table 9. Measurement M1-pterygoid in the presence and absence of M3 mineralization.

Results of statistical analysis using independent sample t-test - Subjects aged 8 to 12 years. Level of significance adopted: 5%.

N: Number of quadrants studied.
SD: Standard deviation.
d: Difference of means between sub-groups.

Maxilla - amount of space (mm) in the RM region vs. M3 mineralization status.

		Mineralization Not in progress			Mineralization In progress				
		N	Mean	SD	N	Mean	SD	D	Sig.
Quadrant	**Age**								
Right	8	10	8.04	1.1	3	8.63	1.1	0.6	.21
	9	4	8.23	0.9	7	8.63	0.3	0.4	.15
	10	6	7.99	1.5	16	10.30	3.0	2.3	.04
	11	8	10.27	1.9	22	12.71	2.3	2.4	.01
	12	8	11.88	1.7	40	14.27	2.6	2.4	.01
	All	36	9.40	2.1	88	12.51	3.2	3.1	< .01
Left	8	9	8.18	1.2	3	8.41	1.4	0.3	.39
	9	4	8.34	0.6	7	8.66	0.4	0.3	.15
	10	7	8.05	3.4	15	11.01	2.1	3.0	.01
	11	10	10.25	2.1	19	12.42	2.5	2.2	.01
	12	10	11.94	1.8	38	13.87	2.7	2.0	.04
	All	40	9.78	2.1	82	12.55	3.1	2.7	< .01

Table 10. Measurement M1-tuberosity in the presence and absence of M3 mineralization.

Results of statistical analysis using independent sample t-test - Subjects aged 8 to 12 years. Level of significance adopted: 5%.

sN: Number of quadrants studied.

SD: Standard deviation.

d: Difference of means between sub-groups.

Mandible - amount of space (mm) in the RM region vs. M3 mineralization status.

		Mineralization Not in progress			**Mineralization In progress**				
		N	Mean	SD	N	Mean	SD	D	Sig.
Quadrant	**Age**								
Right	8	7	22.84	0.6	5	18.66	2.9	4.1	.45
	9	6	23.48	1.1	7	24.47	1.2	1.0	.07
	10	5	23.64	1.7	16	25.38	2.3	1.8	.07
	11	5	25.34	2.2	23	26.85	3.0	1.5	.15
	12	5	26.44	2.0	41	29.33	3.1	2.9	.02
	All	28	24.21	2.0	92	27.31	3.4	3.1	< .01
Left	8	6	22.51	1.0	5	23.83	1.9	1.3	.09
	9	6	23.00	0.8	7	24.00	1.0	1.0	.04
	10	4	23.37	1.5	18	25.21	2.3	1.8	.07
	11	8	23.65	2.5	21	26.58	3.5	3.0	.02
	12	4	26.90	1.7	41	29.54	3.3	2.6	.06
	All	28	23.69	2.1	92	27.29	3.6	3.6	< .01

Table 11. Measurement M1-foramen in the presence and absence of M3 mineralization.
Results of statistical analysis using independent sample t-test - Subjects aged 8 to 12 years. Level of significance adopted: 5%.

N: Number of quadrants studied.
SD: Standard deviation.
d: Difference of means between sub-groups.

Mandible - amount of space (mm) in the RM region vs. M3 mineralization status.

		Mineralization Not in progress			**Mineralization In progress**				
		N	Mean	SD	N	Mean	SD	D	Sig.
Quadrant	**Age**								
Right	8	7	9.31	1.9	5	5.01	2.2	4.3	.15
	9	6	7.05	1.0	7	9.43	1.0	2.4	< .01
	10	5	8.98	2.2	16	11.17	2.6	2.2	.05
	11	5	11.88	2.3	23	12.47	2.4	0.6	.31
	12	5	13.97	3.4	41	14.33	2.5	0.3	.39
	All	28	10.06	3.2	92	12.60	3.0	2.6	< .01
Left	8	6	8.10	2.1	5	8.03	0.9	0.1	.48
	9	6	7.78	0.6	7	9.15	1.1	1.3	.01
	10	4	9.17	1.8	18	11.01	2.3	1.8	.07
	11	8	10.49	2.4	21	13.32	4.3	2.8	.04
	12	4	12.30	3.9	41	15.17	2.3	2.9	.02
	All	28	9.47	2.6	92	13.09	3.6	3.6	< .01

Table 12. Measurement M1-ramus in the presence and absence of M3 mineralization.

Results of statistical analysis using independent sample t-test - Subjects aged 8 to 12 years. Level of significance adopted: 5%.

N: Number of quadrants studied.

SD: Standard deviation.

d: Difference of means between sub-groups.

4.2.3 The amount of space in the jaws was also reduced when the progress of third molar mineralization was delayed

In regards to measurements **M1-pterygoid** and **M1-tuberosity**, in patients of same age and at the level of 5% of significance, **a reduced amount of space was found in maxillary quadrants where M3 mineralization was still initiating** (e.g. quadrants containing M3s with no more than 1/3 of their crowns mineralized) compared to when mineralization was more advanced (e.g. quadrants containing M3s with 2/3 or more of their crowns mineralized). Results for this test were especially significant within ages with a comparable number of patients in both groups (e.g. group 'initial mineralization', and group 'advanced mineralization') or when patients of all ages from eight to twelve are grouped ($p. < .01$) (Table 13-14). This result was not observed in patients aged eight and nine because an insufficient number of M3s in more advanced stages of formation were not present in these subjects.

As for measurements **M1-foramen** and **M1-ramus**, in patients of same age and at the level of 5% of significance, **a reduced amount of space was found in mandibular quadrants where M3 mineralization was still initiating** compared to when 2/3 or more of the M3 crowns were already mineralized. In the mandible, results for this test were especially significant within ages with a comparable number of patients in both groups (e.g. group 'initial mineralization', and group 'advanced mineralization') or when patients of all ages from eight to twelve are grouped ($p. < .01$) (Table 15-16). This result was not observed in patients aged eight and nine because an insufficient number of M3s in more advanced stages of formation were not present in these subjects. A summary of these results shows that **the amount of space to accommodate formation of the M3 was reduced in both jaws when the progress of M3 mineralization was delayed**.

Maxilla - amount of space (mm) in the RM region vs. M3 mineralization status.

		Initial Mineralization			Advanced mineralization				
		N	Mean	SD	N	Mean	SD	D	Sig.
Quadrant	**Age**								
Right	8	3	8.52	1.5	0	-	-	-	*
	9	7	8.93	0.4	0	-	-	-	*
	10	7	9.73	2.0	9	11.61	3.1	1.8	.09
	11	5	11.81	2.4	17	12.64	2.4	0.8	.25
	12	8	12.14	1.9	32	15.00	2.7	2.9	< .01
	All	30	10.41	2.2	58	13.78	3.0	3.3	< .01
Left	8	3	8.56	1.9	0	-	-	-	*
	9	6	8.85	0.5	1	-	-	-	*
	10	8	10.82	1.4	7	11.94	2.8	1.1	.17
	11	2	8.85	1.1	17	13.12	2.2	4.3	*
	12	7	12.51	1.8	31	14.90	2.6	2.4	.01
	All	26	10.41	2.1	56	13.88	2.7	3.4	< .01

Table 13. Measurement M1-pterygoid vs. the degree of M3 mineralization.

Results of statistical analysis using independent sample t-test - Subjects aged 8 to 12 years. Level of significance adopted: 5%.

N: Number of quadrants studied.
SD: Standard deviation.
d: Difference of means between sub-groups.
*: Statistical test not applied due to an insufficient number of cases.

Maxilla - amount of space (mm) in the RM region vs. M3 mineralization status.

		Initial Mineralization			**Advanced mineralization**				
		N	Mean	SD	N	Mean	SD	D	Sig.
Quadrant	**Age**								
Right	8	3	8.63	1.1	0	-	-	-	*
	9	7	8.63	0.3	0	-	-	-	*
	10	7	9.27	2.6	9	11.10	3.2	1.9	.12
	11	5	11.79	2.4	17	12.64	2.4	0.9	.16
	12	8	12.10	1.9	32	14.81	2.5	2.7	< .01
	All	30	10.23	2.4	58	13.70	2.9	3.5	< .01
Left	8	3	8.41	1.4	0	-	-	-	*
	9	6	8.60	0.4	1	9.06	-	-	*
	10	8	10.10	1.7	7	12.05	2.1	1.9	.04
	11	2	8.32	1.1	17	12.90	2.2	4.6	*
	12	7	11.78	1.3	31	14.82	2.6	3.1	< .01
	All	26	9.87	1.8	56	13.79	2.7	3.9	< .01

Table 14. Measurement M1-tuberosity vs. the degree of M3 mineralization.
Results of statistical analysis using independent sample t-test - Subjects aged 8 to 12 years. Level of significance adopted: 5%.

N: Number of quadrants studied.
SD: Standard deviation.
d: Difference of means between sub-groups.
*: Statistical test not applied due to an insufficient number of cases.

Mandible - amount of space (mm) in the RM region vs. M3 mineralization status.

		Initial Mineralization			Advanced mineralization				
		N	Mean	SD	N	Mean	SD	D	Sig.
Quadrant	**Age**								
Right	8	4	24.07	1.9	1	18.66	-	-	*
	9	7	24.47	1.2	0	-	-	-	*
	10	10	24.67	2.1	6	26.56	2.3	1.8	.06
	11	10	25.71	3.2	13	27.73	2.6	2.1	.05
	12	13	27.20	2.2	28	30.32	3.0	3.1	< .01
	All	44	25.57	2.5	48	28.90	3.4	3.3	< .01
Left	8	5	23.83	1.9	0	-	-	-	*
	9	7	24.00	1.0	0	-	-	-	*
	10	12	24.57	2.4	6	26.50	1.4	1.9	.05
	11	8	25.85	2.2	13	27.03	4.1	1.2	.23
	12	8	27.24	1.6	33	30.10	3.3	2.9	.01
	All	40	25.17	2.3	52	28.91	3.7	3.7	< .01

Table 15. Measurement M1-foramen vs. the degree of M3 mineralization.

Results of statistical analysis using independent sample t-test - Subjects aged 8 to 12 years. Level of significance adopted: 5%.

N: Number of quadrants studied.
SD: Standard deviation.
d: Difference of means between sub-groups.
*: Statistical test not applied due to an insufficient number of cases.

Mandible - amount of space (mm) in the RM region vs. M3 mineralization status.

		Initial Mineralization			**Advanced mineralization**				
		N	Mean	SD	N	Mean	SD	D	Sig.
Quadrant	**Age**								
Right	8	4	8.81	1.6	1	5.01	-	-	*
	9	7	9.43	1.0	0	-	-	-	*
	10	10	10.48	1.8	6	12.32	3.4	1.8	.09
	11	10	11.01	2.1	13	13.59	2.2	2.6	< .01
	12	13	12.81	2.1	28	15.03	2.3	2.2	< .01
	All	44	10.97	2.2	48	14.09	2.9	3.0	< .01
Left	8	5	8.03	0.9	0	-	-	-	*
	9	7	9.15	1.1	0	-	-	-	*
	10	12	10.57	1.9	6	11.89	2.8	1.3	.13
	11	8	11.81	1.8	13	14.25	5.1	2.4	.11
	12	8	14.35	0.7	33	15.37	2.5	1.1	.13
	All	40	11.01	2.5	52	14.69	3.5	3.7	< .01

Table 16. Measurement M1-ramus vs. the degree of M3 mineralization.

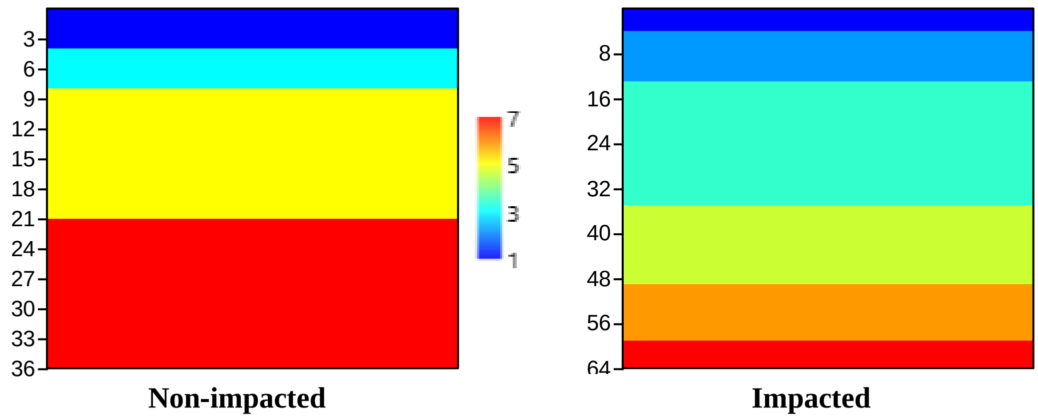
Results of statistical analysis using independent sample t-test - Subjects aged 8 to 12 years. Level of significance adopted: 5%.

N: Number of quadrants studied.
SD: Standard deviation.
d: Difference of means between sub-groups.
*: Statistical test not applied due to an insufficient number of cases.

4.2.4 Third molar mineralization was delayed in the presence of impaction

As discussed previously, since M3 impaction can only be detected in older subjects, the present test was performed using data collected from patients aged 17 to 24 years, and not from those aged eight to twelve years. For details regarding the incidence and distribution of M3 impaction according to the jaws among these subjects please refer to Table 5 (page 62). In regards to the degree of mineralization of the M3s studied, at the level of significance of 5%, **impacted M3s had their mineralization relatively delayed compared to non-impacted ones**. That is, maturation of impacted M3s was delayed compared to non-impacted ones. On a mineralization scale comprised of seven distinct stages, where 1 represents initial mineralization and 7 indicates that mineralization is completed, non-impacted M^{3s} and M_{3s} were approximately two stages more advanced compared to impacted ones (p. < .001 for both M^{3s} and M_{3s}) (Table 17-18). M3s were at comparable stages of mineralization regardless of sex (p .25) (Table 19).

A



Maxilla – Stage of M3 mineralization in the impacted and non-impacted sub-groups

B

	Non-impacted			Impacted				
	N	Mean stage	SD	N	Mean stage	SD	d	Sig.
Quadrant								
Right	17	6.2	1.3	31	4.5	1.3	0.0	< .001
Left	19	6.0	0.9	33	4.5	1.3	0.4	< .001

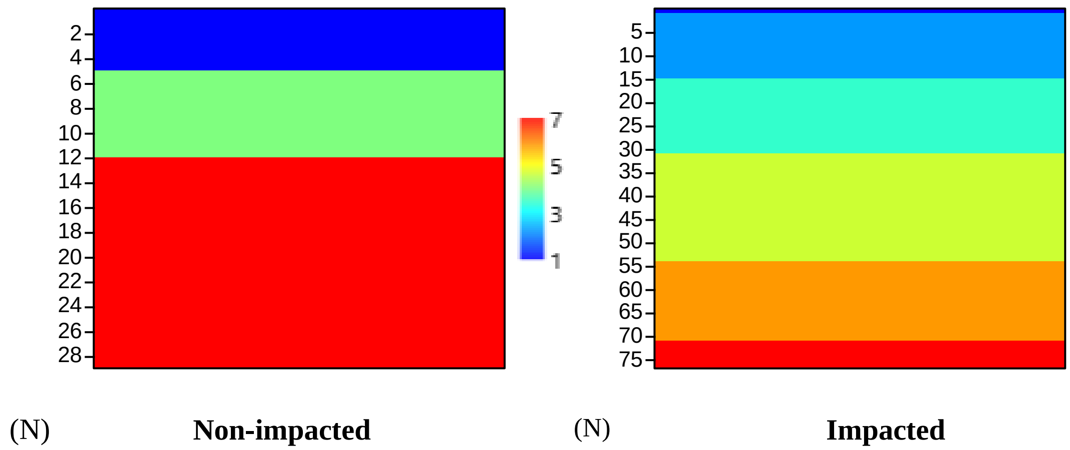
Table 17. Mineralization of non-impacted and impacted maxillary third molars.

A. Each line of the matrix plots above represents an individual M3. Each color represents a distinct stage of tooth mineralization (varying from 1 to 7). Both impacted and non-impacted sub-groups include M3s from right and left quadrants. Red colors suggest presence of more advanced stages of tooth mineralization.

B. Results of statistical analysis using Mann-Whitney test - Subjects aged 17 to 24 years. Mineralization of maxillary M3s is delayed if they are impacted. Level of significance: 5%.

N: Number of quadrants studied.
SD: Standard deviation.
d: Difference of means between sub-groups.

A



Mandible – Stage of M3 mineralization in the impacted and non-impacted sub-

B

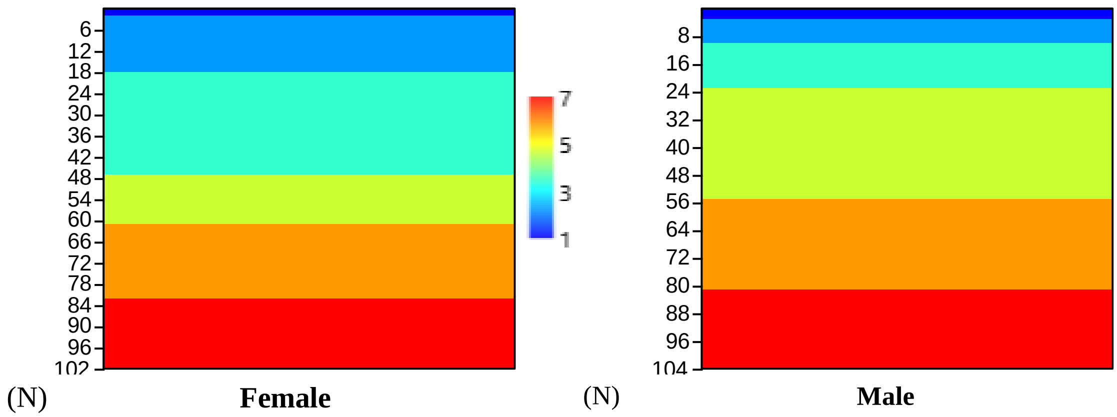
	Non-impacted			Impacted				
	N	Mean stage	SD	N	Mean stage	SD	d	Sig.
Quadrant								
Right	14	6.4	0.8	40	4.8	1.3	0.4	< .001
Left	15	6.5	0.7	37	4.8	1.2	0.5	< .001
	29							

Table 18. Mineralization of non-impacted and impacted mandibular third molars.

A. Each line of the matrix plots above represents an individual M3. Each color represents a distinct stage of tooth mineralization (varying from 1 to 7). Both impacted and non-impacted sub-groups include M3s from right and left quadrants. Red colors suggest presence of more advanced stages of tooth mineralization.

B. Results of statistical analysis using Mann-Whitney test - Subjects aged 17 to 24 years. Mineralization of mandibular M3s is delayed if they are impacted. Level of significance: 5%.

N: Number of quadrants studied.
SD: Standard deviation.
d: Difference of means between sub-groups.



Stage of M3 mineralization according to sex.

B

	Female			Male				
N	Mean stage	SD	N	Mean stage	SD	d	Sig.
102	5.06	1.4	104	5.28	1.3	0.1	.25

Table 19. Third molar mineralization in female and male.

A. Each line of the matrix plots above represents an individual M3. Each color represents a distinct stage of tooth mineralization (varying from 1 to 7). Red colors suggest presence of more advanced stages of tooth mineralization.

B. Results of statistical analysis using Independent sample t-test - Subjects aged 17 to 24 years. Distinct degrees of mineralization were not observed between females and males. Level of significance: 5%.

N: Number of quadrants studied.
SD: Standard deviation.
d: Difference of means between sub-groups.

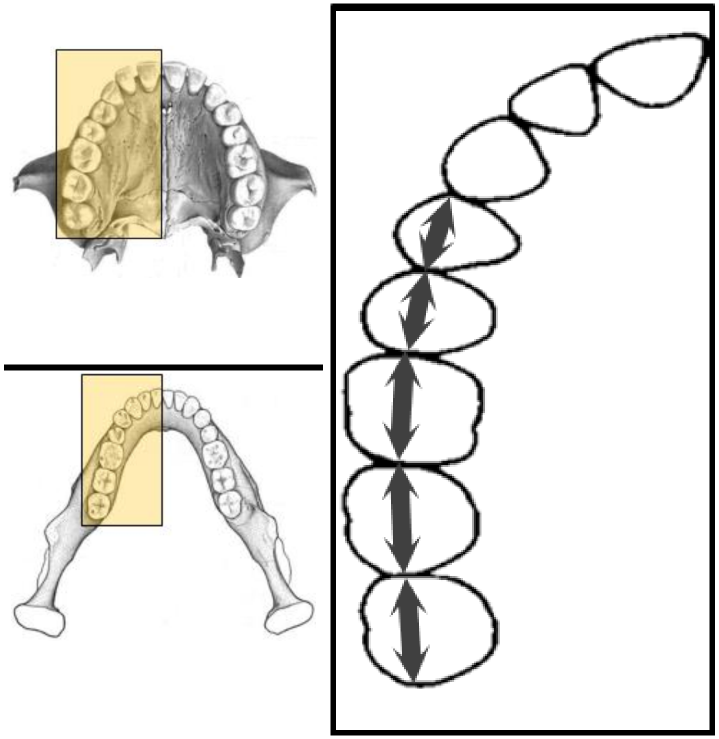
4.3 Hypothesis III: Findings

In the presence of third molar impaction, maxillary and mandibular third molars had larger crowns while premolars and other molars were larger only in the mandible

The M-D width of premolar and molar crowns of fifty-eight subjects aged 17 to 24 years was measured and the size of these teeth was compared between the impacted and non-impacted sub-groups using independent samples t-tests. These tests aimed to determine if the M-D crown width of premolars and molars was increased in subjects with M3 impaction. In regards to the size of premolars and molars between females and males, with the exception of the maxillary PM2, the crowns of all other premolars and molars were significantly larger in males compared to females ($p. \leq .01$) (Table 20). In the **maxilla**, the M-D width of the PM2, M2, and M3 crowns tended to be greater in the presence of M3 impaction; however these differences were not statistically significant (Table 21). In the **mandible**, the crowns of all premolars and molars, including the M3 itself, were significantly larger in the presence of M3 impaction ($p. \leq .03$) (Table 21). In summary, these results show that **only mandibular molars and premolars were significantly larger when M3 impaction was present**.

A

B



Maxilla - tooth crown size in females and males.

	Female			Male				
	N	Mean	SD	N	Mean	SD	D	Sig.
Tooth								
1st premolar	19	6.61	0.4	19	7.01	0.5	0.4	< .01
2nd premolar	19	6.48	0.6	19	6.62	0.5	0.1	.13
1st molar	19	9.69	0.4	19	9.94	0.5	0.3	.01
2nd molar	19	9.28	0.5	19	9.64	0.7	0.4	.01
3rd molar	19	9.34	0.7	19	8.82	0.9	0.5	< .01

Mandible - tooth crown size in females and males.

	Female			Male				
	N	Mean	SD	N	Mean	SD	D	Sig.
Tooth								
1st premolar	22	6.58	0.4	21	6.97	0.5	0.4	< .01
2nd premolar	22	6.79	0.4	21	7.22	0.4	0.4	< .01
1st molar	22	10.53	0.7	21	11.12	0.7	0.6	< .01
2nd molar	22	10.81	0.6	21	11.23	0.7	0.4	< .01
3rd molar	22	10.61	0.8	21	11.11	1.0	0.5	.01

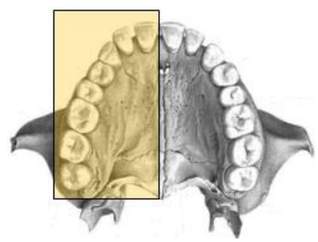
Table 20. Tooth crown size in females and males.

Results of statistical analysis using independent sample t-test - Subjects aged 17 to 24 years. Level of significance adopted: 5%.

A. Maxilla - mesiodistal width of premolars and molars according to sex.
B. Mandible - mesiodistal width of premolars and molars according to sex.

N: Number of patients studied.
SD: Standard deviation.
d: Difference of means between sub-groups.

A



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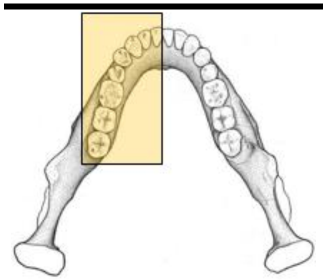
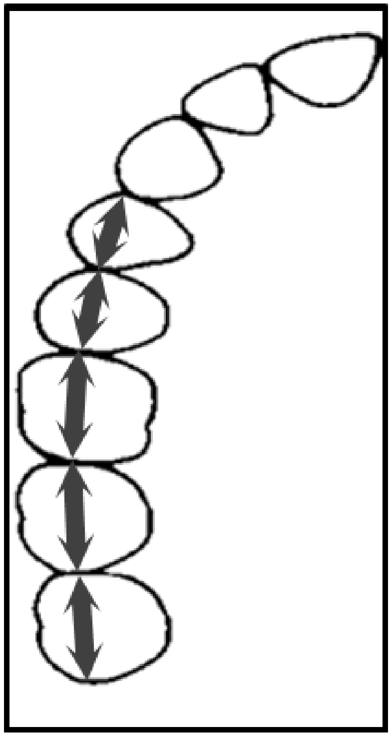




Maxilla - Tooth crown size vs. M3 impaction status.

	Non-impacted			Impacted				
	N	Mean	SD	N	Mean	SD	D	Sig.
Tooth								
1st premolar	13	6.81	0.6	25	6.79	0.4	0.0	.42
2nd premolar	13	6.47	0.5	25	6.58	0.6	0.1	.18
1st molar	13	9.84	0.5	25	9.77	0.5	0.0	.28
2nd molar	13	9.38	0.7	25	9.48	0.6	0.1	.26
3rd molar	13	8.99	0.5	25	9.11	1.0	0.1	.29

Mandible - Tooth crown size vs. M3 impaction status.

	Non-impacted			Impacted				
	N	Mean	SD	N	Mean	SD	D	Sig.
Tooth								
1st premolar	10	6.52	0.4	33	6.84	0.5	0.3	.01
2nd premolar	10	6.82	0.5	33	7.05	0.5	0.2	< .01
1st molar	10	10.51	0.8	33	10.91	0.7	0.4	.03
2nd molar	10	10.53	0.6	33	11.16	0.6	0.6	< .01
3rd molar	10	10.34	0.8	33	11.01	0.9	0.7	.01

Table 21. Tooth crown size in the impacted and non-impacted sub-groups.
Results of statistical analysis using independent sample t-test - Subjects aged 17 to 24 years. Level of significance adopted: 5%.

C. Maxilla - mesiodistal width of premolars and molars according to the impaction status of the M^3.
D. Mandible - mesiodistal width of premolars and molars according to the impaction status of the M_3.

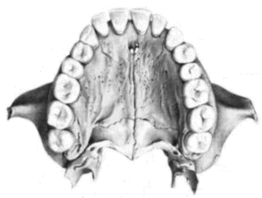
N: Number of patients studied.
SD: Standard deviation.
d: Difference of means between sub-groups.

4.4 Hypothesis IV: Findings

In the presence of third molar impaction only maxillary dental aches had reduced anterior-posterior and lateral-lateral dimensions

Fifty-eight subjects (thirty-five females and twenty-three males) were studied for this test. Thirty-eight of these subjects had both right and left M^3s (twenty-five with M3 impaction) and forty-three had both right and left M_3s (thirty-three with M3 impaction) (Table 4 – page 56). In the **maxillary** dental arch, the dimensions of both the lateral-lateral (which represents the width, or W, of the dental arch) and the anterior-posterior (which represents the depth, or D, of the dental arch) measurements were shorter in the presence of M3 impaction (p .03 and .02, for measurements W and D respectively) (Table 22). In the **mandibular** dental arch, the lengths of W and D were also shorter in the presence of M3 impaction compared to non-impacted cases; however, these differences were small and did not differ significantly (p .49 and .47, for measures W and D respectively) (Table 22). **A summary of these findings shows that only maxillary dental arches had reduced dimensions when M3 impaction was present**. In addition, due to the suggestions that dental crowding is more evident in subjects with M3 impaction (Ng 1986), the presence of this condition, as perceptible on the CBCT images studied, was also recorded and complementary reported here. This observation showed that among the subjects studied, regardless of the jaw, **dental crowding was observed only in those subjects presenting M3 impaction** (Figure 23).

A



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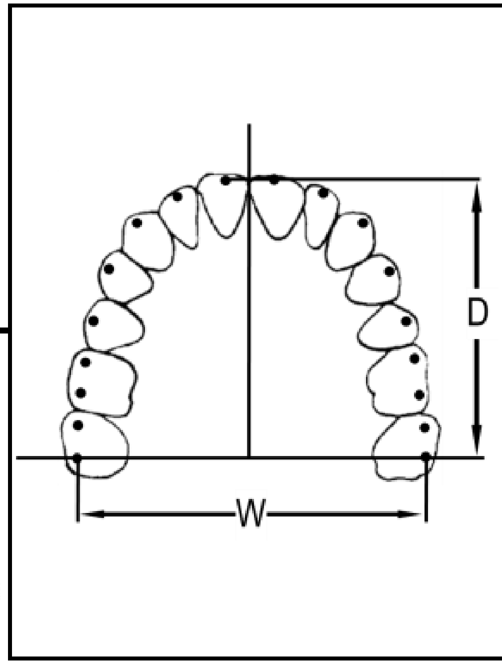


Maxilla – dental arch dimensions vs. M3 impaction status.

	Non-impacted			Impacted				
	N	Mean	SD	N	Mean	SD	D	Sig.
Measurement								
W	13	58.56	3.1	25	56.51	3.2	0.1	.03
D	13	44.76	3.0	25	42.94	2.5	0.5	.02

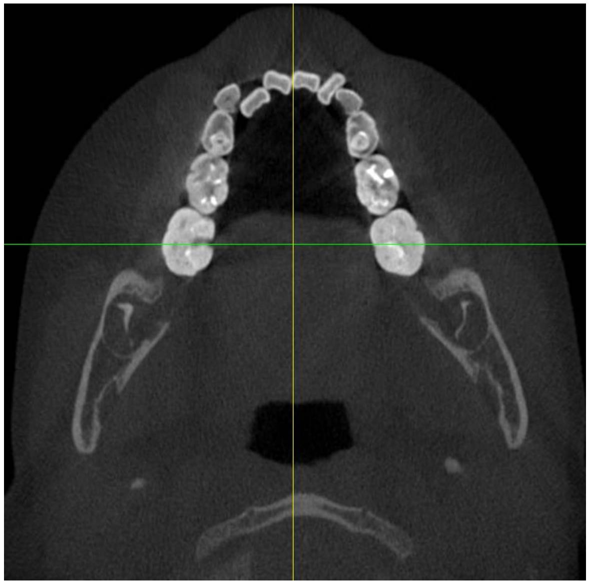
Mandible – dental arch dimensions vs. M3 impaction status.

	Non-impacted			Impacted				
	N	Mean	SD	N	Mean	SD	D	Sig.
Measurement								
W	10	57.13	2.3	33	57.11	4.0	1.3	.49
D	10	42.30	1.7	33	42.25	3.5	1.8	.47

Table 22. Dental arch dimensions according to the M3 impaction status.
Results of statistical analysis using independent sample t-test - Subjects aged 17 to 24 years. Level of significance adopted: 5%.

A. Maxilla – length of measurements W and D according to the impaction status of the M^3.
B. Mandible - length of measurements W and D according to the impaction status of the M_3.

N: Number of patients studied.
SD: Standard deviation.
d: Difference of means between sub-groups.



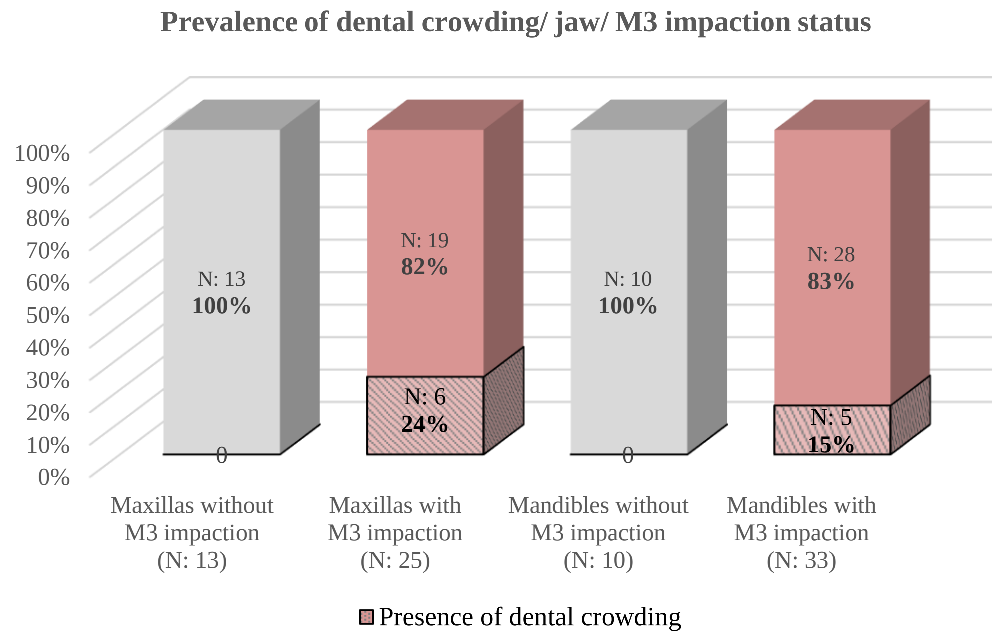


Figure 23. Prevalence of dental crowding.
The prevalence of dental crowding among subjects with and without impacted M3s - Subjects aged 17 to 24 years.

CHAPTER 5
DISCUSSION

5.1 Reduced Retromolar Space was a Factor Reliably Observed in Both Jaws when Third Molar Impaction was Present

In general, impaction of the M3 has been associated with an insufficient amount of space in the posterior regions of the maxilla and the mandible (Bjork 1956, Ricketts 1972, Schulhof 1976, Graber 1981, Ganss 1993, Rodu 1993, Peterson 1998). Since most studies on M3 impaction have concentrated on the M_3, a reduced amount of space between the M_2 and the ramus has been traditionally associated with the development of this condition (Bjork 1963) (Bjork 1956, Olive 1981, Rodu 1993, Lytle 1995, Hattab and Alhaija 1999, Behbehani 2006). The present findings support the literature by showing that the amount of space in the maxilla and mandible to accommodate the eruption of the M3 was significantly reduced in RM regions containing impacted M3s compared to RM regions where these teeth were not impacted (Table 6-7).

A concern, however, relates to the fact that space conditions in the RM region are constantly changing with growth of the maxillofacial skeleton. As a result, previous measurement methods of the RM region alone have not proven efficient at predicting M3 impaction (Gupta 2011). This suggests that the dynamic growth of this region, as well as related factors such as M3 maturation, may need to be jointly considered for M3 impaction to be more accurately predicted. Richardson (1977) for example, studied M_{3s} of ninety-five patients aged ten to eleven years for a period of 7-10 years on cephalometric radiographs (90° left lateral, 60° left and right lateral, and straight P.A. positions) and concluded that accurate prediction of M3 impaction from radiographic measurements is not possible at ages 10 to 11 years. Around the same period, in 1976, Ricketts and colleagues also attempted to develop a method to predict impaction based on measurements of the RM region, including both the M^3 and the M_3. Using lateral cephalometric radiographs (LCR) of seventy-four orthodontic treated cases, they found a threshold value of 25 mm required for M3 eruption from the Xi point (a point located at the geographic center of the mandibular ramus) or the pterygoid to the most distal point of the M_2 and M^2 respectively. They found that the M3 appeared to have limited space for eruption when approximately 20 mm of space was available, and an adequate space when approximately 30 mm was present. As a result, Rickets and colleagues concluded that M3 impaction could be predicted based on these parameters. Despite the relevance of this study, their method was not adopted in clinical practice. The reasons for this could include that LCRs are more commonly utilized by patients undergoing orthodontic treatment; thus, their use is uncommon in general dental practice. In addition, in contrast to what was found by Rickets and colleagues, the present 3D-based study showed that an average amount of space of less 20 mm was sufficient for M3s to erupt (Table 6). Since for Ricketts and colleagues a space of about 20 mm from the M^2 to the pterygoid was unfavorable for the M3 eruption, the present results do not agree with the impaction prediction method suggested by these authors. However, such divergence can be understood if one considers that CBCT images allow linear measurements between two structures to be taken while it cannot be done as accurately using LCRs.

Olive and Bassford (1981) evaluated the reliability of M_3 space-assessment techniques by comparing measurements on LCR, RT (rotational tomograms), intraoral bite-wings, and 60-degree-rotated cephalograms (lateral oblique) with direct measurements on dried human skulls: RTs showed the most accurate estimates of that space, whereas LCRs were unreliable. RTs were used by Ganss and colleagues (1993) in a later study exploring the concepts of M3 impaction prediction based on the amount of space present in RM region. In their study, maxillary and mandibular RM regions of twenty-seven patients were studied for seven years, from age 13 to age 20, and the spaces M^2-pterygoid and M_2-ramus were measured as well as the M-D crown width of M3s. Although RTs are acceptable for such measurements, they are 2D images on which linear measurements cannot be obtained accurately. For that reason, Ganss and colleagues' study was based on the principle that the space in the RM region needs to at least exceed the M-D width of the M3 crown for this tooth to erupt. They concluded that a jaw space/crown width ratio ≥ 1 seems to increase the probability of eruption of both the M^3 and the M_3, regardless of the patient's age. As a result, they suggested that prophylactic removal of the M3 should not be performed if a jaw space/crown width ratio ≥ 1 as measured on RT is identified. The present 3D-based results also support this idea by showing that if the same measurements used by Ganss and colleagues are considered (e.g. M^2-pterygoid and M_2-ramus), space/crown width ratios ≥ 1 and ≤ 1 occur for erupted M3s and impacted M3s respectively (Table 6-7). This association between tooth crown size and M3 impaction is discussed by hypothesis III.

Additionally, in contrast to this publication by Ganss and colleagues where only ratios, and no actual measurements, were reported, the present 3D-based study provides the linear distance between either the M^1/M_1 or the M^2/M_2 and the established landmarks (Table 6-7). These measurements were shorter in the presence of M3 impaction, and this suggests that the distance between the M1 or the M2 and either the landmark 1 or landmark 2 as a good predictive measure for this condition. Because the ascending mandibular ramus and also the point where the pterygoid process connects anatomically with the maxillary bone were regions relatively easily identifiable on conventional radiographs (e.g. panoramic), they were most commonly used landmarks by previous studies on M3 impaction in the maxilla (Ganss 1993, Artun 2005) and the mandible (Ganss 1993, Hattab 1999) respectively. Since the 3D characteristics of the CBCT images allow the distance between the M2 and virtually any surrounding anatomical structure to be measured, the present project contributes by measuring also the amount of space available between the M^2 and the maxillary tuberosity as well as between the M_2 and the mandibular foramen. These are landmarks easily identified on CBCT images and their adoption by further investigations on M3 impaction using this imaging resource in their methodology would allow good reproducibility of the results found by the present project.

CBCT-based results provide not only a clearer picture of the actual amount of space required for the M3 to erupt - and not only estimates of that space as provided by investigations using standard 2D radiographs – but also set grounds for exploration of M3 impaction predictive methods based on the actual amount of space available to accommodate the eruption of this tooth. Since CBCT imaging is becoming increasingly more commonly employed in the dental practice, such prediction methods may become possible in the near future.

5.2 Present 3D-based Results Suggest that Timing of Third Molar Mineralization is a Significant Predictor for Impaction

The onset of M3 mineralization commences most frequently at age nine (Gravely 1965, Richardson 1980, Ragini 2003). This fact was confirmed by the present study which showed that initiation of mineralization of both M^{3s} and M_{3s} at age nine was greater than in ages eight, ten, eleven, or twelve (Table 8). Not only are the causes for these significant variations not well understood, but also, whether or not delays in M3 mineralization are influenced by skeletal growth and the size of the jaws. The present study results suggest unavailability of space in the posterior region of both jaws as a factor reliably observed when there is delay of M3 mineralization. A reduced amount of space distal to the M1 was observed not only when M3 mineralization was delayed (e.g. M3s that take longer than usual to maturate), but also when late onset of mineralization occurred (e.g. M3s that initiated mineralizing later than expected). Although this observation does not confirm that lack of space in the jaws leads the M3 to initiate mineralization later, it suggests that some correlation between skeletal growth and M3 maturation may exist. The present study results show for instance that subjects aged ten years - where the M3 is usually expected to be starting its mineralization – with about 8 mm of space from the M^1 to the pterygoid did not have their M^3s mineralizing yet. However, when that space was of about 11 mm, M3 mineralization could be observed (Table 9-10). Similar results were observed in the mandible of these subjects, especially in ages with a comparable number of patients in both groups (e.g. M3 mineralization in progress vs. M3 mineralization not in progress), which allowed results of increased statistical significance to be returned (Table 11-12). With growth of the maxilla and the mandible, the length of these measurements gradually increased in ages ten, eleven and twelve (Table 9-12).

Although the present results suggest a link between late onset of M3 mineralization and reduced space in the jaws, results for eight year old subjects were never consistent with the results found in upper ages. In the maxilla and the mandible of these subjects, the amount of space distal to the M1 was reduced – however, not supported significantly in none of the tests - when M3 mineralization had not yet begun, compared to when M3 mineralization was already in progress. This suggests that availability of space in the jaws is not the only factor influencing tooth mineralization. Since M3 mineralization can begin as early as age five or as late as age fourteen (Garn 1962, Gravely 1965), and because spacing conditions in the jaws vary significantly over this age range, other factors (e.g. genetic) likely influence the timing of M3 mineralization more significantly. Genetic factors may be also associated with the fact that, in about 12% of the cases, M3s never form (tooth agenesis) (Dermaut 1986). Although it has been demonstrated that occurrence of M3 agenesis depends to some extent on the sagittal dimensions of the maxilla (Kajii 2004), in some cases even with favorable space conditions agenesis of this tooth is still observed, and it is suggested that genes associated with tooth morphogenesis are causing or influencing this agenesis (Kajii 2004, Hillerup 2008). Therefore, not only is the extent of the influence of availability of space in the jaws on the onset time of M3 mineralization not well understood, but also whether or not delays in this mineralization process result in M3 impaction.

While suggestions are present in the literature that M3s that take longer than usual to mineralize are more likely to become impacted (Svendsen 1988, Rodu 1993), this question has not been extensively explored by previous studies, especially because, in order to do so, patients need to be followed clinically for several years. As a result, published reports on M3 mineralization are few within the literature and are usually based on limited samples. Svendsen and Bjork, for example, studied 2D radiographs of 91 patients and found a higher incidence of M3 impaction among subjects with delayed mineralization of the M_3. As a result, they suggested that delayed mineralization is a factor of significance in the prediction of M3 impaction. Despite the positive contribution of their study, one limitation was the fact that only M_{3s} were studied and no M^{3s} were included in this study. In addition, no measurements were performed to attempt to determine availability of space in the jaws with the timing of M3 mineralization. Based on 3D imaging data from 213 subjects, the present study shows that for ages ten, eleven, or twelve the amount of space distal to the M1 in both jaws was significantly reduced when the M3 was still beginning to mineralize (i.e., delayed), compared to when mineralization was already in more advanced stages (Table 13-16). Interestingly, not only was a reduced amount of space in the jaws observed when M3 mineralization was delayed but also when impaction of this tooth had occurred (Table 17-18). **These findings suggest that a delicate balance between the growth of the jaws and the M3 mineralization process needs to exist for the M3 to erupt successfully within the oral cavity**.

A final interpretation of these findings therefore suggests that the timing of M3 mineralization is an important potential predictive factor for M3 impaction, along with availability of space in the posterior regions of the jaws. However, since the extent that availability of space in the jaws influences the rate at which M3 mineralization progresses is not yet known, it is still not possible to affirm that all later-initiating M3s will eventually become impacted; this is an area for further investigation. In that way, such M3s may not necessarily mineralize more slowly than ones in which mineralization had begun at the expected age (i.e. age nine) and they may never become impacted if space conditions in the jaws become appropriate. While these are currently only speculations supported by feasible evidence from both the literature and the results of the present study, new investigations using longitudinal designs are necessary to examine these factors more thoroughly.

5.3 New Data Suggest that Tooth Crown Size is a Potential Predictive Factor for Mandibular Third Molar Impaction

It has been speculated that subjects with M3 impaction usually have larger teeth than those with erupted M3s (Richardson 1977, Ng 1986, Venta 1997, Hattab 1999). This hypothesis suggests that the space available in the dental arches is a function not only of the size and morphology of the bony bases of the jaws, but is also associated with the size of the teeth (Forsberg 1988). It was observed, for example, that crowding is more common in people whose teeth have large M-D dimensions than in people with smaller teeth (Moorrees and Reed 1954, Doris, Bernard et al. 1981). In order to measure tooth size variation, which is generally small among subjects (Ng 1986), precise measurement tools are necessary.

The present 3D-based results of tooth measurements showed that premolar and molar crowns were significantly larger in males compared to females (Table 20), which is in accordance with previous findings that women on average have smaller teeth than men (Adams 1982, Lysell 1982, Forsberg 1988). In the mandible of subjects with impacted M3s, the M-D crown width of premolars and molars was significantly increased than in subjects who did not present M3 impaction. However, similar results were not statistically significant in the maxilla (Table 21). These results show therefore that **M_{3s} had larger crowns when they were impacted**. If, for the M3 to erupt, the space in the RM region needs to exceed the M-D width of its crown (Venta 1991, Ganss 1993) then the fact that larger crowns may prevent eruption can be comprehended. Although a tendency for impacted M_{3s} to be larger than erupted ones had been observed by previous studies based on panoramic radiographs (Venta 1997, Hattab 1999), and cephalometric radiographs (Richardson 1977), significant results have been rarely found. The present findings therefore show that the M3 crown size is now supported by accurate data as an additional predictive factor for M_3 impaction.

Additionally, the present CBCT-based results demonstrates that significant differences in tooth crown size do exist between impacted and non-impacted M3s, especially in the mandible where all the results were statistically significant. In this jaw, **not only the M3 was larger in the presence of impaction but were also adjacent molars and premolars**. This suggests that variations in the size of the crowns of adjacent teeth is not a factor as significant for impaction in the maxilla as it is in the mandible. Forsberg (1988) for example, had already cogitated that because size variations of premolars, the M1, and the M2 are usually smaller than the ones observed for the M3, the size of adjacent teeth probably has a smaller influence on M3 impaction than growth of the maxillofacial skeleton. In general, studies testing this question only managed to find a tendency for adjacent teeth to be larger in the presence of M3 impaction; without however, statistical significance (Forsberg 1988, Tsai 2005). In addition, most studies have only tested this question in the mandible. Ng (1986), for example, measured tooth crown size on dental casts of the mandibular arch and found that only lateral incisors and PM2s had a significantly increased crown size in subjects with impacted M_{3s}. However, maxillary teeth and the M_2 were not included in this study. In a more recent study performed by Kaya (2010), all mandibular teeth were measured on panoramic radiographs and both the M1 and the M2 were found to have increased M-D widths when an impacted M3 was present in the same quadrant. However, once more this question was investigated only in the mandible and, obviously as a result, no information regarding the influence of the crown size of the M3's adjacent teeth was available for the maxilla. For that reason, the observation on CBCT-based data that mandibular premolar and molar crowns were larger only in the mandible when M3 impaction was present also suggests that the patterns of M3 impaction may differ between the maxilla and the mandible. Further investigations would help determine if development of specific clinical management standards for M^3 and M_3 is necessary.

5.4 Third Molar Impaction seems to be less Influenced by the Dimensions of the Entire Dental Arch than by Local Factors Such as the Amount of Space in the RM Region.

The dental arch form is believed to be initially shaped by the configuration of the supporting bones (Brash 1956) and, following eruption of the permanent teeth, by the circum-oral musculature and intraoral functional forces (Weinstein 1963). Evidence that dental arches with dental crowding are narrower (Mills 1964, Howe 1983), and that dental crowding is more evident in subjects with M3 impaction (Ng 1986), suggests the presence of narrower dental arches when impacted M3s are present. CBCT-based results confirm these suggestions as dental crowding was observed only in dental arches with impacted M3s. Such results were seen in both the maxilla and the mandible. In addition, maxillary dental arches had reduced dimensions in subjects presenting M3 impaction (Table 22). In the mandible, however, differences were slight and not statistically significant, although arch dimensions still tended to be reduced in subjects with M3 impaction than in subjects with erupted M3s.

The fact that **only maxillary dental arches had reduced dimensions when impacted M3s were present** suggests that the dimensions of the entire dental arch may not be as significant in determining the impaction condition as are local factors such as the availability of space in the RM region. In addition, small differences in arch dimensions between the impacted and non-impacted groups were noticed in the study of Ng (1986), which showed a tendency for the dental arch dimensions to be greater in subjects with impacted M3s. One possible reason for these divergences between the present project's results and the ones found by Ng and colleagues may be related to their methods. While the present study's results are based on linear lateral-lateral and anterior-posterior measurements of the dental arches, Ng et al.'s measurements accounted additionally for the curvature of the dental arch. Another difference is that, while Ng and colleagues measured arch dimensions anterior to the M1, the present study included the M2 in the measurements to obtain a better picture of the dimensions of the entire dental arch in the presence and absence of M3 impaction. However, only mandibular dental arches were studied by Ng and colleagues and a comparison of results for maxillary dental arches is not possible.

An additional consideration is that dental arches have been measured in most studies based on landmarks established on teeth, not taking in account the bony bases of the jaws. Kim

(2003), for example, cites three conditions which may predispose to crowding in the dental arches: (a) excessively large teeth, (b) excessively small bony bases of the jaws, and (c) a combination of large teeth and small jaws. Although the present study has applied the traditional measurement methodologies in an attempt to compare 3D-based data with previously published studies, exploration of the bony bases of the jaws by future investigations may provide further information regarding general dental arch characteristics in the presence and absence of M3 impaction.

In the context of the present study, the following main results can be summarized:

1. A reduced amount of space in the RM region to accommodate the eruption of M^3s and M_3s was observed when this tooth was impacted, compared to when it was erupted.

2. The proportion of M^3 and M_3 initiating mineralization at age nine was greater than in ages eight, ten, eleven, or twelve.

3. In ages nine, ten, eleven, and twelve, the amount of space in the jaws (distal to the M1) was reduced when the mineralization of the M^3s and M_3s had not yet been initiated, compared to when some degree of mineralization was already observed.

4. In ages ten, eleven or twelve, the amount of space in the jaws (distal to the M1) was reduced when the mineralization of the M^3s and M_3s were only commencing, compared to ones already in more advanced stages of mineralization.

5. The mineralization of impacted M^3s and M_3s was significantly delayed compared to non-impacted ones.

6. M_3s had larger crowns when they were impacted.

7. Premolars and molars had larger crowns when M3 impaction was present. However, this result was supported statistically only in the mandible.

8. Dental arches had reduced dimensions when M3 impaction was present. However, this result was supported statistically only in the maxilla.

5.5 Final Considerations and Conclusions

Delayed M3 mineralization was observed not only when this tooth was impacted but also when there was less space in the posterior region of maxilla and mandible. This combination of factors suggests that a delicate balance between M3 maturation and the growth of the jaws must be struck for the M3 to fully erupt within the oral cavity. The present 3D-based results therefore suggest that **the timing of M3 mineralization may be a reliable factor for prediction of M3 impaction, in addition to availability of space in the RM region**. However, a later-initiating M3 may in fact mineralize at a faster rate, and for this reason, the M3 may not necessarily become impacted if sufficient space is available for normal eruption. Since the pace of M3 maturation has never been intensively explored, longitudinal studies are necessary to elucidate if late-forming M3s will become impacted. The investigation of such question is an exciting opportunity that I will pursue during my PhD program through the development of a longitudinal study. Further studies that probe M3 mineralization are essential to advance our knowledge on the mechanisms that influence timing of tooth maturation. Only by understanding these mechanisms will it be possible to develop more accurate predictive methods for M3 impaction.

Also of importance is the fact that the present CBCT-based results re-affirm insufficient space in the RM region as a factor of significance for M3 impaction. Since CBCT images allow the dimensions of anatomical structures to be captured with greater accuracy compared to standard 2D radiographs, a more accurate picture of the space necessary to accommodate the eruption of the M3 may be available here. Since conclusions so far have been based only on estimates of space available in the RM region as measured on 2D radiographs, further investigations testing the accuracy of 2D and 3D imaging modalities in reproducing the actual dimensions of the RM region are important for improvement of the prediction methods of third molar impaction. Despite of the significance of the “space factor”, it is also important to consider that availability of space in the RM region does not always guarantee the full eruption of the M3. This fact suggests that availability of space in the RM region may not be the only factor affecting M3 impaction. For example, for the M3 to erupt, the space in the RM region needs to at least exceed the M-D width of this tooth crown (Venta 1991, Ganss 1993), and this suggests that larger M3 crowns may also be a factor of significance for complete eruption to occur. This idea was confirmed by the results of the present study, which showed that M_3s had larger crowns when they were impacted, while other molar and the premolar crowns were larger only in the mandible (in the presence of M3 impaction) (Figure 24). This supports the idea that **the size of the M_3 crown itself is a significant factor that influences the dynamics of its own eruption,** while the size of adjacent teeth may act only as a secondary determinant of impaction. That, added to **the observation of dental arches with reduced dimensions in only one of the jaws (i.e. maxilla) when M3 impaction was present, suggests that the patterns of this condition are distinct between the maxilla and the mandible** (Figure 25)**.** Furthermore, it may be an indication that the dimensions of the entire dental arch are not as significant in determining the impaction condition as are local factors such as the availability of space in the RM region. Since a very small number of studies comparing the characteristics of M3 impaction between the maxilla and the mandible exist, further investigations would help determine if development of specific clinical management standards for M^{3s} and M_{3s} is necessary. If new findings demonstrate that the risks of association of the M3s with impaction are jaw specific, then it is possible that a great number of extraction surgeries that currently are done prophylactically can be reduced if only those M3s at high risk of becoming associated with pathoses and/or other complications are considered for surgical removal.

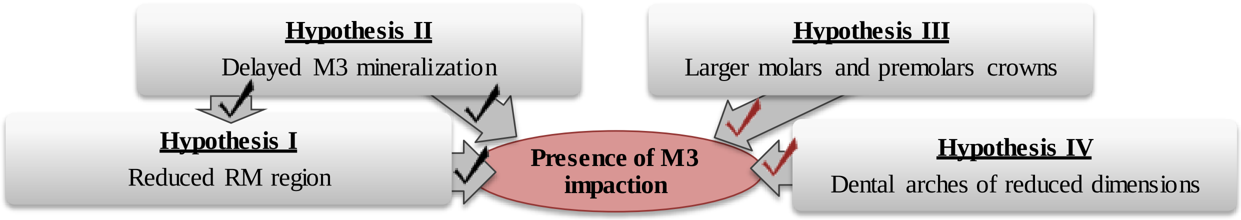


Figure 24. Summary of the project results.
While hypothesis I and II were confirmed in both the maxilla and the mandible, hypotheses III and IV were confirmed in only one of the jaws (red marks).

Hypothesis I – Third Molar Impaction is Observed When the Amount of Space in the Jaws to Accommodate the Eruption of this Tooth is reduced

	Maxilla	Mandible
• Is the amount of RM space to accommodate M3 eruption reduced when this tooth is impacted?	✓	✓

Hypothesis II - Third Molar Mineralization is delayed and has a Later Onset when the Amount of Space in the Jaws to Accommodate the Development of this Tooth is reduced

	Maxilla	Mandible
• Is the amount of space to accommodate M3 development reduced when M3 mineralization begins later?	✓	✓
• Is the amount of space to accommodate M3 development reduced when M3 mineralization is being delayed?	✓	✓
• Is M3 mineralization delayed when the same tooth is impacted?	✓	✓

Hypothesis III - Third Molar Impaction is observed in the presence of Premolar and Molar Crowns of Increased Mesiodistal Width

	Maxilla	Mandible
• Is the M-D width of impacted M3s' crowns reduced?	**No**	✓
• Is the M-D width of premolars and molars (except the M3) increased in the presence of M3 impaction?	**No**	✓

Hypothesis IV - Third Molar Impaction is observed in Patients with Dental Arches of reduced Anterior-posterior and Lateral-lateral Dimensions

	Maxilla	Mandible
• Are dental arches of reduced dimensions observed in the presence of M3 impaction?	✓	**No**

Figure 25. Summary of the project questions.
Summary of the questions addressed and results obtained by jaw.

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APPENDIX A
INTRA-OBSERVER AND INTER-OBSERVERS TESTS

To test the reproducibility and reliability of the methodology used to measure the anatomical structures studied in this project, an initial set of twenty tests were performed before initiating this study. Two distinct trained researchers took measurements and independent samples t-tests were applied. Therefore, at the level of significance of 5%, **no evidence exists to reject the assumption that the individual measurement values taken by each researcher are not different** (P-values are > 0.05)**.** The results for the intra-observer and inter-observers tests are shown in the next pages of this appendix.

Individual ID#	Gender	Age	Tooth studied	Measurement #	M-D Crown Length: M1		M-D Crown Length: M2		M-D Crown Length: M3		Jaw Space from: M1-Lk		Jaw Space from: M2-Lk	
					Observer 1	Observer 2	Observer 1	Observer 2	Observer 1	Observer 2	Observer 1	Observer 2	Observer 1	Observer 2
1	F	16	18	1	10.00	10.40	8.99	9.20	8.40	9.48	18.50	16.33	9.68	9.67
				2	10.00	10.40	8.99	9.60	8.40	9.21	18.87	16.82	10.00	9.54
				3	10.40	10.80	9.36	9.60	8.38	9.54	18.87	17.76	9.68	11.45
				Mean	10.13	10.53	9.11	9.47	8.39	9.41	18.75	16.97	9.79	10.22
				Std. Error	0.13	0.13	0.12	0.13	0.01	0.10	0.12	0.42	0.11	0.62
				Std. dev.	0.23	0.23	0.21	0.23	0.01	0.18	0.21	0.73	0.18	1.07
				Sig.	0.20		0.20		0.10		0.10		0.70	
2	F	16	48	1	10.81	11.20	10.80	11.20	11.45	11.48	33.74	34.07	22.61	23.18
				2	10.80	10.80	10.80	10.90	11.38	11.40	34.13	34.43	22.70	23.03
				3	10.80	10.80	10.80	10.90	11.30	11.46	33.67	34.89	23.09	23.52
				Mean	10.80	10.93	10.80	11.00	11.38	11.45	33.85	34.46	22.80	23.24
				Std. Error	0.00	0.13	0.00	0.10	0.04	0.02	0.14	0.24	0.15	0.14
				Std. dev.	0.01	0.23	0.00	0.17	0.08	0.04	0.25	0.41	0.26	0.25
				Sig.	1.00		0.10		0.20		0.20		0.20	
3	F	18	18	1	10.80	10.80	10.40	10.40	9.13	9.33	21.05	19.50	10.77	11.06
				2	10.40	10.80	10.00	10.80	9.54	9.67	21.05	19.76	10.63	10.47
				3	10.80	10.80	10.00	10.40	9.33	10.03	21.05	20.40	10.63	11.89
				Mean	10.67	10.80	10.13	10.53	9.33	9.68	21.05	19.89	10.68	11.14
				Std. Error	0.13	0.00	0.13	0.13	0.12	0.20	0.00	0.27	0.05	0.41
				Std. dev.	0.23	0.00	0.23	0.23	0.21	0.35	0.00	0.46	0.08	0.71
				Sig.	0.70		0.20		0.20		0.10		0.70	
4	F	18	48	1	11.20	11.60	11.60	11.55	12.09	12.39	36.50	39.00	24.64	24.00
				2	11.22	11.20	11.60	11.60	12.32	12.14	36.56	40.40	24.56	24.17
				3	11.20	11.20	11.60	11.62	12.32	12.20	36.56	41.30	24.64	24.50
				Mean	11.21	11.33	11.60	11.59	12.24	12.24	36.54	40.23	24.61	24.22
				Std. Error	0.01	0.13	0.00	0.02	0.08	0.08	0.02	0.67	0.03	0.15
				Std. dev.	0.01	0.23	0.00	0.04	0.13	0.13	0.03	1.16	0.05	0.25
				Sig.	1.00		0.10		0.10		0.10		0.10	
5	M	13	18	1	10.75	10.50	9.00	9.75	8.08	8.20	15.17	13.65	6.56	6.88
				2	10.50	9.75	9.00	9.41	7.95	8.25	14.92	15.46	6.32	5.90
				3	10.75	10.50	9.00	9.50	8.25	8.23	14.96	15.53	6.32	9.19
				Mean	10.67	10.25	9.00	9.55	8.09	8.23	15.02	14.88	6.40	7.32
				Std. Error	0.08	0.25	0.00	0.10	0.09	0.01	0.08	0.62	0.08	0.98
				Std. dev.	0.14	0.43	0.00	0.18	0.15	0.03	0.13	1.07	0.14	1.69
				Sig.	0.20		0.10		0.40		0.70		0.70	

M1/M2/M3: First/Second/Third Molars
M-D: Mesio-distal

Lk: In maxilla, it refers to the landmark "tuberosity"
Lk: In mandible, it refers to the landmark "foramen"

Individual ID#	Gender	Age	Tooth studied	Measurement #	M-D Crown Length						Jaw Space from:			
					M1		M2		M3		M1-Lk		M2-Lk	
					Observer 1	Observer 2	Observer 1	Observer 2	Observer 1	Observer 2	Observer 1	Observer 2	Observer 1	Observer 2
6	M	13	48	1	10.50	10.75	10.75	11.00	10.11	10.20	35.02	35.90	25.12	25.61
				2	10.75	10.75	10.75	10.75	9.65	10.18	35.26	40.55	25.18	29.84
				3	10.50	10.50	10.75	10.75	10.35	9.84	35.10	42.21	25.18	31.72
				Mean	10.58	10.67	10.75	10.83	10.04	10.07	35.13	39.55	25.16	29.06
				Std. Error	0.08	0.08	0.00	0.08	0.21	0.12	0.07	1.89	0.02	1.81
				Std. dev.	0.14	0.14	0.00	0.14	0.36	0.20	0.12	3.27	0.03	3.13
				Sig.	0.70		0.70		1.00		0.10		0.10	
7	F	13	18	1	10.80	10.40	9.60	10.00	8.99	9.33	18.16	17.55	2.83	9.37
				2	10.80	10.80	9.60	9.60	8.88	9.54	17.76	23.69	2.83	14.88
				3	10.80	10.80	9.60	9.60	9.12	9.33	18.28	17.18	2.43	9.37
				Mean	10.80	10.67	9.60	9.73	9.00	9.40	18.07	19.47	2.70	11.21
				Std. Error	0.00	0.13	0.00	0.13	0.07	0.07	0.16	2.11	0.13	1.84
				Std. dev.	0.00	0.23	0.00	0.23	0.12	0.12	0.27	3.66	0.23	3.18
				Sig.	0.70		0.70		0.10		0.70		0.10	
8	F	13	48	1	10.80	11.20	11.60	11.20	12.21	12.11	32.64	34.93	21.69	21.45
				2	10.80	10.80	11.60	11.60	12.27	12.18	32.64	40.17	21.69	21.45
				3	10.80	11.20	11.60	11.20	12.18	12.13	32.64	42.42	21.48	21.60
				Mean	10.80	11.07	11.60	11.33	12.22	12.14	32.64	39.17	21.62	21.50
				Std. Error	0.00	0.13	0.00	0.13	0.03	0.02	0.00	2.22	0.07	0.05
				Std. dev.	0.00	0.23	0.00	0.23	0.05	0.04	0.00	3.84	0.12	0.09
				Sig.	0.20		0.20		0.10		0.10		0.20	
9		14	18	1	11.50	11.25	9.75	9.75	8.19	8.75	15.89	16.12	7.35	7.48
				2	11.25	10.75	9.75	9.75	8.63	9.00	16.08	16.24	7.67	7.46
				3	11.25	10.75	9.75	9.50	8.34	8.75	15.59	16.16	7.43	7.42
				Mean	11.33	10.92	9.75	9.67	8.39	8.83	15.85	16.17	7.48	7.45
				Std. Error	0.08	0.17	0.00	0.08	0.13	0.08	0.14	0.04	0.10	0.02
				Std. dev.	0.14	0.29	0.00	0.14	0.22	0.14	0.25	0.06	0.17	0.03
				Sig.	0.20		0.70		0.10		0.10		1.00	
10		14	48	1	10.76	11.50	11.60	11.75	11.88	12.12	34.93	34.77	23.25	23.12
				2	10.80	11.50	11.10	11.50	12.01	12.08	34.98	34.82	22.87	23.23
				3	10.53	11.50	11.57	11.75	12.02	12.23	34.66	34.80	23.42	23.17
				Mean	10.70	11.50	11.42	11.67	11.97	12.14	34.86	34.80	23.18	23.17
				Std. Error	0.08	0.00	0.16	0.08	0.05	0.04	0.10	0.01	0.16	0.03
				Std. dev.	0.15	0.00	0.28	0.14	0.08	0.08	0.17	0.03	0.28	0.06
				Sig.	0.10		0.40		0.10		0.70		0.70	

M1/M2/M3:First/Second/Third Molars
M-D:Mesio-distal

Lk: In maxilla, it refers to the landmark "tuberosity"
Lk: In mandible, it refers to the landmark "foramen"

Individual ID#	Gender	Age	Tooth studied	Measurement #	M-D Crown Length						Jaw Space from:			
					M1		M2		M3		M1-Lk		M2-Lk	
					Observer 1	Observer 2	Observer 1	Observer 2	Observer 1	Observer 2	Observer 1	Observer 2	Observer 1	Observer 2
11	F	14	18	1	11.60	10.80	10.77	11.20	10.81	11.66	20.00	20.80	9.12	9.00
				2	10.80	10.80	11.16	11.20	10.81	11.66	19.61	20.12	8.74	8.99
				3	10.80	11.20	10.77	10.80	10.81	11.29	19.61	20.08	8.85	8.87
				Mean	11.07	10.93	10.90	11.07	10.81	11.54	19.74	20.33	8.90	8.95
				Std. Error	0.27	0.13	0.13	0.13	0.00	0.12	0.13	0.23	0.11	0.04
				Std. dev.	0.46	0.23	0.23	0.23	0.00	0.21	0.23	0.40	0.20	0.07
				Sig.	1.00		0.20		0.10		0.10		0.70	
12	F	14	48	1	11.20	10.80	11.23	11.20	11.68	12.01	32.09	31.99	21.15	28.14
				2	10.81	11.20	10.81	11.20	11.68	11.81	32.56	31.87	21.65	26.10
				3	10.80	10.80	11.60	11.20	11.37	12.27	32.49	33.12	21.93	27.10
				Mean	10.94	10.93	11.21	11.20	11.58	12.03	32.38	32.33	21.58	27.11
				Std. Error	0.13	0.13	0.23	0.00	0.10	0.13	0.15	0.40	0.23	0.59
				Std. dev.	0.23	0.23	0.40	0.00	0.18	0.23	0.25	0.69	0.40	1.02
				Sig.	0.70		0.70		0.10		0.70		0.10	
13	M	14	18	1	11.20	11.20	10.13	10.20	9.61	9.55	18.61	21.26	8.04	7.90
				2	11.20	11.60	10.00	10.12	9.63	9.62	18.61	21.65	7.69	8.00
				3	11.60	11.60	10.40	10.12	9.63	9.60	18.61	19.62	7.77	7.99
				Mean	11.33	11.47	10.18	10.15	9.62	9.59	18.61	20.84	7.83	7.96
				Std. Error	0.13	0.13	0.12	0.03	0.01	0.02	0.00	0.62	0.11	0.03
				Std. dev.	0.23	0.23	0.20	0.05	0.01	0.04	0.00	1.08	0.18	0.06
				Sig.	0.70		1.00		0.20		0.10		0.70	
14	M	14	48	1	11.60	11.60	11.60	12.00	12.17	12.00	34.69	34.70	24.56	24.00
				2	11.60	11.60	12.00	12.00	12.17	12.10	34.69	34.60	23.87	24.00
				3	11.60	12.00	12.00	11.60	12.12	12.21	34.69	34.66	24.22	24.15
				Mean	11.60	11.73	11.87	11.87	12.15	12.10	34.69	34.65	24.22	24.05
				Std. Error	0.00	0.13	0.13	0.13	0.02	0.06	0.00	0.03	0.20	0.05
				Std. dev.	0.00	0.23	0.23	0.23	0.03	0.11	0.00	0.05	0.35	0.09
				Sig.	0.70		1.00		0.70		0.70		0.70	
15	F	12	18	1	10.80	11.20	10.41	10.40	8.59	10.00	19.70	21.11	8.35	8.52
				2	10.40	11.16	10.13	10.40	8.94	9.34	19.22	21.68	8.10	8.47
				3	10.80	10.80	10.20	10.80	9.33	9.37	19.61	23.08	8.99	8.69
				Mean	10.67	11.05	10.25	10.53	8.95	9.57	19.51	21.96	8.48	8.56
				Std. Error	0.13	0.13	0.08	0.13	0.21	0.22	0.15	0.59	0.27	0.07
				Std. dev.	0.23	0.22	0.15	0.23	0.37	0.37	0.26	1.01	0.46	0.12
				Sig.	0.20		0.40		0.10		0.10		0.70	

M1/M2/M3:First/Second/Third Molars
M-D:Mesio-distal

Lk: In maxilla, it refers to the landmark "tuberosity"
Lk: In mandible, it refers to the landmark "foramen"

Individual ID#	Gender	Age	Tooth studied	Measurement #	M-D Crown Length						Jaw Space from:			
					M1		M2		M3		M1-Lk		M2-Lk	
					Observer 1	Observer 2	Observer 1	Observer 2	Observer 1	Observer 2	Observer 1	Observer 2	Observer 1	Observer 2
16	F	12	48	1	12.50	12.00	11.71	12.80	11.66	12.55	39.00	39.00	26.85	26.77
				2	12.46	12.00	12.24	12.40	11.81	12.17	38.64	39.20	27.05	27.00
				3	12.06	12.80	11.85	12.00	12.01	12.65	39.00	39.19	26.68	27.11
				Mean	12.34	12.27	11.93	12.40	11.83	12.46	38.88	39.13	26.86	26.96
				Std. Error	0.14	0.27	0.16	0.23	0.10	0.15	0.12	0.07	0.11	0.10
				Std. dev.	0.24	0.46	0.27	0.40	0.18	0.25	0.21	0.11	0.19	0.17
				Sig.	0.70		0.20		0.10		0.20		0.70	
17	F	14	18	1	11.25	11.25	10.75	11.00	9.42	9.65	19.04	19.12	8.79	8.68
				2	11.25	11.50	10.75	10.75	9.19	10.06	19.29	19.00	8.68	8.57
				3	11.50	11.50	10.75	10.75	9.52	10.20	19.28	19.26	8.92	8.60
				Mean	11.33	11.42	10.75	10.83	9.38	9.97	19.20	19.13	8.80	8.62
				Std. Error	0.08	0.08	0.00	0.08	0.10	0.17	0.08	0.08	0.07	0.03
				Std. dev.	0.14	0.14	0.00	0.14	0.17	0.29	0.14	0.13	0.12	0.06
				Sig.	0.70		0.70		0.10		0.40		0.10	
18	F	14	48	1	12.01	12.25	12.13	12.00	12.31	12.87	34.41	34.44	23.37	23.00
				2	12.29	12.00	12.10	12.50	12.31	12.86	34.40	34.44	23.15	23.16
				3	11.82	12.25	12.13	12.25	12.31	12.73	34.39	34.60	23.26	23.30
				Mean	12.04	12.17	12.12	12.25	12.31	12.82	34.40	34.49	23.26	23.15
				Std. Error	0.14	0.08	0.01	0.14	0.00	0.05	0.01	0.05	0.06	0.09
				Std. dev.	0.24	0.14	0.02	0.25	0.00	0.08	0.01	0.09	0.11	0.15
				Sig.	1.00		0.70		0.10		0.10		0.70	
19	F	10	18	1	9.60	10.80	10.40	10.40	8.00	8.21	15.44	14.99	7.16	7.00
				2	9.23	10.80	10.00	10.40	8.40	8.25	15.06	15.15	6.88	6.99
				3	9.41	10.80	10.00	10.00	8.00	8.21	15.82	15.10	7.89	6.96
				Mean	9.41	10.80	10.13	10.27	8.13	8.22	15.44	15.08	7.31	6.98
				Std. Error	0.11	0.00	0.13	0.13	0.13	0.01	0.22	0.05	0.30	0.01
				Std. dev.	0.19	0.00	0.23	0.23	0.23	0.02	0.38	0.08	0.52	0.02
				Sig.	0.10		0.70		0.70		0.40		0.70	
20	F	10	48	1	10.40	10.40	10.80	10.80	10.98	10.38	27.75	28.00	17.39	18.00
				2	10.01	10.40	10.40	10.80	10.77	10.40	27.86	28.00	17.39	17.60
				3	10.41	10.80	10.80	10.80	10.77	10.90	27.86	27.60	17.23	17.53
				Mean	10.27	10.53	10.67	10.80	10.84	10.56	27.82	27.87	17.34	17.71
				Std. Error	0.13	0.13	0.13	0.00	0.07	0.17	0.04	0.13	0.05	0.15
				Std. dev.	0.23	0.23	0.23	0.00	0.12	0.29	0.06	0.23	0.09	0.25
				Sig.	0.70		0.70		0.40		0.70		0.10	

M1/M2/M3:First/Second/Third Molars
M-D:Mesio-distal

Lk: In maxilla, it refers to the landmark “tuberosity”
Lk: In mandible, it refers to the landmark “foramen”

APPENDIX B
GROUP OF INDIVIDUALS AGED 8 TO 12 YEARS
ORIGINAL RAW DATA

The data obtained from the study of the group of subjects aged eight to twelve years was analyzed to test the hypotheses I of the present research project.

The original data and measurements taken from CBCT images of the subjects included in this group are shown in the next pages of this appendix.

Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-pterygoid'	Space 'M1-tuberosity'	Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-pterygoid'	Space 'M1-tuberosity'	Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-pterygoid'	Space 'M1-tuberosity'
Mineralization not in progress								**1/3- of the crown formed**								**2/3+ of the crown formed**							
Maxillary Third Molars																							
8.1	M	**8**	18	3	0	8.06	7.59	9.13	M	**8**	18	4	1	6.75	7.57								
8.1	M	**8**	28	3	0	9.53	9.55	9.13	M	**8**	28	4	1	6.33	7.00								
8.3	M	**8**	18	4	0	8.41	8.88	8.2	F	**8**	18	3	1	9.41	8.51								
8.3	M	**8**	28	4	0	9.20	8.88	8.2	F	**8**	28	3	1	9.81	8.42								
8.4	F	**8**	18	4	0	8.55	9.23	8.10	M	**8**	18	4	1	9.40	9.80								
8.4	F	**8**	28	4	0	9.02	8.84	8.10	M	**8**	28	4	1	9.54	9.80								
8.6	M	**8**	18	3	0	5.14	7.00																
8.6	M	**8**	28	3	0	5.71	6.31																
8.7	F	**8**	18	3	0	6.08	7.11																
8.7	F	**8**	28	3	0	8.27	8.34																
8.11	F	**8**	18	3	0	10.98	9.65																
9.5	M	**8**	18	3	0	6.51	7.38																
9.5	M	**8**	28	3	0	8.41	9.02																
9.6	F	**8**	18	3	0	8.11	8.83																
9.6	F	**8**	28	3	0	7.55	8.78																
9.7	M	**8**	18	7	0	7.21	6.40																
9.7	M	**8**	28	7	0	7.77	6.41																
9.12	F	**8**	18	4	0	7.54	8.28																
9.12	F	**8**	28	4	0	7.11	7.50																
9.8	M	**9**	18	3	0	6.30	7.00	9.1	M	**9**	18	5	1	9.38	8.89	9.14	F	**9**		5	2	9.06	9.06
9.8	M	**9**	28	3	0	7.60	7.60	9.1	M	**9**	28	5	1	8.89	8.79								
10.3	F	**9**	18	2	0	9.00	8.49	9.2	M	**9**	18	5	1	9.09	8.64								
10.3	F	**9**	28	2	0	9.02	8.64	9.2	M	**9**	28	5	1	9.51	8.40								
10.9	M	**9**	18	3	0	8.55	9.03	9.4	F	**9**	18	5	1	9.12	8.49								
10.9	M	**9**	28	3	0	7.69	9.03	9.4	F	**9**	28	5	1	9.23	8.81								
10.10	F	**9**	18	3	0	8.99	8.40	9.14	F	**9**	18	5	1	9.31	9.11								
10.10	F	**9**	28	3	0	7.77	8.09	10.6	F	**9**	18	5	1	8.42	8.32								
								10.6	F	**9**	28	5	1	8.29	8.21								
								10.11	F	**9**	18	5	1	8.39	8.11								
								10.11	F	**9**	28	5	1	8.41	8.25								
								9.11	M	**9**	18	3	1	8.78	8.83								
								9.11	M	**9**	28	3	1	8.75	9.12								

Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-pterygoid'	Space 'M1-tuberosity'	Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-pterygoid'	Space 'M1-tuberosity'	Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-pterygoid'	Space 'M1-tuberosity'
Mineralization not in progress								**1/3- of the crown formed**								**2/3+ of the crown formed**							
Maxillary Third Molars																							
10.4	M	**10**	18	4	0	7.13	8.00	10.8	M	**10**	18	4	1	6.88	5.64	10.2	F	**10**	18	6	2	9.77	9.16
10.4	M	**10**	28	4	0	8.40	9.83	10.16	F	**10**	18	5	1	9.12	9.50	10.5	M	**10**	18	5	2	9.59	9.58
10.8	M	**10**	28	4	0	6.62	8.31	10.17	F	**10**	18	6	1	12.21	13.35	10.5	M	**10**	28	5	2	9.37	11.47
10.13	F	**10**	18	4	0	10.34	9.72	10.17	F	**10**	28	6	1	11.60	11.63	10.7	M	**10**	18	5	2	9.00	7.71
10.13	F	**10**	28	4	0	10.52	10.24	11.5	F	**10**	18	5	1	8.55	6.62	10.7	M	**10**	28	5	2	8.99	8.19
11.1	F	**10**	28	6	0	10.75	10.43	11.5	F	**10**	28	5	1	10.03	8.77	10.16	F	**10**	28	5	2	9.86	10.78
11.3	M	**10**	18	4	0	7.38	7.61	11.12	F	**10**	28	5	1	8.92	9.28	11.1	F	**10**	18	6	2	10.28	9.83
11.3	M	**10**	28	4	0	7.61	7.77	11.16	M	**10**	18	5	1	12.49	10.31	11.4	F	**10**	18	6	2	11.71	12.98
11.12	F	**10**	18	5	0	10.50	9.57	11.19	M	**10**	18	5	1	8.59	8.88	11.4	F	**10**	28	6	2	12.32	12.46
11.17	M	**10**	18	4	0	8.35	7.30	11.19	M	**10**	28	5	1	11.54	11.26	11.11	F	**10**	18	6	2	17.27	15.46
11.17	M	**10**	28	4	0	8.40	9.28	11.20	M	**10**	18	5	1	10.24	10.61	11.11	F	**10**	28	6	2	16.00	13.89
11.27	F	**10**	18	4	0	6.51	5.73	11.20	M	**10**	28	5	1	12.41	11.88	11.22	M	**10**	18	4	2	10.61	9.28
11.27	F	**10**	28	4	0	7.21	6.60	11.22	M	**10**	28	4	1	10.07	9.03	11.23	F	**10**	18	5	2	9.71	9.09
								11.23	F	**10**	28	5	1	9.37	7.29	10.2	F	**10**	28	6	3	11.82	13.12
								11.16	M	**10**	28	6	1	12.61	11.64	11.10	F	**10**	18	6	3	16.57	16.80
																11.10	F	**10**	28	6	3	15.20	14.46

Maxillary Third Molars

Mineralization not in progress

Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-pterygoid'	Space 'M1-tuberosity'
11.9	F	**11**	18	5	0	11.10	9.46
11.9	F	**11**	28	5	0	10.33	9.58
11.13	M	**11**	18	6	0	14.53	13.68
11.13	M	**11**	28	6	0	12.75	12.97
11.21	M	**11**	18	5	0	9.80	9.55
11.21	M	**11**	28	5	0	8.04	7.85
11.24	M	**11**	18	6	0	8.41	9.12
11.24	M	**11**	28	6	0	10.47	10.25
12.6	F	**11**	28	5	0	12.80	12.15
12.7	F	**11**	18	3	0	7.04	7.70
12.7	F	**11**	28	3	0	6.29	6.73
12.12	F	**11**	18	5	0	12.50	12.24
12.12	F	**11**	28	5	0	12.46	11.01
12.22	M	**11**	18	4	0	9.32	9.47
12.22	M	**11**	28	4	0	8.75	9.38
12.28	F	**11**	18	6	0	12.06	10.92
12.28	F	**11**	28	6	0	9.73	9.34
12.34	M	**11**	28	5	0	12.43	13.21

1/3- of the crown formed

Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-pterygoid'	Space 'M1-tuberosity'
11.18	F	**11**	18	6	1	8.04	8.25
11.18	F	**11**	28	6	1	8.04	7.52
11.29	F	**11**	18	5	1	13.76	13.73
12.6	F	**11**	18	5	1	13.61	13.82
12.18	F	**11**	28	6	1	9.66	9.12
12.30	M	**11**	18	5	1	10.81	10.67
12.34	M	**11**	18	5	1	12.81	12.46

2/3+ of the crown formed

Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-pterygoid'	Space 'M1-tuberosity'
11.2	M	**11**	18	5	2	10.52	11.31
11.2	M	**11**	28	5	2	11.31	10.28
11.8	M	**11**	18	6	2	13.61	13.35
11.8	M	**11**	28	6	2	14.80	14.28
11.25	M	**11**	18	5	2	13.25	13.58
11.25	M	**11**	28	5	2	12.63	12.31
11.26	M	**11**	18	6	2	13.20	13.58
11.26	M	**11**	28	6	2	13.20	14.29
11.28	F	**11**	18	5	2	8.88	9.90
11.28	F	**11**	28	5	2	11.63	11.38
11.29	F	**11**	28	5	2	14.30	14.76
12.2	F	**11**	18	6	2	18.47	17.96
12.2	F	**11**	28	6	2	18.00	17.43
12.3	F	**11**	18	5	2	9.82	11.58
12.3	F	**11**	28	5	2	11.60	10.79
12.8	F	**11**	18	6	2	13.22	12.50
12.8	F	**11**	28	6	2	13.02	11.06
12.9	F	**11**	18	6	2	12.82	13.30
12.10	F	**11**	18	6	2	13.62	12.17
12.10	F	**11**	28	6	2	13.61	13.35
12.18	F	**11**	18	5	2	10.76	10.89
12.30	M	**11**	28	5	2	11.38	10.77
12.33	F	**11**	18	5	2	9.63	9.02
12.33	F	**11**	28	5	2	8.49	9.34
11.7	F	**11**	18	6	3	14.82	15.46
11.7	F	**11**	28	6	3	16.44	15.53
11.14	M	**11**	18	6	3	14.49	16.18
11.14	M	**11**	28	6	3	15.28	15.44
11.15	F	**11**	18	7	3	14.85	14.93
12.9	F	**11**	28	6	3	12.17	12.32
12.17	F	**11**	18	5	3	11.63	12.96
12.17	F	**11**	28	5	3	12.41	12.17
12.20	F	**11**	18	6	3	11.31	12.01
12.20	F	**11**	28	6	3	12.82	13.81

Maxillary Third Molars

Mineralization not in progress

Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-pterygoid'	Space 'M1-tuberosity'
12.11	M	**12**	18	4	0	7.64	9.28
12.11	M	**12**	28	4	0	6.81	7.77
12.23	M	**12**	18	6	0	14.14	13.41
12.23	M	**12**	28	6	0	15.21	13.22
12.29	F	**12**	18	5	0	14.41	12.60
12.31	F	**12**	18	5	0	12.46	11.63
12.31	F	**12**	28	5	0	13.69	13.25
12.32	F	**12**	18	4	0	13.22	13.21
12.32	F	**12**	28	4	0	11.26	11.63
13.12	F	**12**	28	4	0	12.36	11.46
13.13	F	**12**	18	4	0	10.98	9.28
13.13	F	**12**	28	4	0	9.62	10.01
13.28	M	**12**	28	5	0	12.50	13.12
13.43	M	**12**	18	5	0	14.14	13.04
13.43	M	**12**	28	5	0	14.50	12.75
13.49	F	**12**	28	6	0	13.61	13.49
13.58	M	**12**	18	6	0	16.00	12.61
13.58	M	**12**	28	5	0	15.05	12.65

1/3- of the crown formed

Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-pterygoid'	Space 'M1-tuberosity'
12.19	F	**12**	18	6	1	10.41	10.01
12.19	F	**12**	28	6	1	12.46	11.66
12.24	F	**12**	18	5	1	10.81	10.52
12.24	F	**12**	28	5	1	10.43	10.23
13.14	M	**12**	18	5	1	11.08	11.08
13.14	M	**12**	28	5	1	12.31	11.46
13.28	M	**12**	18	6	1	15.60	15.53
13.31	F	**12**	28	5	1	11.79	11.14
13.42	F	**12**	18	5	1	12.06	11.85
13.42	F	**12**	28	5	1	10.80	10.92
13.49	F	**12**	18	6	1	13.42	13.97
13.64	F	**12**	18	6	1	13.62	13.02
13.64	F	**12**	28	6	1	14.41	14.20
12.29	F	**12**	28	5	1	15.37	12.83
13.12	F	**12**	18	5	1	10.12	10.80

2/3+ of the crown formed

Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-pterygoid'	Space 'M1-tuberosity'
12.13	M	**12**	18	7	4	18.29	17.90
12.13	M	**12**	28	7	4	16.57	16.38
12.21	F	**12**	28	6	4	10.75	10.93
13.29	M	**12**	18	6	4	20.42	20.53
13.29	M	**12**	28	6	4	20.28	19.89
12.1	F	**12**	18	5	2	19.60	18.68
12.1	F	**12**	28	5	2	18.80	19.53
12.4	F	**12**	18	6	2	16.32	15.07
12.4	F	**12**	28	6	2	16.78	15.35
12.5	F	**12**	18	6	2	18.06	17.12
12.5	F	**12**	28	6	2	17.53	16.61
12.14	F	**12**	18	6	2	15.05	14.71
12.14	F	**12**	28	6	2	15.28	12.49
12.16	M	**12**	18	6	2	15.61	14.65
12.16	M	**12**	28	6	2	13.55	13.83
12.25	F	**12**	18	5	2	14.85	14.28
12.25	F	**12**	28	5	2	15.78	14.28
12.26	M	**12**	18	6	2	13.20	14.92
12.26	M	**12**	28	6	2	13.20	14.01
13.20	M	**12**	18	5	2	9.94	9.47
13.20	M	**12**	28	5	2	9.32	9.72
13.26	F	**12**	18	4	2	15.30	15.42
13.26	F	**12**	28	4	2	14.58	15.17
13.30	F	**12**	18	6	2	9.97	10.15
13.31	F	**12**	18	5	2	12.34	12.77
13.33	F	**12**	18	5	2	13.65	14.46
13.33	F	**12**	28	5	2	14.29	13.42
13.40	F	**12**	18	6	2	12.90	11.13
13.40	F	**12**	28	6	2	12.63	11.54
13.45	M	**12**	18	5	2	16.52	15.85
13.45	M	**12**	28	5	2	14.76	14.61
13.51	F	**12**	28	6	2	15.33	15.20
13.55	F	**12**	18	5	2	13.31	12.31
13.55	F	**12**	28	5	2	12.75	12.62
13.66	F	**12**	18	7	2	17.20	16.70
13.66	F	**12**	28	7	2	16.02	16.79
12.15	F	**12**	18	6	3	10.20	12.15

Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-pterygoid'	Space 'M1-tuberosity'	Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-pterygoid'	Space 'M1-tuberosity'	Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-pterygoid'	Space 'M1-tuberosity'
Mineralization not in progress								**1/3- of the crown formed**								**2/3+ of the crown formed**							
Maxillary Third Molars																							
																12.15	F	**12**	28	6	3	10.82	11.55
																12.21	F	**12**	18	6	3	11.25	11.39
																12.27	M	**12**	18	6	3	15.62	16.18
																12.27	M	**12**	28	6	3	13.60	14.28
																13.5	F	**12**	18	7	3	18.40	16.21
																13.5	F	**12**	28	7	3	19.22	19.61
																13.11	M	**12**	18	6	3	14.26	13.93
																13.11	M	**12**	28	6	3	12.95	12.75
																13.15	M	**12**	18	6	3	12.40	12.71
																13.15	M	**12**	28	6	3	12.80	12.53
																13.19	M	**12**	18	6	3	15.53	14.45
																13.19	M	**12**	28	6	3	16.00	16.92
																13.25	M	**12**	18	6	3	18.02	18.16
																13.25	M	**12**	28	6	3	18.04	18.84
																13.27	M	**12**	18	6	3	12.76	13.70
																13.27	M	**12**	28	6	3	14.02	14.53
																13.30	F	**12**	28	6	3	12.31	12.77
																13.44	F	**12**	18	6	3	15.22	15.33
																13.44	F	**12**	28	6	3	14.40	13.89
																13.51	F	**12**	18	6	3	15.22	14.82
																13.61	M	**12**	18	6	3	17.77	17.47
																13.61	M	**12**	28	6	3	17.03	17.43
																13.62	F	**12**	18	5	3	14.42	14.23
																13.62	F	**12**	28	5	3	15.24	15.18
																13.65	M	**12**	18	6	3	16.40	16.97
																13.65	M	**12**	28	6	3	17.20	16.71

Mandibular Third Molars

Mineralization not in progress

Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-foramen'	Space 'M1-ramus'
8.1	M	**8**	38	3	0	22.96	9.71
8.1	M	**8**	48	3	0	22.06	8.00
8.3	M	**8**	48	4	0	23.08	8.32
8.4	F	**8**	38	3	0	23.30	10.65
8.4	F	**8**	48	3	0	23.27	12.90
8.6	M	**8**	38	3	0	22.69	6.18
8.6	M	**8**	48	3	0	22.39	8.82
8.11	F	**8**	48	2	0	22.16	10.60
9.5	M	**8**	38	3	0	22.73	7.69
9.5	M	**8**	48	3	0	23.27	7.55
9.7	M	**8**	38	7	0	20.42	5.12
9.12	F	**8**	38	4	0	22.95	9.22
9.12	F	**8**	48	4	0	23.64	9.01
9.8	M	**9**	38	3	0	23.43	7.03
9.8	M	**9**	48	3	0	22.55	6.33
9.11	M	**9**	38	4	0	23.80	7.78
9.11	M	**9**	48	3	0	23.89	7.74
10.3	F	**9**	38	3	0	23.72	7.99
10.3	F	**9**	48	3	0	23.72	5.51
10.9	M	**9**	38	2	0	22.64	8.44
10.9	M	**9**	48	2	0	24.76	8.44
10.10	F	**9**	38	4	0	21.76	8.25
10.10	F	**9**	48	4	0	24.09	7.12
10.11	F	**9**	38	5	0	22.64	7.21
10.11	F	**9**	48	5	0	21.84	7.16

1/3- of the crown formed

Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-foramen'	Space 'M1-ramus'
8.2	F	**8**	38	3	1	27.07	8.99
8.2	F	**8**	48	3	1	26.63	10.77
8.10	M	**8**	38	4	1	22.86	8.80
8.10	M	**8**	48	4	1	22.21	9.20
9.13	M	**8**	38	4	1	23.16	6.90
9.13	M	**8**	48	4	1	23.63	6.96
8.3	M	**8**	38	4	1	22.41	7.21
8.7	F	**8**	38	3	1	23.64	8.25
8.7	F	**8**	48	3	1	23.80	8.32
9.1	M	**9**	38	5	1	23.44	10.75
9.1	M	**9**	48	5	1	24.06	9.99
9.2	M	**9**	38	5	1	24.97	8.88
9.2	M	**9**	48	5	1	24.52	8.65
9.4	F	**9**	38	3	1	22.92	7.69
9.4	F	**9**	48	3	1	23.98	7.89
9.9	F	**9**	48	3	1	22.74	9.68
9.14	F	**9**	38	5	1	24.97	9.84
9.14	F	**9**	48	5	1	26.71	9.57
10.6	F	**9**	38	5	1	23.24	8.76
10.6	F	**9**	48	5	1	24.73	11.16
10.15	M	**9**	38	5	1	25.26	8.16
10.15	M	**9**	48	5	1	24.55	9.07
9.9	F	**9**	38	3	1	23.20	10.00

2/3+ of the crown formed

Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-foramen'	Space 'M1-ramus'
9.7	M	**8**	48	7	3	18.66	5.01

Mandibular Third Molars

Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-foramen'	Space 'M1-ramus'
Mineralization not in progress							
10.4	M	**10**	38	3	0	22.98	8.41
10.4	M	**10**	48	3	0	22.56	7.08
10.13	F	**10**	48	4	0	25.68	11.50
10.17	F	**10**	38	6	0	25.56	11.37
10.17	F	**10**	48	6	0	25.31	11.23
11.3	M	**10**	38	3	0	22.43	9.68
11.3	M	**10**	48	3	0	22.78	7.34
11.27	F	**10**	38	3	0	22.52	7.21
11.27	F	**10**	48	3	0	21.86	7.77

Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-foramen'	Space 'M1-ramus'
1/3- of the crown formed							
10.13	F	**10**	38	4	1	27.58	11.83
10.16	F	**10**	48	5	1	25.00	11.79
10.2	F	**10**	38	6	1	22.30	8.75
11.1	F	**10**	38	6	1	25.30	10.98
11.1	F	**10**	48	6	1	25.74	10.74
11.12	F	**10**	38	5	1	25.03	10.26
11.12	F	**10**	48	5	1	23.80	9.30
11.16	M	**10**	38	5	1	24.49	10.55
11.16	M	**10**	48	5	1	23.67	8.75
11.17	M	**10**	38	3	1	22.19	8.55
11.17	M	**10**	48	3	1	21.75	9.54
11.19	M	**10**	38	5	1	23.58	9.65
11.19	M	**10**	48	5	1	24.50	8.05
11.20	M	**10**	38	5	1	24.97	10.15
11.20	M	**10**	48	5	1	25.74	14.34
11.22	M	**10**	38	5	1	29.75	10.97
11.22	M	**10**	48	5	1	29.58	11.56
11.23	F	**10**	38	5	1	20.62	8.73
11.23	F	**10**	48	5	1	22.95	10.85
11.4	F	**10**	38	6	1	23.67	15.78
11.5	F	**10**	38	5	1	25.30	10.65
11.5	F	**10**	48	5	1	23.96	9.85

Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-foramen'	Space 'M1-ramus'
2/3+ of the crown formed							
10.2	F	**10**	48	5	2	23.15	8.75
10.5	M	**10**	38	5	2	25.59	9.86
10.5	M	**10**	48	5	2	26.84	8.76
10.7	M	**10**	38	5	2	26.35	9.42
10.7	M	**10**	48	5	2	28.50	10.68
10.8	M	**10**	38	6	2	24.53	9.86
10.16	F	**10**	38	5	2	26.35	11.55
11.4	F	**10**	48	6	2	24.32	13.54
11.11	F	**10**	38	6	2	28.20	15.78
11.11	F	**10**	48	6	2	28.28	16.46
11.10	F	**10**	38	6	3	27.99	14.89
11.10	F	**10**	48	6	3	28.26	15.74

Mandibular Third Molars

Mineralization not in progress

Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space ‘M1-foramen’	Space ‘M1-ramus’
11.6	M	**11**	38	5	0	21.30	8.97
11.13	M	**11**	38	6	0	26.37	12.65
11.13	M	**11**	48	6	0	28.34	13.80
11.21	M	**11**	38	5	0	22.98	8.88
11.24	M	**11**	38	6	0	26.51	11.54
11.24	M	**11**	48	6	0	26.09	11.87
11.6	M	**11**	48	5	0	22.49	11.12
12.22	M	**11**	38	3	0	23.38	8.24
12.22	M	**11**	48	3	0	24.06	8.41
12.34	M	**11**	38	6	0	24.08	13.31
12.34	M	**11**	48	6	0	25.74	14.20
12.6	M	**11**	38	6	0	25.20	12.88
12.7	M	**11**	38	2	0	19.36	7.43

1/3- of the crown formed

Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space ‘M1-foramen’	Space ‘M1-ramus’
11.21	M	**11**	48	5	1	23.75	8.88
11.28	M	**11**	38	5	1	24.30	9.33
11.28	M	**11**	48	5	1	25.19	9.33
11.29	M	**11**	48	6	1	30.33	13.09
11.8	M	**11**	38	6	1	28.32	14.88
11.8	M	**11**	48	6	1	27.99	13.45
11.9	M	**11**	38	5	1	25.10	11.37
12.10	M	**11**	38	6	1	26.69	11.81
12.10	M	**11**	48	6	1	27.78	12.01
12.12	M	**11**	38	6	1	26.63	13.10
12.18	M	**11**	38	5	1	22.27	10.75
12.18	M	**11**	48	5	1	22.88	10.00
12.30	M	**11**	38	6	1	28.98	12.88
12.30	M	**11**	48	6	1	29.51	13.31
12.33	M	**11**	38	5	1	24.52	10.38
12.33	M	**11**	48	5	1	24.52	9.54
12.6	M	**11**	48	6	1	25.07	12.43
12.7	M	**11**	48	2	1	20.11	8.05

2/3+ of the crown formed

Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space ‘M1-foramen’	Space ‘M1-ramus’
11.14	M	**11**	38	6	3	30.66	17.37
11.14	M	**11**	48	6	3	30.74	17.09
11.15	M	**11**	38	7	2	28.84	15.31
11.15	M	**11**	48	7	2	28.64	16.65
11.18	M	**11**	38	5	2	23.75	11.87
11.18	M	**11**	48	5	2	25.66	14.14
11.25	M	**11**	38	5	2	28.73	12.35
11.25	M	**11**	48	5	2	30.72	13.99
11.26	M	**11**	38	6	2	27.93	12.56
11.26	M	**11**	48	6	2	29.68	13.44
11.29	M	**11**	38	6	2	31.64	14.45
11.7	M	**11**	38	6	2	16.75	29.73
11.9	M	**11**	48	5	2	24.78	12.01
12.12	M	**11**	48	6	2	27.86	13.31
12.17	M	**11**	38	6	2	27.74	12.76
12.17	M	**11**	48	6	2	25.41	12.76
12.2	M	**11**	38	6	2	31.95	14.65
12.2	M	**11**	48	6	2	31.29	15.65
12.20	M	**11**	38	6	2	28.09	13.21
12.20	M	**11**	48	6	3	27.93	15.04
12.3	M	**11**	38	6	2	24.72	9.96
12.3	M	**11**	48	6	2	28.19	10.85
12.8	M	**11**	38	6	2	27.18	11.87
12.8	M	**11**	48	6	2	27.04	11.81
12.9	M	**11**	38	6	2	23.41	9.21
12.9	M	**11**	48	6	2	22.52	9.88

Mandibular Third Molars

Mineralization not in progress

Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-foramen'	Space 'M1-ramus'
12.11	M	**12**	38	5	0	25.76	12.00
12.11	M	**12**	48	5	0	28.07	14.09
12.25	F	**12**	48	6	0	25.86	18.53
12.31	F	**12**	38	5	0	27.86	9.33
12.32	F	**12**	38	4	0	25.25	10.02
12.32	F	**12**	48	4	0	25.31	9.33
13.43	M	**12**	48	6	0	28.96	15.33
13.51	F	**12**	38	6	0	28.74	17.86
13.64	F	**12**	48	6	0	24.00	12.56

1/3- of the crown formed

Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-foramen'	Space 'M1-ramus'
12.26	M	**12**	38	6	1	25.81	14.40
12.29	F	**12**	38	5	1	27.95	13.74
12.29	F	**12**	48	5	1	30.37	14.82
12.31	F	**12**	48	5	1	26.00	11.11
12.4	F	**12**	48	6	1	28.04	14.15
12.5	F	**12**	48	6	1	25.68	11.83
13.14	M	**12**	48	5	1	26.10	9.18
13.20	M	**12**	48	4	1	25.55	9.98
13.28	M	**12**	48	6	1	24.01	10.76
13.42	F	**12**	38	6	1	26.29	13.65
13.42	F	**12**	48	6	1	25.85	14.09
13.43	M	**12**	38	6	1	29.31	15.66
13.45	M	**12**	48	5	1	26.14	14.56
13.49	F	**12**	38	6	1	26.69	15.12
13.49	F	**12**	48	6	1	29.57	15.12
13.51	F	**12**	48	6	1	25.76	15.76
13.55	F	**12**	38	6	1	27.25	13.73
13.58	M	**12**	48	6	1	29.70	12.70
13.62	F	**12**	38	6	1	29.58	14.06
13.62	F	**12**	48	6	1	30.84	12.42
13.64	F	**12**	38	6	1	25.07	14.42

2/3+ of the crown formed

Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-foramen'	Space 'M1-ramus'
12.1	F	**12**	38	5	2	34.53	15.56
12.1	F	**12**	48	5	2	33.95	13.67
12.13	M	**12**	38	7	5	33.22	17.82
12.13	M	**12**	48	7	5	33.50	16.51
12.14	F	**12**	38	6	2	32.59	13.99
12.14	F	**12**	48	6	2	33.35	13.43
12.15	F	**12**	38	6	3	28.50	12.84
12.15	F	**12**	48	6	3	26.58	12.00
12.16	M	**12**	38	6	2	30.34	13.02
12.16	M	**12**	48	6	2	30.15	12.66
12.19	F	**12**	38	6	2	28.45	14.31
12.19	F	**12**	48	6	2	29.88	14.49
12.21	F	**12**	38	6	4	28.51	10.53
12.21	F	**12**	48	6	4	29.47	11.45
12.23	M	**12**	38	6	3	29.53	14.32
12.23	M	**12**	48	6	3	31.29	14.76
12.24	F	**12**	38	6	2	27.65	14.54
12.24	F	**12**	48	6	2	29.64	15.09
12.25	F	**12**	38	7	3	23.12	12.24
12.26	M	**12**	48	6	2	26.89	12.90
12.27	M	**12**	38	6	3	30.53	16.54
12.27	M	**12**	48	6	3	29.72	15.39
12.4	F	**12**	38	6	2	30.09	16.22
12.5	F	**12**	38	6	2	29.87	16.22
13.11	M	**12**	38	6	3	29.70	16.80
13.11	M	**12**	48	6	3	31.77	16.85
13.12	F	**12**	38	5	2	25.96	12.98
13.12	F	**12**	48	5	2	26.71	13.23
13.13	F	**12**	38	6	2	29.22	14.89
13.13	F	**12**	48	6	2	29.51	14.76
13.15	M	**12**	38	6	3	31.21	15.98
13.15	M	**12**	48	6	3	32.21	18.07
13.19	M	**12**	38	7	3	30.87	16.88
13.19	M	**12**	48	7	3	30.27	17.56
13.25	M	**12**	38	6	3	35.44	18.61
13.25	M	**12**	48	6	3	35.33	19.00
13.26	F	**12**	38	6	2	30.10	14.15
13.26	F	**12**	48	6	2	28.97	14.55
13.27	M	**12**	38	6	2	27.27	10.82
13.27	M	**12**	48	6	2	26.52	10.62
13.28	M	**12**	38	6	2	28.94	15.13

Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-foramen'	Space 'M1-ramus'	Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-foramen'	Space 'M1-ramus'	Patient ID#	Sex	**Age (years)**	M3 / quadrant studied	M2 formation status	M3 formation status	Space 'M1-foramen'	Space 'M1-ramus'
Mineralization not in progress								**1/3- of the crown formed**								**2/3+ of the crown formed**							
Mandibular Third Molars																							
																13.29	M	**12**	38	6	3	34.22	18.32
																13.29	M	**12**	48	6	3	32.47	18.39
																13.30	F	**12**	38	6	3	28.05	16.98
																13.31	F	**12**	38	5	2	23.41	11.88
																13.31	F	**12**	48	5	2	25.87	15.19
																13.40	F	**12**	38	6	2	25.53	13.43
																13.40	F	**12**	48	6	2	27.46	12.15
																13.44	F	**12**	38	6	2	26.50	12.71
																13.44	F	**12**	48	6	2	29.43	14.89
																13.45	M	**12**	38	6	2	31.01	16.17
																13.5	F	**12**	38	7	3	37.24	20.59
																13.5	F	**12**	48	7	3	36.72	18.97
																13.55	F	**12**	48	6	2	25.34	13.89
																13.58	M	**12**	38	6	2	32.32	16.32
																13.61	M	**12**	38	6	3	32.40	19.27
																13.61	M	**12**	48	6	3	32.11	16.91
																13.65	M	**12**	38	6	3	35.88	19.76
																13.65	M	**12**	48	6	3	34.09	18.11
																13.66	F	**12**	38	7	2	30.96	17.31
																13.66	F	**12**	48	7	2	29.72	15.39

APPENDIX C
GROUP OF INDIVIDUALS AGED 17 TO 24 YEARS
ORIGINAL RAW DATA

The data obtained from the study of the group of subjects aged 17 to 24 years was analyzed to test hypotheses I, II, III, and IV of the present research project.

The original data and measurements taken from CBCT images of the subjects included in this group are shown in the next pages of this appendix.

Patient ID#	Sex	Age	18/28	M3 present?	M-D tilt	B-L tilt	M3 Impacted?	Arch type	Width	Depth	Crowding?	PM1	PM2	M1	M2	M3	M2-Pterygoid	M2-tuberosity	Excl. factors
								Dental Arch				M-D Crown Length							
Maxillary third molars																			
17.3	F	17	18	Yes	D	*	YES	O	56.40	43.20	NO	6.46	5.95	9.51	9.62	9.13	6.00	5.82	
17.3	F	17	28	Yes	D	*	YES	O	56.40	43.20	NO	6.71	6.09	10.03	10.20	9.62	6.01	5.26	
17.6	M	17	18	Yes	M	*	YES	S	60.40	40.80	NO	6.45	6.45	9.33	9.51	9.12	12.03	9.41	
17.6	M	17	28	Yes	M	B	YES	S	60.40	40.80	NO	6.84	6.09	9.44	9.88	9.34	11.66	9.67	
17.7	M	17	18	Yes	D	*	YES	O	60.25	47.75	YES	7.06	7.36	9.89	9.10	9.78	10.05	9.33	
17.7	M	17	28	Yes	D	*	YES	O	60.25	47.75	YES	7.11	7.65	9.80	9.28	10.26	9.12	7.75	
17.9	F	17	18	Yes	M	*	YES	OW	58.41	42.00	NO	6.45	5.91	9.30	9.28	7.47	8.16	7.30	
17.9	F	17	28	Yes	M	*	YES	OW	58.41	42.00	NO	6.60	5.82	9.30	9.02	8.41	7.59	6.41	
17.10	M	17	18	Yes	*	B	YES	O	54.40	39.20	NO	6.09	6.26	8.62	8.35	8.00	9.67	7.77	
17.10	M	17	28	Yes	*	B	YES	O	54.40	39.20	NO	6.32	6.32	9.12	8.48	8.44	8.40	8.49	
17.14	M	17	28	Yes	*	*	YES	O	58.80	45.20	NO	7.34	6.80	9.51	9.20	8.81	9.23	8.01	
17.16	M	17	18	Yes	*	*	YES	O	51.20	40.00	NO	6.91	6.45	9.67	9.61	6.99	8.04	7.77	
17.16	M	17	28	Yes	M	*	YES	O	51.20	40.00	NO	6.84	6.62	9.77	9.67	7.89	7.61	7.61	
17.18	M	17	18	Yes	*	*	YES	O	57.60	47.60	NO	7.00	6.45	10.12	9.36	9.02	10.81	10.98	
17.18	M	17	28	Yes	*	*	YES	O	57.60	47.60	NO	7.21	6.46	10.00	10.25	8.84	12.17	11.23	
17.19	M	17	18	Yes	D	*	YES	T	65.00	45.00	NO	7.62	6.93	10.29	9.73	8.31	7.95	6.25	
17.19	M	17	28	Yes	D	*	YES	T	65.00	45.00	NO	7.62	7.39	10.18	10.08	9.39	7.95	7.22	
17.21	M	17	18	Yes	*	B	YES	O	60.80	46.00	NO	6.80	7.21	9.88	10.12	9.21	7.69	7.09	
17.21	M	17	28	Yes	D	B	YES	O	60.80	46.00	NO	6.80	7.21	9.90	10.20	8.44	9.14	6.85	
17.24	M	17	18	Yes	*	B	YES	O	59.60	45.20	NO	7.34	6.62	10.12	9.90	9.67	11.31	10.20	
17.24	M	17	28	Yes	*	*	YES	O	59.60	45.20	NO	7.16	6.99	10.25	9.67	9.61	11.23	10.47	
17.26	M	17	18	Yes	D	B	YES	…	…	…	…	6.45	5.44	9.14	9.12	8.77	6.81	5.66	
17.32	F	17	18	Yes	D	*	YES	O	55.20	46.00	NO	6.62	6.62	9.88	9.12	9.51	7.38	6.91	
17.32	F	17	28	Yes	D	*	YES	O	55.20	46.00	NO	6.91	6.51	9.74	9.81	9.90	8.04	7.77	
17.36	F	17	18	Yes	D	B	YES	S	54.40	42.00	YES	6.99	7.21	10.02	9.30	10.32	4.95	4.18	
17.36	F	17	28	Yes	D	B	YES	S	54.40	42.00	YES	6.99	6.84	10.12	9.36	10.38	5.44	3.69	
17.37	F	17	18	Yes	*	B	NO	O	54.00	42.00	NO	6.56	5.94	9.41	9.22	6.58	10.75	10.20	
17.37	F	17	28	Yes	M	*	YES	O	54.00	42.00	NO	6.43	6.37	8.96	8.54	7.49	10.53	9.33	
17.39	M	17	18	Yes	D	*	YES	…	…	…	…	7.35	7.44	11.21	10.47	10.13	11.01	6.99	
17.42	M	17	18	Yes	*	*	YES	O	57.00	45.00	NO	6.82	6.41	10.44	9.65	10.00	11.52	10.57	
17.42	M	17	28	Yes	D	*	YES	O	57.00	45.00	NO	6.79	6.18	9.96	9.52	9.75	9.50	9.71	
17.43	M	17	18	Yes	*	B	NO	O	58.00	45.00	NO	7.52	6.26	9.74	8.85	8.41	12.11	10.20	
17.43	M	17	28	Yes	*	B	NO	O	58.00	45.00	NO	7.21	6.46	9.88	8.63	8.63	13.75	12.06	
18.1	F	17	18	Yes	D	B	YES	O	58.00	48.00	YES	7.70	8.61	10.83	10.36	9.58	7.79	7.54	
18.1	F	17	28	Yes	D	B	YES	O	58.00	48.00	YES	7.52	7.22	10.51	9.82	11.07	9.66	7.27	
18.7	F	17	18	Yes	D	*	YES	O	55.00	41.00	NO	6.46	6.46	9.51	8.99	10.32	7.30	6.45	
18.7	F	17	28	Yes	D	*	YES	O	55.00	41.00	NO	6.62	6.46	9.74	8.77	9.33	6.62	6.05	
18.13	M	17	18	Yes	*	B	YES	S	56.80	40.40	YES	6.84	6.09	9.67	8.77	9.28	9.61	8.25	
18.13	M	17	28	Yes	M	B	YES	S	56.80	40.40	YES	7.21	5.91	9.88	9.23	8.74	10.01	8.55	
18.26	M	17	18	Yes	*	*	YES	O	48.75	38.75	YES	7.91	6.71	9.98	9.10	8.84	8.84	6.25	
18.26	M	17	28	Yes	*	*	YES	O	48.75	38.75	YES	7.52	6.25	10.74	9.50	9.25	6.25	6.29	
18.29	M	17	18	Yes	D	B	YES	O	56.40	46.00	NO	6.84	6.46	10.12	10.25	9.30	9.23	8.44	
18.29	M	17	28	Yes	D	B	YES	O	56.40	46.00	NO	6.99	6.32	10.20	10.12	9.67	8.16	7.69	
18.10	M	18	18	Yes	*	*	YES	O	52.00	43.60	NO	6.71	6.46	9.37	10.00	8.84	5.66	5.34	
18.10	M	18	28	Yes	*	*	YES	O	52.00	43.60	NO	6.51	6.60	9.88	10.77	9.90	6.01	5.26	
18.11	F	18	18	Yes	*	*	YES	OW	56.00	37.00	NO	6.50	6.04	9.66	8.73	9.17	11.00	10.75	
18.11	F	18	28	Yes	*	*	YES	OW	56.00	37.00	NO	6.80	5.62	9.19	8.72	8.51	10.05	9.22	

							Dental Arch				M-D Crown Length							
Patient ID#	Sex	Age	18/28	M-D tilt	B-L tilt	M3 impacted?	Arch type	Width	Depth	Crowding?	PM1	PM2	M1	M2	M3	M2-Pterygoid	M2-tuberosity	Excl. factors
Maxillary third molars																		
18.14	M	18	18	D	B	YES	O	56.00	43.00	NO	7.12	6.97	10.06	9.40	9.65	12.25	10.13	
18.14	M	18	28	D	B	YES	O	56.00	43.00	NO	7.16	6.49	10.35	9.60	10.18	12.17	10.08	
18.18	F	18	18	*	*	YES	T	59.25	44.25	NO	7.29	7.20	10.41	9.73	9.83	9.06	8.25	
18.18	F	18	28	*	*	YES	T	59.25	44.25	NO	7.08	7.38	10.74	10.12	9.55	10.25	8.81	
18.20	F	18	18	*	*	YES	O	53.00	43.00	NO	7.04	6.60	9.62	9.65	8.50	7.50	6.86	
18.20	F	18	28	D	*	YES	O	53.00	43.00	NO	6.80	6.32	9.89	9.83	7.89	5.84	5.77	
18.30	M	18	18	*	B	YES	OW	60.00	45.00	NO	7.11	6.59	9.79	9.93	6.12	8.92	6.41	
18.30	M	18	28	D	*	YES	OW	60.00	45.00	NO	7.16	6.59	10.53	10.57	8.82	10.71	9.72	
18.31	F	18	18	D	*	YES	O	60.00	43.00	NO	7.00	6.45	9.62	10.01	9.63	6.09	2.04	
18.31	F	18	28	D	B	YES	O	60.00	43.00	NO	6.99	6.62	9.74	9.67	10.03	7.21	3.42	
19.2	F	18	28	D	L	YES	O	58.00	40.40	NO	6.32	6.32	9.34	8.88	7.86	8.01	7.64	
19.5	F	18	18	D	B	YES	O	50.50	42.75	NO	6.43	6.01	9.17	9.41	9.17	8.68	7.81	
19.5	F	18	28	D	B	YES	O	50.50	42.75	NO	6.56	6.41	8.96	9.25	9.00	9.10	7.11	
19.11	F	18	18	D	B	YES	O	55.00	42.00	NO	6.32	6.32	9.51	9.41	9.02	5.82	5.61	
19.11	F	18	28	D	B	YES	O	55.00	42.00	NO	6.84	6.84	9.23	8.35	9.67	5.57	4.95	
19.4	F	19	18	D	*	YES	O	56.50	42.00	NO	6.04	7.12	9.75	9.98	9.95	9.30	9.55	
19.4	F	19	28	D	*	YES	O	56.50	42.00	NO	7.04	6.88	9.95	9.39	9.65	7.67	7.00	
19.6	M	19	28	*	B	NO	…	…	…	…	6.60	6.99	9.34	9.34	9.12	10.01	9.60	
19.8	F	19	18	*	*	YES	S	54.00	39.60	NO	6.09	5.73	10.02	8.77	8.84	10.03	8.25	
19.8	F	19	28	*	B	YES	S	54.00	39.60	NO	6.09	5.91	9.30	9.12	9.02	12.03	7.21	
19.10	M	19	18	D	B	YES	…	…	…	…	6.46	6.46	9.88	9.67	10.03	6.41	6.41	AI
19.10	M	19	28	D	B	YES	…	…	…	…	6.09	6.26	10.20	9.48	8.25	3.30	3.30	AI
19.12	M	19	18	D	B	YES	O	59.20	42.80	YES	7.00	6.99	10.22	10.56	8.88	12.15	7.77	
19.12	M	19	28	D	*	YES	O	59.20	42.80	YES	7.69	7.24	10.88	10.00	10.00	11.66	11.66	
20.1	F	19	18	D	*	YES	OW	56.40	41.20	NO	6.46	6.09	9.51	9.12	7.89	8.74	7.64	
20.4	F	19	28	D	*	YES	O	55.50	45.00	NO	6.58	6.18	9.79	9.64	8.08	7.13	6.00	
20.6	F	19	18	D	B	YES	…	…	…	…	6.21	6.05	10.12	9.62	8.41	7.09	5.60	
20.6	F	19	28	D	B	YES	…	…	…	…	6.32	6.46	9.67	9.51	8.40	6.71	5.66	AI
20.11	M	19	18	D	B	YES	OW	59.00	43.25	NO	6.71	6.50	10.44	9.50	9.53	6.79	5.15	
20.11	M	19	28	*	*	YES	OW	59.00	43.25	NO	6.39	6.45	10.18	9.51	9.57	8.49	5.84	
20.14	F	19	18	D	B	YES	OW	56.40	41.20	NO	6.09	5.57	9.62	8.85	8.65	10.20	7.69	
20.14	F	19	28	D	B	YES	OW	56.40	41.20	NO	5.95	6.32	9.51	9.28	8.77	11.52	6.40	
20.15	M	19	28	D	*	YES	O	56.00	42.40	NO	6.99	6.80	10.38	8.84	9.90	6.21	5.26	
20.9	M	20	18	*	B	NO	O	63.60	49.20	NO	7.69	6.99	10.63	10.98	8.41	12.03	7.61	
20.9	M	20	28	D	B	NO	O	63.60	49.20	NO	8.05	7.69	11.38	10.98	8.74	11.46	4.95	
20.12	F	20	18	*	B	NO	T	54.40	43.20	NO	6.21	5.95	9.74	8.63	8.81	11.93	9.28	
20.12	F	20	28	*	B	NO	T	54.40	43.20	NO	5.95	6.21	9.30	8.94	9.12	11.21	10.52	
20.13	M	20	18	*	*	YES	OW	56.70	42.30	NO	6.18	5.79	9.30	9.18	7.20	8.49	7.06	
20.13	M	20	28	D	*	YES	OW	56.70	42.30	NO	6.36	6.18	9.60	8.72	7.31	7.80	7.35	
20.18	M	20	18	D	B	NO	T	53.60	43.60	NO	6.32	6.09	9.67	9.23	6.99	10.41	10.01	
20.19	M	20	18	D	*	YES	…	…	…	…	6.99	6.51	10.28	10.25	9.62	9.20	8.81	
20.21	F	20	18	*	B	YES	T	52.80	41.20	NO	6.46	6.46	9.14	8.85	9.02	12.90	11.66	
20.21	F	20	28	*	B	YES	T	52.80	41.20	NO	6.26	6.09	9.51	8.85	8.85	13.65	12.11	
20.22	F	20	18	*	B	YES	OW	54.80	43.20	NO	6.84	6.45	9.48	9.02	8.84	9.34	8.88	
20.22	F	20	28	D	B	YES	OW	54.80	43.20	NO	6.62	6.84	9.88	8.94	8.85	9.73	8.84	
21.18	F	20	28	D	B	YES	O	58.00	49.26	NO	7.43	7.28	10.51	10.44	11.21	7.04	7.04	
21.1	M	21	18	*	*	YES	O	60.40	45.20	NO	6.99	7.21	10.93	10.50	10.03	9.73	8.94	

Patient ID#	Sex	Age	18/28	M-D tilt	B-L tilt	M3 Impacted?	Arch type	Width	Depth	Crowding?		PM1	PM2	M1	M2	M3	M2-Pterygoid	M2-tuberosity	Excl. factors
							Dental Arch					M-D Crown Length							
Maxillary third molars																			
21.14	F	21	18	*	B	NO	O	58.00	40.40	NO		6.71	7.21	9.51	8.62	8.48	12.82	11.31	
21.14	F	21	28	*	B	NO	O	58.00	40.40	NO		6.46	6.62	9.36	9.62	8.85	11.45	10.40	
22.3	F	22	28	*	B	YES	OW	59.20	42.80	NO		6.62	6.84	10.50	9.36	8.59	8.99	7.24	
22.10	F	22	18	*	B	YES	O	54.40	43.20	NO		5.95	6.09	9.74	9.62	10.43	9.51	6.91	
22.10	F	22	28	M	B	YES	O	54.40	43.20	NO		6.46	6.21	10.12	9.36	10.43	9.73	6.51	
22.11	F	22	28	D	B	YES	…	…	…	…		6.97	6.43	10.68	9.41	9.74	8.10	7.32	
23.2	F	23	18	*	B	NO	O	58.80	46.00	NO		6.46	6.84	9.90	9.63	9.61	14.49	14.45	
23.2	F	23	28	*	B	NO	O	58.80	46.00	NO		6.71	6.99	9.36	9.67	9.62	12.56	11.26	
23.4	F	23	18	D	*	YES	O	57.60	43.60	NO		6.51	6.46	10.12	9.73	9.63	6.00	6.01	
23.4	F	23	28	D	*	YES	O	57.60	43.60	NO		6.62	7.16	*	*	*	7.20	6.41	RE
23.9	M	23	18	*	*	YES	OW	60.80	43.20	NO		5.95	5.95	10.65	9.23	9.63	8.41	4.87	
23.9	M	23	28	*	*	YES	OW	60.80	43.20	NO		6.09	6.09	10.07	9.20	9.23	10.03	7.30	
23.11	M	23	18	*	B	YES	O	54.40	41.60	YES		6.32	7.00	8.94	8.80	7.47	11.38	10.80	
23.11	M	23	28	*	B	YES	O	54.40	41.60	YES		5.95	5.77	8.85	8.44	8.09	9.63	8.84	
24.9	F	23	28	*	*	YES	*	*	*	NO	*	*	*	9.30	9.51	8.44	9.02	7.61	AM
24.14	F	23	28	*	B	NO	O	52.00	42.75	NO		6.73	6.49	10.13	9.41	8.49	9.91	8.50	
24.12	F	24	28	M	*	YES	O	57.20	40.80	NO		6.71	6.09	9.13	9.62	8.41	7.47	6.05	

AI: Absence of incisive(s)
AC: Absence of Canine(s)
AM: Absence of premolar(s) and/or molar(s)
IM: Imperfections in CBCT image
RE: Major restoration(s) observed
LE: Lesions or osseous defects observed
JA: Jaw not covered by CBCT image
* : No/ not applicable

Patient ID#	Sex	Age	38/48		M-D tilt	B-L tilt	M3 impacted?	Arch type	Width	Depth	Crowding?	PM1	PM2	M1	M2	M3	M2-Pterygoid	M2-tuberosity	Excl. factors
								Dental Arch				M-D Crown Length							
Mandibular Third Molars																			
17.3	F	17	38	Y	M	L	YES	S	55.60	40.40	NO	6.99	7.21	10.63	11.01	11.27	19.57	8.21	
17.3	F	17	48	Y	M	L	YES	S	55.60	40.40	NO	6.25	6.88	10.63	10.73	10.81	17.82	7.08	
17.6	M	17	38	Y	M	L	YES	S	60.00	36.80	YES	*	*	*	*	*	21.87	9.94	IM
17.6	M	17	48	Y	M	L	YES	S	60.00	36.80	YES	*	*	*	*	*	21.50	11.31	IM
17.9	F	17	38	Y	M	L	YES	O	57.60	41.20	NO	6.26	6.84	9.51	10.87	10.65	20.40	5.37	
17.9	F	17	48	Y	M	L	YES	O	57.60	41.20	NO	6.56	6.45	10.03	10.38	9.94	20.31	7.00	
17.10	M	17	38	Y	M	L	NO	O	55.60	38.40	NO	6.62	6.32	10.50	10.52	10.93	26.17	12.24	
17.10	M	17	48	Y	M	L	NO	O	55.60	38.40	NO	6.62	6.26	10.77	9.84	10.56	26.17	11.37	
17.14	M	17	38	Y	M	L	YES	O	59.60	41.20	NO	7.16	7.21	10.28	11.26	11.37	21.12	8.00	
17.14	M	17	48	Y	M	L	YES	O	59.60	41.20	NO	7.12	7.16	11.09	10.59	10.88	20.44	6.81	
17.15	M	17	38	Y	M	L	YES	O	60.50	47.00	NO	7.08	7.67	11.23	12.19	11.17	20.91	7.97	
17.15	M	17	48	YY	M	L	YES	O	60.50	47.00	NO	7.38	7.29	11.30	11.86	11.10	19.65	7.30	
17.16	M	17	38	Y	M	L	YES	S	62.00	42.00	NO	7.55	7.44	10.77	10.73	9.77	16.65	3.44	
17.16	M	17	48	Y	M	L	YES	S	62.00	42.00	NO	7.92	7.44	10.57	10.93	9.63	16.56	7.44	
17.18	M	17	38	Y	M	L	YES	O	55.20	45.60	NO	7.59	7.35	11.06	12.17	12.19	25.74	9.54	
17.18	M	17	48	Y	M	L	YES	O	55.20	45.60	NO	7.34	7.73	11.14	11.82	12.17	25.85	8.32	
17.19	M	17	38	Y	M	L	YES	O	62.50	44.25	NO	7.62	7.52	11.47	11.52	12.26	21.91	10.62	
17.19	M	17	48	Y	M	L	YES	O	62.50	44.25	NO	7.49	7.62	11.79	11.71	11.67	21.51	9.85	
17.21	M	17	38	Y	M	L	YES	O	57.20	44.80	NO	7.00	7.73	11.52	11.65	11.63	21.44	11.44	
17.21	M	17	48	Y	M	L	YES	O	57.20	44.80	NO	6.80	7.52	11.14	11.14	12.45	21.87	9.94	
17.24	M	17	38	Y	M	L	NO	O	60.00	44.00	NO	7.44	7.35	12.15	11.85	11.27	21.88	7.55	
17.24	M	17	48	Y	M	L	YES	O	60.00	44.00	NO	7.00	7.52	11.65	11.54	11.33	21.68	6.80	
17.36	F	17	38	Y	M	L	YES	O	56.80	41.20	YES	6.62	6.81	11.23	12.17	12.19	16.71	3.69	
17.36	F	17	48	Y	M	L	YES	O	56.80	41.20	YES	6.71	6.99	11.16	11.66	12.76	16.44	4.53	
17.37	F	17	38	Y	*	L	NO	O	53.50	39.25	NO	6.49	6.37	9.42	9.98	9.09	23.15	10.90	
17.37	F	17	48	Y	*	L	NO	O	53.50	39.25	NO	6.37	6.50	9.52	9.85	8.31	21.80	11.25	
17.38	M	17	38	Y	M	*	YES	O	60.30	44.70	NO	7.50	7.50	11.42	12.31	12.15	23.72	9.99	
17.38	M	17	48	Y	*	L	NO	O	60.30	44.70	NO	7.41	7.65	11.67	12.34	12.75	26.13	11.07	
17.39	M	17	48	Y	M	L	YES	O	62.40	44.40	YES	7.64	7.77	12.03	11.82	12.76	23.53	7.77	
17.42	M	17	38	Y	M	L	YES	O	57.50	42.25	NO	7.06	7.28	11.35	11.07	10.98	19.30	10.10	
17.42	M	17	48	Y	M	L	YES	O	57.50	42.25	NO	7.00	7.20	11.16	11.14	10.96	21.41	10.10	
17.43	M	17	38	Y	M	L	YES	O	56.00	45.60	NO	7.55	7.21	11.89	11.65	12.17	23.08	6.09	
17.43	M	17	48	Y	M	L	YES	O	56.00	45.60	NO	7.88	7.47	11.76	11.26	11.76	23.47	9.13	
18.1	F	17	38	Y	M	L	YES	O	59.75	45.00	NO	7.62	7.59	11.88	12.17	11.24	19.29	6.05	
18.7	F	17	38	Y	M	L	NO	O	58.40	40.80	NO	6.32	7.21	10.77	11.06	10.12	22.13	8.84	
18.7	F	17	48	Y	*	L	NO	O	58.40	40.80	NO	6.45	6.62	10.93	10.25	11.06	21.82	11.06	
18.12	M	17	38	Y	M	L	YES	S	63.60	47.60	NO	7.38	7.69	12.42	12.65	12.21	19.23	5.38	
18.12	M	17	48	Y	M	L	YES	S	63.60	47.60	NO	7.35	7.38	12.91	13.06	11.66	19.24	6.22	
18.13	M	17	38	Y	M	L	YES	S	59.00	39.20	NO	6.71	7.21	10.00	11.01	11.31	21.31	6.84	
18.13	M	17	48	Y	M	L	YES	S	59.00	39.20	NO	6.22	7.34	10.77	11.16	11.21	21.93	6.88	
18.26	M	17	38	Y	M	L	YES	O	57.00	42.25	YES	7.29	7.52	11.52	11.10	10.75	14.72	4.80	
18.26	M	17	48	Y	M	L	YES	O	57.00	42.25	YES	7.08	7.20	11.47	10.97	9.62	11.98	3.35	
18.29	M	17	38	Y	M	*	NO	S	58.00	43.20	NO	7.35	7.21	11.45	12.24	12.76	24.63	11.54	
18.29	M	17	48	Y	M	*	YES	S	58.00	43.20	NO	*	*	*	*	*	23.97	8.05	LE

Patient ID#	Sex	Age	38/48		M-D tilt	B-L tilt	M3 impacted?	Arch type	Width	Depth	Crowding?	PM1	PM2	M1	M2	M3	M2-Pterygoid	M2-tuberosity	Excl. factors
								Dental Arch				M-D Crown Length							
Mandibular Third Molars																			
18.10	M	18	38	Y	M	L	YES	O	56.00	41.60	NO	6.62	6.99	10.25	11.14	11.87	23.20	7.68	
18.11	F	18	38	Y	M	L	YES	S	54.00	37.50	NO	6.54	6.49	10.20	10.37	10.61	22.21	8.75	
18.11	F	18	48	Y	M	L	YES	S	54.00	37.50	NO	6.37	6.04	10.20	10.54	10.35	22.55	9.65	
18.14	M	18	38	Y	*	*	NO	O	56.00	42.00	NO	6.73	7.16	10.61	10.85	11.14	24.35	15.40	
18.14	M	18	48	Y	*	*	NO	O	56.00	42.00	NO	7.08	7.95	10.68	10.74	11.00	23.90	15.31	
18.15	M	18	38	Y	M	L	NO	O	60.40	44.40	NO	7.17	7.34	11.41	11.35	9.28	27.85	11.09	
18.15	M	18	48	Y	M	L	NO	O	60.40	44.40	NO	7.00	7.25	11.90	11.07	9.62	25.42	10.88	
18.18	F	18	38	Y	M	L	YES	O	59.00	44.50	NO	7.16	7.16	11.15	11.40	11.41	19.36	6.86	
18.20	F	18	38	Y	M	L	YES	S	54.75	40.50	YES	7.29	6.80	10.85	11.71	10.40	18.03	5.48	
18.20	F	18	48	Y	M	L	YES	S	54.75	40.50	YES	6.93	6.60	11.07	11.54	9.78	19.53	8.51	
19.1	F	18	38	Y	M	L	YES	O	55.20	38.40	NO	*	*	*	*	*	18.74	7.68	AM
19.1	F	18	48	Y	M	L	YES	O	55.20	38.40	NO	*	*	*	*	*	19.87	7.94	AM
19.3	M	18	38	Y	M	*	NO	O	60.40	40.80	NO	*	*	*	*	*	29.37	10.57	AM
19.3	M	18	48	Y	M	*	NO	O	60.40	40.80	NO	*	*	*	*	*	29.20	7.21	AM
19.5	F	18	38	Y	M	L	YES	O	52.50	37.75	NO	6.52	6.05	9.33	10.08	9.30	20.26	5.96	
19.5	F	18	48	Y	M	L	YES	O	52.50	37.75	NO	6.49	6.37	9.57	10.45	9.30	19.50	5.86	
19.9	F	18	38	Y	M	L	YES	O	55.20	43.20	NO	6.71	7.20	10.87	10.43	12.24	18.14	5.12	
19.11	F	18	38	Y	M	L	YES	O	56.00	42.40	NO	6.80	6.46	10.67	10.77	11.32	20.00	5.77	
19.11	F	18	48	Y	M	L	YES	O	56.00	42.40	NO	6.62	6.71	11.26	11.06	11.87	23.00	6.25	
19.6	M	19	38	Y	M	L	YES	O	54.40	44.80	NO	7.52	7.77	11.06	11.29	12.43	21.87	4.82	
19.6	M	19	48	Y	M	L	YES	O	54.40	44.80	NO	7.52	7.73	10.67	11.16	12.11	22.74	7.21	
19.7	F	19	38	Y	M	L	YES	S	56.40	36.40	NO	6.32	6.51	10.20	10.81	9.94	17.01	4.53	
19.7	F	19	48	Y	M	L	YES	S	56.40	36.40	NO	6.56	6.46	10.28	10.77	10.20	16.69	5.95	
19.8	F	19	38	Y	M	L	YES	O	56.00	38.80	NO	6.09	6.84	10.12	10.25	10.92	22.23	9.67	
19.8	F	19	48	Y	M	L	YES	O	56.00	38.80	NO	6.22	6.25	9.74	10.57	10.22	19.80	8.21	
19.10	M	19	38	Y	M	L	YES	OW	63.60	41.60	NO	6.46	7.35	11.14	11.45	12.01	14.99	3.69	
19.10	M	19	48	Y	M	L	YES	OW	63.60	41.60	NO	6.32	7.21	11.46	11.66	10.92	18.18	5.09	
19.12	M	19	48	Y	M	L	YES	S	60.00	44.00	NO	6.51	7.38	11.09	11.27	10.88	19.00	4.82	
20.1	F	19	38	Y	M	L	YES	O	56.80	41.60	NO	*	*	*	*	*	19.57	6.51	
20.1	F	19	48	Y	M	L	YES	O	56.80	41.60	NO	*	*	*	*	*	21.20	8.88	
20.2	F	19	38	Y	M	L	NO	S	54.00	40.20	YES	7.25	6.85	10.36	10.92	9.68	26.23	6.66	
20.4	F	19	38	Y	M	L	YES	O	60.00	41.70	NO	6.49	7.52	11.13	11.01	10.74	18.16	7.98	
20.4	F	19	48	Y	M	L	YES	O	60.00	41.70	NO	6.38	6.85	10.55	10.84	10.22	18.00	7.45	
20.6	F	19	38	Y	M	L	YES	O	56.80	41.60	NO	*	*	*	*	*	21.53	5.44	
20.11	M	19	38	Y	M	L	YES	O	58.50	40.00	NO	6.52	7.04	10.75	10.75	10.85	23.64	5.71	
20.11	M	19	48	Y	M	L	YES	O	58.50	40.00	NO	6.60	6.66	10.29	10.97	9.76	20.72	8.16	
20.15	M	19	38	Y	M	L	YES	O	56.40	41.60	NO	6.45	6.88	11.01	11.16	10.65	18.32	4.00	
20.15	M	19	48	Y	M	L	YES	O	56.40	41.60	NO	6.51	6.56	11.52	10.56	10.56	20.88	4.33	
20.9	M	20	38	Y	*	*	NO	O	60.80	45.60	NO	7.21	7.52	11.76	12.11	10.67	24.91	12.35	
20.9	M	20	48	Y	*	*	NO	O	60.80	45.60	NO	6.79	6.79	11.82	11.38	10.12	24.74	12.09	
20.12	F	20	38	Y	*	L	NO	O	54.00	39.20	NO	6.26	6.84	9.51	10.38	10.67	23.76	13.76	
20.12	F	20	48	Y	*	L	NO	O	54.00	39.20	NO	6.45	6.46	9.62	10.50	10.59	25.30	14.65	
20.13	M	20	38	Y	M	L	YES	O	57.00	40.80	NO	6.18	6.36	11.10	9.97	9.00	20.47	7.16	
20.13	M	20	48	Y	M	L	YES	O	57.00	40.80	NO	6.16	6.18	10.60	10.53	9.77	20.90	6.00	

Patient ID#	Sex	Age	38/48		M-D tilt	B-L tilt	M3 impacted?	Arch type	Width	Depth	Crowding?	PM1	PM2	M1	M2	M3	M2-Pterygoid	M2-tuberosity	Excl. factors
								Dental Arch				M-D Crown Length							
Mandibular Third Molars																			
20.18	M	20	38	Y	M	*	NO	O	52.80	40.00	NO	6.11	6.84	10.28	10.28	10.92	27.30	12.40	
20.18	M	20	48	Y	*	*	NO	O	52.80	40.00	NO	6.26	7.09	10.50	10.50	10.92	28.00	15.12	
20.19	M	20	48	Y	M	L	YES	O	57.20	42.00	NO	7.16	6.99	9.62	10.47	12.88	26.08	10.98	
20.21	F	20	38	Y	*	L	YES	O	52.00	40.80	NO	6.00	6.71	10.25	9.51	10.67	26.29	13.87	
20.21	F	20	48	Y	*	L	YES	O	52.00	40.80	NO	6.09	6.32	10.38	9.84	10.20	22.52	12.98	
20.22	F	20	38	Y	M	L	YES	O	41.20	54.40	NO	6.26	7.21	10.77	10.52	10.47	20.65	6.66	
20.22	F	20	48	Y	M	L	YES	O	41.20	54.40	NO	6.25	6.62	10.67	10.59	10.88	23.63	11.21	
21.18	F	20	38	Y	M	L	YES	T	59.75	46.75	NO	7.29	7.99	11.62	12.03	11.51	18.63	6.75	
21.18	F	20	48	Y	M	L	YES	T	59.75	46.75	NO	7.49	7.75	11.62	11.98	11.03	21.20	6.80	
21.1	M	21	38	Y	M	L	YES	O	58.80	44.80	NO	6.84	7.21	11.65	11.85	12.90	23.93	7.68	
21.1	M	21	48	Y	M	L	YES	O	58.80	44.80	NO	6.88	7.16	11.76	12.03	13.35	22.65	9.44	
21.10	F	21	48	Y	M	L	YES	S	57.60	40.80	NO	*	*	*	*	*	20.65	8.65	RE
21.14	F	21	38	Y	M	L	NO	OW	58.00	37.20	NO	6.26	6.09	9.90	10.20	10.80	23.63	11.21	
21.14	F	21	48	Y	M	L	NO	OW	58.00	37.20	NO	6.21	6.81	9.60	10.41	10.20	22.97	10.65	
21.15	M	21	38	Y	M	*	YES	O	59.25	42.25	YES	7.02	7.29	11.47	12.09	9.15	19.62	8.53	
22.5	F	22	48	Y	M	L	NO	OW	62.40	41.60	NO	7.00	7.21	11.14	10.77	11.26	19.31	8.50	
22.11	F	22	38	Y	M	L	YES	O	57.50	41.50	YES	7.12	6.93	11.19	11.67	11.16	17.80	5.15	
22.11	F	22	48	Y	M	L	YES	O	57.50	41.50	YES	6.73	6.88	10.74	11.40	11.52	17.61	6.75	
23.6	F	22	38	Y	M	L	NO	O	59.20	43.60	NO	6.11	7.09	11.45	11.76	12.86	26.41	14.65	
23.10	F	22	48	Y	M	No	NO	O	58.20	42.00	NO	6.44	6.55	10.84	10.50	10.82	23.23	11.16	
23.4	F	23	38	Y	M	L	YES	S	60.40	44.00	NO	6.46	6.46	11.93	11.77	10.98	18.00	5.44	
23.4	**F**	23	48	Y	M	L	YES	S	60.40	44.00	NO	6.26	6.46	11.45	11.26	11.31	19.57	5.38	
23.7	M	23	38	Y	M	L	YES	O	55.20	41.60	NO	6.26	6.84	10.28	10.59	11.89	25.63	7.44	
23.7	M	23	48	Y	No	No	NO	O	55.20	41.60	NO	6.46	6.46	10.50	10.88	11.26	25.85	11.87	
23.11	M	23	38	Y	M	L	YES	O	58.80	41.60	NO	7.09	7.21	9.81	10.52	10.38	20.42	8.56	
23.11	M	23	48	Y	M	L	YES	O	58.80	41.60	NO	6.99	7.16	9.90	10.20	10.65	23.53	8.65	
24.14	F	23	38	Y	M	L	YES	O	51.00	40.25	YES	6.58	7.16	10.07	10.55	10.76	22.82	10.08	
24.14	F	23	48	Y	M	L	YES	O	51.00	40.25	YES	6.52	7.12	10.61	10.51	9.99	25.95	10.06	
24.12	F	24	48	Y	M	No	NO	T	57.20	40.80	NO	6.45	6.26	9.84	9.88	9.88	21.08	8.65	

AI: Absence of incisive(s)
AC: Absence of Canine(s)
AM: Absence of premolar(s) and/or molar(s)
IM: Imperfections in CBCT image
RE: Major restoration(s) observed
LE: Lesions or osseous defects observed
JA: Jaw not covered by CBCT image
* : No/ not applicable

APPENDIX D

MINERALIZATION STATUS OF THIRD MOLARS

The following tables provide details on the mineralization stages observed for M2s and M3s among subjects aged eight to twelve years studied in this project.

Maxilla - Stage of mineralization of M3/ age group

Number of cases studied / Age group

	Stage 0	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Total
Age 8	**19**	6	0	0	0	0	0	0	25
Age 9	8	**13**	1	0	0	0	0	0	22
Age 10	13	**15**	13	3	0	0	0	0	44
Age 11	18	7	**24**	10	0	0	0	0	59
Age 12	18	15	**31**	27	5	0	0	0	96

Maxilla - Stage of mineralization of M3/ age group

Most frequently observed stages of mineralization/ age group

	Stage 0	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Total
Age 8	**76%**	24%	0%	0%	0%	0%	0%	0%	100%
Age 9	36%	**59%**	5%	0%	0%	0%	0%	0%	100%
Age 10	30%	**34%**	30%	7%	0%	0%	0%	0%	100%
Age 11	31%	12%	**41%**	17%	0%	0%	0%	0%	100%
Age 12	19%	16%	**32%**	28%	5%	0%	0%	0%	100%

Mandible - Stage of mineralization of third molars / age group

Number of cases studied / Age group

	Stage 0	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Total
Age 8	**13**	9	0	1	0	0	0	0	23
Age 9	12	**14**	0	0	0	0	0	0	26
Age 10	9	**22**	10	2	0	0	0	0	43
Age 11	13	18	**23**	3	0	0	0	0	57
Age 12	9	21	**33**	24	2	2	0	0	91

Mandible - Stage of mineralization of third molars / age group

Most frequently observed stages of mineralization/ age group

	Stage 0	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Total
Age 8	**57%**	39%	0%	4%	0%	0%	0%	0%	100%
Age 9	46%	**54%**	0%	0%	0%	0%	0%	0%	100%
Age 10	21%	**51%**	23%	5%	0%	0%	0%	0%	100%
Age 11	23%	32%	**40%**	5%	0%	0%	0%	0%	100%
Age 12	10%	23%	**36%**	26%	2%	2%	0%	0%	100%