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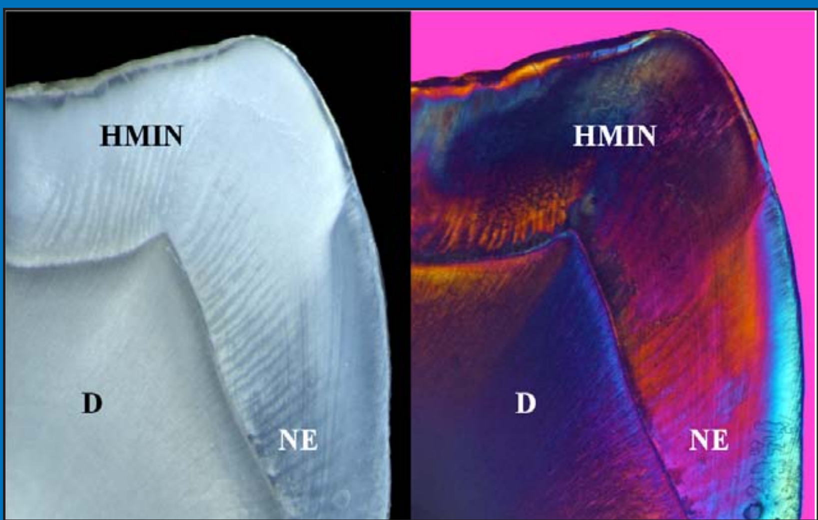

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Onset of Molar Incisor Hypomineralization (MIH)

Tobias G. Fagrell[1,3], Phil Salmon[2], Lisa Melin[3], Jörgen G. Norén[3]

Abstract

◎ The etiological factors and timing of the onset of molar incisor hypomineralization (MIH) are still not clear. The aim of this study was to examine ground radial and sagittal sections from teeth diagnosed with MIH using light microscopy, polarized light microscopy and X-ray micro-computed tomography (XMCT) and to estimate the onset and timing of the MIH and to relate the hypomineralized enamel to the incremental lines. Thirteen extracted permanent first molars diagnosed MIH, were analyzed with light microscopy and XMCT.

The hypomineralized areas were mainly located in the mesio-buccal cusps, starting at the enamel-dentin-junction and continuing towards the enamel surface. In a relative gray scale analysis the values decreased from the EDJ towards the enamel surface.

The findings indicate that the ameloblasts in the hypomineralized enamel are capable of forming an enamel of normal thickness, but with a substantial reduction of their capacity for maturation of enamel. Chronologically, it is estimated that the timing of the disturbance is at a period during the first 6-7 months of age.

Key words

Enamel, light microscopy, molar incisor hypomineralization, polarized light microscopy, X-ray micro-computed tomography.

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Start för Molar Incisor Hypomineralization (MIH)

Tobias G. Fagrell, Phil Salmon, Lisa Melin, Jörgen G. Norén

Sammanfattning

◎ De etiologiska faktorerna och timingen för start av mineraliseringsstörningen molar incisor hypomineralization (MIH) är inte klarlagda. Syftet med denna studie var att studera ourkalkade radiala och sagittala snitt från tänder med diagnosen MIH med ljusmikoroskop, polarisationsmikroskop och röntgenmikro-datortomografi (XMCT) och uppskatta tidpunkten för start av MIH, samt att relatera den hypomineraliserade emaljen till emaljens inkrementlinjer. Totalt undersöktes 13 extraherade permanenta förstamolarer med diagnosed MIH.

Den hypomineraliserade emaljen var främst lokaliserad till molarernas mesio-buckala delar och började vid emalj-dentingränsen för att fortsätta ut mot emaljytan. I en gråskaleanalys av XMCT-bilderna sågs att värdet minskade från emalj-dentingränsen mot emaljytan.

Fynden pekar mot att ameloblasterna i den hypomineraliserade emaljen klarar att bilda en emalj av normal tjocklek men har en kraftigt reducerad förmåga till maturation av emaljen. Tidsmässigt uppskattas att störningen har uppkommit under de första 6-7 levnadsmånaderna.

Introduction

During the last decades much interest has been focused on a condition called Molar Incisor Hypomineralization (MIH) (15, 18, 29), which is a developmental disturbance of the enamel mainly occuring in the permanent first molars. Clinical studies in almost all parts of the world have revealed an overall prevalence of around 20% (17), but lower figures for the most severe forms with loss of substance (15, 18). MIH is by definition a chronological developmental disturbance in the enamel. One characteristic of MIH is variation in the number of molars affected - some cases only one permanent first molar may be affected while in other cases two, three or four molars. Furthermore, the degree of hypomineralization may vary between the first permanent molars in the same dentition.

From a clinical point of view MIH is associated with extensive objective and subjective problems such as hypersensitivity of the affected teeth, enamel breakdown and problems with retention of fillings (14, 19). The condition often also leads to dental fear and dental management problems(14).

Several attempts have been made to find the etiological factors behind MIH and a number of possible factors have been suggested (1, 6). In a recent paper it was shown that nutritional factors around 6 months postnatally may have an impact on the development of MIH (10).

In a number of articles the histological, chemical and mechanical properties of the hypomineralized enamel has been described (9, 12, 20, 28, 30) sometimes even with conflicting results. Histologically the hypomineralized enamel extends from the enamel-dentin junction towards the enamel surface and the disturbance has a distinct cervical border to normal enamel along a prism.

In order to be able to have a realistic discussion of possible etiological factors the timing of the onset of the disturbance must be thoroughly elucidated, as well as the extension of the defect within the crown. These parameters for the hypomineralized enamel are crucial to know in order to find a relevant time period for potential causative factors. Most often only sagittal sections are made but radial sections may provide information of relevance. Serial sectioning of un-decalcified dental hard tissues may, at least for the moment, only be performed using a saw microtome. For every section of 100 µm there is a loss of 300 µm due to the thickness of the saw blade. Therefore, substantial and vital information is lost. One way of overcoming this is the use of X-ray micro computed tomography (XMCT) (11, 13).

Micro computed tomography or "micro-CT" is X-ray imaging in 3D. The method is based on tomographic X-ray scans with massively increased resolution, where very fine scale internal structure of objects is imaged non-destructively (11). The sample's internal 3D structure at high resolution may be provided, and in the case of a MIH tooth a 3D image is reconstructed of the hypomineralized enamel in relation to the normal enamel and the dentin.

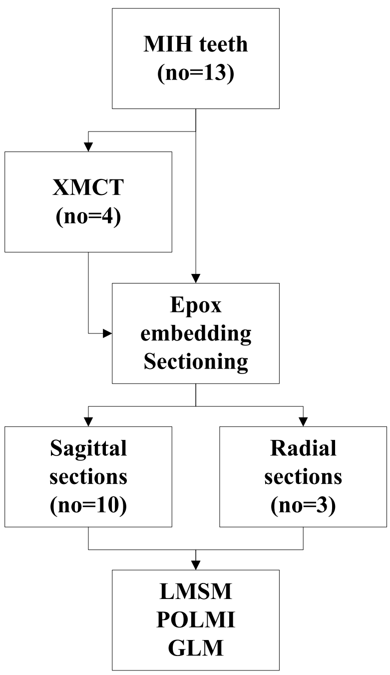
The aim of this study was to use light microscopy, polarized light microscopy and X-ray micro-computed tomography, to examine radial and sagittal un-demineralized sections from teeth diagnosed MIH, and to determine the onset and timing of the enamel hypomineralization (relative to normative development) in relation to the incremental lines.

Material and methods

Tooth material

The tooth material consisted of 13 permanent first molars, collected from 9 individuals, with the diagnosis of MIH, extracted due to severe hypomineralized enamel and for orthodontic reasons. 8 teeth

Figure 1. Schematic drawing of the study design. (MIH=Molar Incisor Hypomineralization, no=number; XMCT=X-ray micro-computed tomography; LMSM=light microscopy-stereo microscopy; POLMI=polarized light microscopy; GLM=gray level measurements.)



were maxillary molars and 5 teeth were mandibular molars. The study design is shown in Figure 1. After extraction the teeth were stored in plastic tubes containing 70% ethanol. Four of the teeth derived from the same patient and were numbered 16, 26, 36 and 46 according to their position in the permanent dentition.

Cutting procedure

The teeth were stored in 70% ethanol until further preparation. After macro photos of the teeth were taken, four teeth were selected for micro-CT X-ray analysis. The remaining nine teeth were embedded in an epoxy-resin (Epofix®, Electron Microscopy Sciences, Fort Washington, PA, USA) and serially sectioned with an approximate thickness of 120 µm, in a Leica SP1600 Saw Microtome (Leica Mikrosysteme Vertrieb GmbH, Wetzlar, Germany).

Sagittal bucco-lingual sections were prepared from six teeth and radial sections were prepared from three teeth. Before cutting a section an object glass was glued onto the previously cut surface, with a light curing one-component adhesive (Technovit 7210 VLC, Heraeus Kulzer GmbH, Hanau, Germany). This technique allows optimal positioning of the sample on the glass and prevents loss of enamel during the cutting procedure.

Light microscopy - Stereo microscopy (LMSM)

All sagittal and radial sections were examined in a Leica M80 stereo microscope (Leica M80 with 8:1 zoom, 0.75x-6x, Leica Mikrosysteme Vertrieb GmbH, Wetzlar, Germany) in incident light with a matt black background. Digital images were taken of all sections using a Leica digital camera (Leica DFC420 C, Leica Mikrosysteme Vertrieb GmbH, Wetzlar, Germany) equipped with Leica Application Suite LAS V3.7.0 (Leica Microsystems AG, Heerbrugg, Switzerland).

Polarized light microscopy (POLMI)

All sections were examined dry in air and after soaking in water in an Olympus polarizing light microscope (Olympus, Tokyo, Japan). Digital images were produced using a Leica digital camera and Leica Application Suite.

X-ray Micro Computed Tomography (XMCT)

The SkyScan 1172 (SkyScan N.V., Kontich, Belgium), XMCT system was used to scan the teeth. The parameters used were: camera pixel size 9.07 µm, source voltage 74 kV, source current 120 mA, image pixel size 15.80 µm, copper+aluminium filter (38 µm Cu, 0.5mm Al), rotation step 0.360°, 360° rotation, frame averaging 8, and geometrical correction, flat field correction and median filtering on.

The software package CT Analyser (Version 1.11.6.0+, SkyScan N.V., Kontich, Belgium) was used for analysis. For each sample in the study, the enamel gray levels (0–255) were measured in two directions.

The relative gray level in normal and hypomineralized enamel was measured in CT Analyser in a series of XMCT scans from the cuspal parts to the cervical parts of the crown.

Relative gray level measurements

The digital images taken in the stereo microscope of the sagittal and radial sections were analyzed with ImageJ (Research Services Branch, National Institute of Mental Health, Bethesda, Maryland, USA).

Ethical considerations

All the examined teeth had been extracted due to severe hypomineralized enamel and for orthodontic reasons and given by the patient of his/her own free will. The teeth were stored in plastic tubes without any identification, which is why none of the teeth could be traced to any specific patient.

Results

LMSM

Normal mineralized enamel appeared as translucent in incident light. The hypomineralized enamel most often appeared as opaque with a whitish color, in some cases slightly beige. Hunter-Schreger bands, Retzius lines and the overall appearance of the enamel prisms were readily seen (Fig. 2) in both normal and hypomineralized enamel. The degree of opaqueness reflects the degree of hypomineralization (degree of porosity), implicating that the more opaque the enamel appears in incident light, the more porous it is.

In all examined teeth the hypomineralized enamel was mainly located at the buccal cusps and the hypomineralized areas started at the enamel-dentin-junction (EDJ) and continued up to the enamel surface (Figs. 2 & 3). In 2 of the mandibular molars and 3 of the maxillary molars the hypomineralized area extended over to the occlusal area of the tooth (Fig. 4). In all these teeth hypomineralized enamel was also found in the lingual/palatinal part of the crown. The largest extension of hypomineralized enamel was found in the mesial part of the crowns, where also the most severely affected enamel was seen. The

Figure 2. Light microscopic images of an un-demineralized sagittal section of a permanent first molar seen in incident light (left) and after water imbibition in polarized light (right). (HMIN=hypomineralized enamel; NE=normal enamel; D=dentin.)

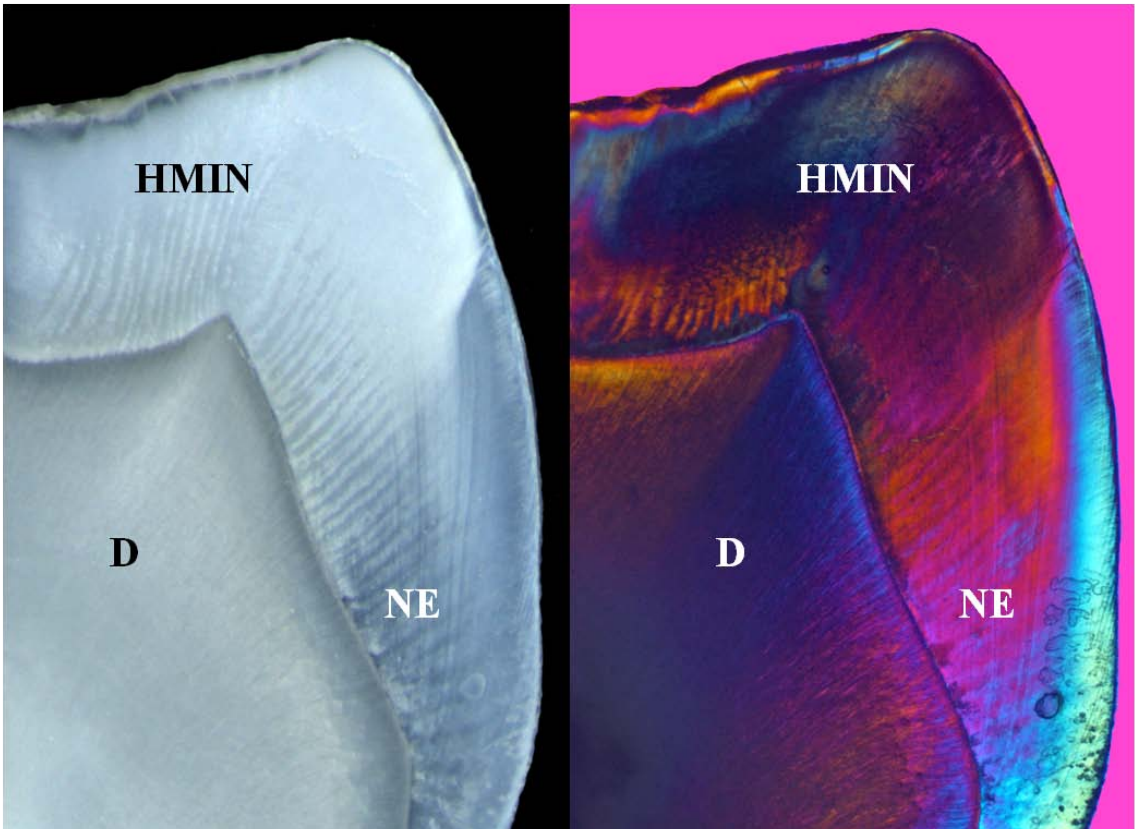


Figure 3. Un-demineralized sagittal section of a permanent first molar seen in polarized light after water imbibition. A hypomineralized lesion is seen as a darker area extending from the enamel-dentin junction towards the surface with a porous surface zone. To the left of the lesion the enamel has a normal degree of mineralization and a normal surface zone. (HMIN=hypomineralized enamel; NE=normal enamel; D=dentin; PES=porous surface enamel; NES=normal enamel surface.)

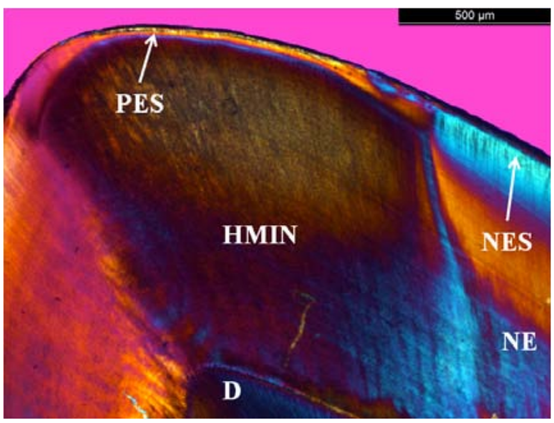


Figure 4. Light microscopic images of an un-demineralized sagittal section of a permanent first molar seen in incident light with a hypomineralization extending over the occlusal area of the crown. (HMIN=hypomineralized enamel; NE=normal enamel; D=dentin.)

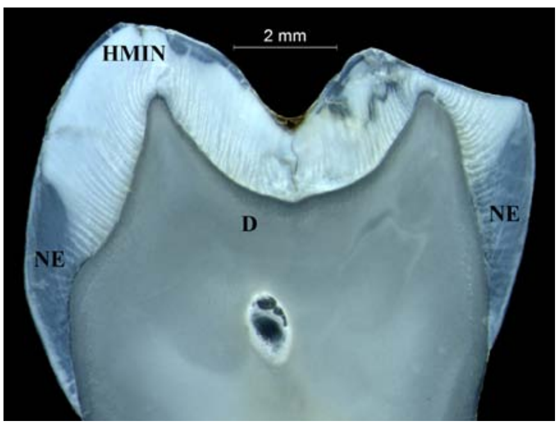
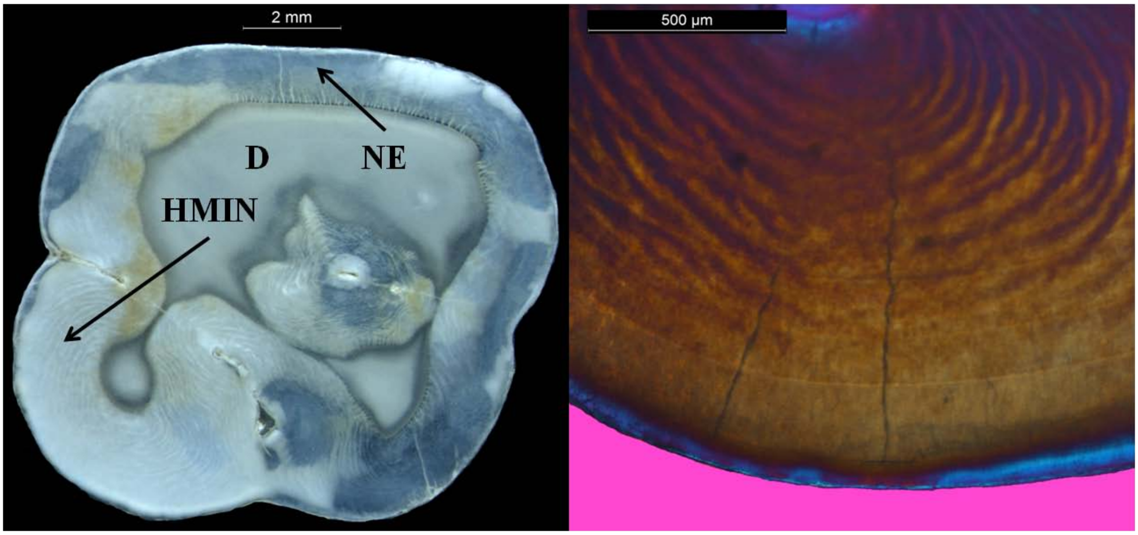


Figure 5. Light microscopic images of an un-demineralized radial section of a permanent first molar seen in incident light (left) and after water imbibition in polarized light (right). (HMIN=hypomineralized enamel; NE=normal enamel; D=dentin.)



cervical extension reached from half till 2/3 of the coronal height.

Enamel breakdown and loss of substance was seen in all mandibular molars. Caries lesions associated with the hypomineralized enamel were found in all mandibular molars and in 2 maxillary molars.

When comparing the 4 permanent first molars from the same patient, one of the mandibular molars was more affected than the other three molars, both with regard to the spatial extent and the degree of hypomineralization.

The central part of the hypomineralized enamel appeared distinct, but became gradually less discrete towards the cervical part of the section. The extension towards the enamel surface of the hypomineralized zone decreased in the adjacent sections. The border between hypomineralized and normal enamel followed a prism and appeared not to be related to the incremental lines.

A surface zone of normal enamel was seen in most sections. However, in some sections the hypomineralized enamel extended to the outermost enamel surface, thus leaving part of the enamel surface with a porous outer zone.

In the radial sections the hypomineralization showed in principle the same pattern as in the sagittal sections (Fig. 5). The hypomineralization starting at the EDJ and, depending on severity, extended towards the enamel surface. In areas with marked opacity no surface zone of normal mineralized enamel was found, which was present in other areas.

POLMI

The enamel corresponding to the translucent areas seen in LMSM appeared when examined dry in air with a blue surface zone (negative birefringence) leaving the remaining portion of the enamel with a red color (positive birefringence). After hydration the red color turned blue, indicating a pore volume less than 5% (Fig. 2). The overall morphology and structure were normal and the Hunter-Schreger bands and the Retzius lines were readily seen. The surface enamel appeared normal. However, in some sections a thin hypomineralized band could be seen extending over parts of the enamel surface.

When examined dry in air the enamel in the opaque areas had a color that ranged from dark brown to dark yellow, the central part of the affected enamel being the darkest color. After hydration the brown-yellow color remained in the central part, indicating a pore volume of more than 5% (Fig. 3). The central part of the hypomineralized enamel extended from the EDJ to the enamel surface, which either exhibited a thin normal mineralized enamel surface or a porous enamel (Fig. 3). The porous surface zone varied in extent. The borders of the central part of the hypomineralized enamel were distinct and followed a prism. The enamel surface had a yellow color that remained yellow after soaking in water. The overall structure was less distinct compared with normal enamel. The surrounding hypomineralized enamel changed in color to yellow or red, indicating a pore volume of around 5%. The enamel surface appeared normal with a blue color.

Figure 6. Example of an X-ray micro-computed tomography image of a MIH tooth. The more compact opaque areas represent hypomineralized enamel.

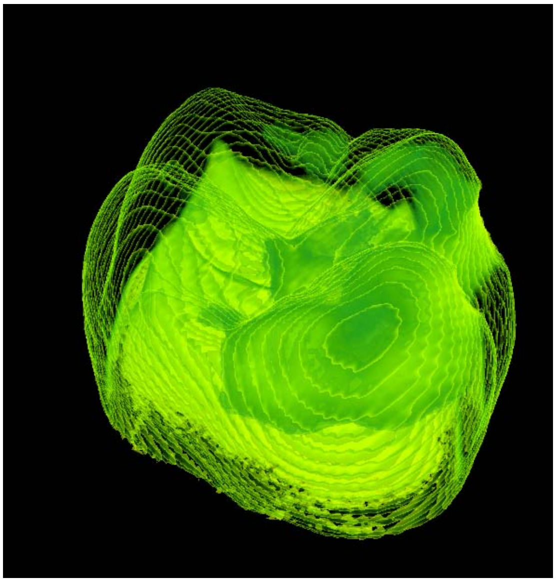
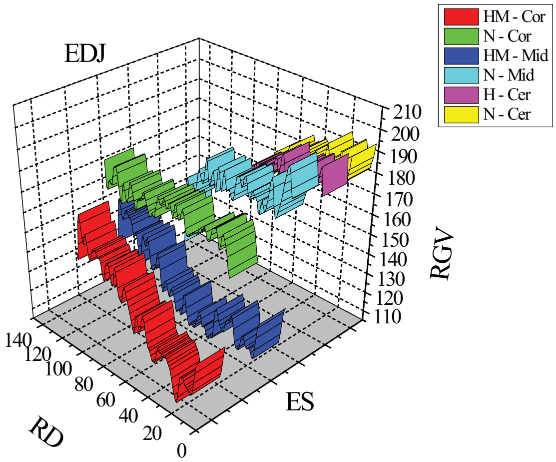


Figure 7. 3D ribbon plot of relative gray level measurements from the enamel surface towards the enamel-dentin-junction in X-ray micro-computed tomographic radial images of a tooth diagnosed with MIH. (HM-Cor=hypomineralized enamel coronal part; N-Cor=normal enamel coronal part; HM-Mid=hypomineralized enamel middle part; N-Mid=normal enamel middle part; HM-Cer=hypomineralized enamel cervical part; N-Cer=normal enamel cervical part; ES=enamel surface; EDJ=enamel-dentin-junction; RGV=relative gray value; RD=relative distance.)



X-ray Micro Computed Tomography (XMCT)

The XMCT revealed the location of the hypomineralized enamel as a coherent volume of tissue with a higher degree of radio-lucency having its origin at the enamel-dentin-junction (Fig. 6). The hypomineralized enamel was located on the buccal side of the tooth crown, the enamel around the mesio-buccal cusp being the most affected, followed by the disto-buccal cusp. However, the hypomineralized enamel did not extend into the outermost part of the cusp. A more limited hypomineralized area was seen in the disto-lingual cuspal area. Examination of the sections from the tooth analyzed with XMCT in incident light and in POLMI confirmed the hypomineralized character of the radio-lucent volume seen and its location.

Gray level measurements

Radial XMCT images (27 images) were used to analyze the relative gray value intensities of the enamel in two locations in each image (Fig. 7). Exactly the same two locations were measured in all images, thus values within the same section and from the coronal enamel to the cervical could be measured for normal and hypomineralized enamel.

The relative gray scale values in the coronal and middle parts of the enamel were markedly higher in normal enamel compared with hypomineralized enamel. In the hypomineralized enamel the relative gray values decreased from the EDJ towards the enamel surface, while the values in normal enamel, irrespective of location, had a slight increase towards the enamel surface. Both locations for measurement in the cervical part of the enamel represented normal enamel.

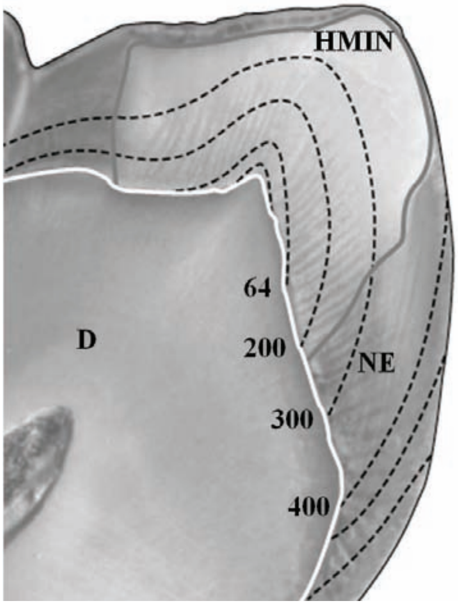
Timing of enamel hypomineralization

Since the incremental lines were easily discernable it became possible to estimate the appositional enamel growth over a certain period of time. Even though incremental lines are found in the radial sections, the sagittal sections from the central part of the crown through a cusp are more suitable for estimating the timing of the affected enamel.

An estimation of the timing was performed on the most central mesial-sagittal sections and based on enamel development and secretion rate for molars (5, 22). An image of the most central mesio-buccal section was compared with a schematic drawing of the same area with incremental lines (Fig. 8).

Hypomineralization started below the dentin cusp in five of the first molars (2 mandibular, 3 maxillary), whereas in the remaining two mandibular teeth the hypomineralization started at the top of the dentin cusp. The relative extension of hypomineralized enamel towards the cervical part of the crown

Figure 8. Light microscopic images of an un-demineralized radial section of a permanent first molar seen in incident light with plotted incremental lines and corresponding time in days (relative values). (HMIN=hypomineralized enamel; NE=normal enamel; D=dentin.)



in six teeth (3 mandibular, 3 maxillary) was equal to 200 days and to a relative value of 300 days in one maxillary first permanent molar.

Discussion

This study has shown that the hypomineralized enamel in first permanent molars associated with MIH was mainly located in the buccal enamel of the teeth and had a high degree of porosity extending from enamel-dentin-junction (EDJ) towards the enamel surface. Its cervical extension was well demarcated along a prism. The bulk of the lesions exhibited an enamel surface with low degree of mineralization. The X-ray micro-computerized tomography revealed the hypomineralized enamel as a volume extending from the EDJ towards the surface. An estimation of onset and extension in time for the hypomineralized enamel ranged from the start of the enamel mineralization at the tip of the dentin cusp up to a relative value of 200 days.

Sectioning of un-demineralized dental hard tissues creates certain problems due to hardness and brittleness, especially of enamel. Sectioning of teeth must be performed with a diamond-edged band saw. The thickness of the cutting blade determines how much tooth substance is lost for every cut. Therefore, serial sectioning per se is not possible since for each section cut with a thickness of 100 µm there is a loss of 300 µm. Three times more information is lost compared with what is gained. The interpretation of histological sections in 3-dimensions is extremely unreliable. However, the use of X-ray micro-computed tomography may greatly improve the possibility of understanding aberrations in the mineralization process in all dimensions.

In the LMSM analyses the degree of opacity reflected the degree of hypomineralization (degree of porosity), indicating that the more opaque the enamel appears in incident light, the more porous it is. This is in line with earlier studies where the color of the hypomineralization was used as a variable to determine the degree of hypomineralization (7, 11). These findings were also confirmed in the POLMI analyses showing a high degree of porosity in the areas of hypomineralization.

Analyses of the enamel surface demonstrated a thin normal outer layer of the enamel in some of the teeth affected by MIH, which has previously been shown (16). However, no normal enamel surface zone was seen in the surface of more pronounced hypomineralization, which could constitute a possible pathway for bacteria and other materials from the oral cavity. Teeth affected by MIH are often associated with different subjective symptoms, one of them being hypersensitivity. In a previous study of MIH-teeth bacteria were found both in hypomineralized enamel and in the dentinal tubules (8, 9). The finding of a porous enamel surface would thus explain how bacteria can penetrate deep into the dentin through the enamel.

The findings that the hypomineralized enamel starts at the EDJ extending towards the enamel surface and that the hypomineralization has a cervical limitation along a prism, have also been shown in earlier studies (12, 11, 16), in contradiction however, to the result presented in a study by Farah 2010 (11). The start of the hypomineralization close to the EDJ indicated that an onset of the hypomineralization is early in the enamel mineralization. The gray value analyses showed that the coronal enamel was more hypomineralized than the cervical enamel. The degree of hypomineralization increased slowly towards the enamel surface in contrast to normal enamel, which had a flat gradient of gray value.

An understanding of the timing of crown formation is crucial in order to be able to identify the time of a possible insult to the ameloblasts. *Boyde* (5) used a histologically derived method to calculate the cuspal enamel formation rate of a lower first permanent molar as 334 days. The variations in enamel formation time have been shown to be limited (24). In analyzed sagittal and radial sections the mesio-buccal cusps of the molar teeth were affected most often and most severely. Considering the possibility of a limited and early period of lifetime for an insult to the ameloblasts would be in agreement with the findings of several previous studies that the initiation of the mineralization of the mesio-buccal cusp of the first permanent molars starts one to seven weeks before birth (3, 21).

Enamel proteins play a crucial role in organizing and controlling the orientation of calcium phosphate crystals in the hydroxyapatite within the crystallites (4). An early insult on the ameloblast may influence the cell in at least three different ways, the first being a disturbance of the ameloblast's ability to produce the correct deposition of proteins. If the protein deposition is incorrect, subsequent accurate maturation is impossible. An increase of 3-15 times more protein in hypomineralized enamel has been found (23). Most of the amelogenin was resorbed. However, other proteins such as albumin, which is a protein known to inhibit tooth mineralization, persisted (28).

Secondly ameloblasts in a transitional stage (between secretory and maturation) during enamel mineralization, are the most vulnerable type of ameloblast (12). An insult to the ameloblasts at a specific time of this sensitive transition may affect the ameloblasts and cause a disturbed function.

A third possibility is a problem in the maturation. If the mechanisms of water and protein resorption do not work, calcium and phosphate ions will not be able to enhance the prism development (27).

The enamel mineralization front is subject to periodic changes and regular variations in ameloblast activity. These variations produce short- and long-period incremental lines in the enamel. The long-period growth lines, or Retzius lines, mark the layers of enamel produced by the secretory ameloblasts, which occur every 6 to 12 days in modern humans (25). Short-period growth lines, or cross-striations, represent a daily circadian rhythm in secretory ameloblast activity (2, 21). Both short- and/or long-period growth lines have been used to calculate rates of enamel secretion and cusp formation time (5). Even if the estimation of the timing of disturbance of the ameloblasts is crude, a possible time range covers a period up to around 200 days after the start of the enamel mineralization. The location of a Retzius line at the enamel surface of the hypomineralized enamel would correspond to 300-400 days, which cannot be realistic since the hypomineralized zone has a cervical limitation along a prism.

A plausible conclusion of the findings from the different methods used is that the ameloblasts in the hypomineralized enamel are capable of forming an enamel of normal thickness, but with a substantial reduction in their maturation capacity. Further, the histological appearance and the estimation of timing indicate that ameloblast disturbance in MIH is limited to a period within the first 6-7 months of life.

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Treatment with local hemostatic agents and primary closure after tooth extraction in warfarin treated patients

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Abstract

◎ The aim of this retrospective study was to assess the frequency of postoperative bleeding in patients on warfarin after tooth removal followed by a complete soft tissue closure of the surgical site.

A total of 124 consecutive patients, 69 males and 55 females with a mean age of 71 years (range 28-95 years) were included in this study. Inclusion criteria were patients on warfarin with an INR ≤3.5 who were referred for tooth removal (single or multiple) during 2004-2009. After tooth extraction all sockets were packed with an absorbable haemostatic gelatin sponge or a collagen fleece and subsequently the sockets was primary closed with sutures.

5/124 (4%) patients returned with postoperative bleedings. All patients with a postoperative bleeding had received a surgical extraction in the posterior part of the maxilla. Consequently no patient had a postoperative bleeding in the mandible. None of the 124 patients returned to the clinic with a dry socket or postoperative pain. 3/124 (2%) patients returned with postoperative infection that required antibiotic treatment. All patients who bled were managed conservatively and none was admitted to hospital.

Conclusion: According to the protocol of this study (local hemostatic, primary closure, sutures and tranexamic acid) the risk of postoperative bleeding after tooth removal in patients on continued warfarin medication is low.

Key words

Anticoagulants, tooth extraction, warfarin

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Behandling med lokalhemostatika och primärslutning efter tandextraktion hos warfarin-behandlade patienter

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Sammanfattning

◎ Avsikten med denna retrospektiva studie var att fastställa frekvensen av postoperativ blödning efter tandextraktion hos patienter som behandlas med warfarin och postoperativt erhållit lokalhemostatika och primärsuturering.

124 patienter, 69 män och 55 kvinnor med en medelålder av 71 år (28-95 år), deltog i studien. Inklusionskriterierna var att patienten remitterats för en eller flera tandextraktioner 2004-2009 och stod på warfarin med ett International Normalized Ratio (INR) ≤3,5. Efter extraktionerna applicerades en resorberbar blodstillande gelatinsvamp eller en kollagentamponad i alveolerna varpå såret primärsuturerades.

5/124 (4 %) av patienterna återvände med postoperativ blödning. Samtliga patienter med postoperativ blödning hade genomgått kirurgisk extraktion posteriort i överkäken. Inga patienter fick blödningar i underkäken som krävde återbesök. Ingen av de 124 patienterna återvände till kliniken med alveolit eller postoperativ smärta. 3/124 (2 %) av patienterna kom tillbaka till kliniken med en postoperativ infektion som krävde antibiotikabehandling. Samtliga patienter med blödningar behandlades konservativt och ingen krävde inläggning.

Slutsats: Om man ger lokalhemostatika, primärsuturerar och ger tranexamsyra efter tandextraktion är risken för blödning hos patienter som står på Warfarin låg.

Introduction

Since six decades warfarin is a widely used oral anticoagulant in the treatment and prevention of venous and arterial thrombosis (10). Warfarin inhibits vitamin K dependent clotting factors which results in the liver producing and excreting partially carboxylated and decarboxylated coagulation proteins (11).

Modification or interruption of warfarin treatment before a dental extraction and when the patient is in the recommended therapeutic interval (2,7), does no longer seem to be necessary. The risk of a thromboembolism is considered a greater problem for the patient than a postoperative bleeding after a dental extraction (8,9). There is no fatal bleeding reported in the literature in association with continuation of warfarin and a dental extraction. But some patients have died in relation to withdrawal of anticoagulants before dental extractions and the risk of thromboembolism has been reported in up to 71% of cases (21).

There are several papers on how warfarin and tooth removal should be managed. Several authors have shown that there is no increase in postoperative bleeding in patients with warfarin treatment, when they continue with the medication and use a protocol of postoperative rinsing with tranexamic acid, often in combination with other local hemostatic agents, and compression (5,16,22). Recent studies have shown that postoperative compression with biting on a gauze soaked in a tranexamic acid solution, instead of rinsing for several days with or without a combination of a local hemostatic agent, is sufficient in preventing postoperative bleeding (2,7,18).

The uses of local hemostatic agents such as gelatin sponge or oxidised regenerated cellulose are common in patients taking warfarin at tooth removal. Several studies are repeated and show similar results of postoperative bleeding (6,18,22). Complete avoidance of hemostatics is unusual (7). There is no international consensus on proper preoperative, peroperative and postoperative care of patients on warfarin.

The aim of this retrospective study was to assess the frequency of postoperative bleeding in patients on warfarin after tooth removal followed by a complete soft tissue closure of the surgical site.

Material and methods

Subjects

At the Department of Oral and Maxillofacial Surgery (OMFS), Skåne University Hospital, Malmö, Sweden, a total of 124 consecutive patients, 69 males and 55 females with a mean age of 71 years (range 28-95 years) were treated by the same oral and maxillofacial surgeon. Inclusion criteria were patients on warfarin with an International Normalized Ratio (INR) ≤3.5 who were referred for tooth removal (single or multiple) during 2004-2009. Patients with congenital bleeding disorders were excluded.

The INR value was measured within 24 hours before surgery. The INR mean value was 2.4 (range 1.0-3.5). The warfarin medication was not altered. In addition to warfarin 11 patients also received acetylsalicylic acid.

In total, 194 teeth were removed. Forty-eight patients had teeth removed because of advanced caries/apical periodontitis, 38 because of root rests/fractures and 28 because of marginal periodontitis. Medical data were collected from patient records and recorded on a standardised form.

Preoperative care

Xylocain® Dental adrenalin 20 mg/ml + 12,5 µg/ml was used for local anaesthesia. When the risk of endocarditis was increased 2g of amoxicillin or 600mg of clindamycin was given 1 hour preoperatively. The risk was considered increased when a patient had heart valve problems or an artificial heart valve, certain congenital heart defects or had a previous episode of infective endocarditis.

Peroperative care

The tooth removal was either a non-surgical procedure, not raising a flap, or a surgical procedure, raising a flap. Granulation tissue was thoroughly removed. Before suturing, one of two types of resorbable haemostatic dressings was placed in the alveolus. An absorbable haemostatic gelatin sponge (Spongostan®) was used in 64 patients and a hemostatic collagen fleece (TissuFleece E®) in 60 patients, subsequently the socket was closed with sutures (Vicryl Plus® 4/0).

When a non-surgical extraction was performed, the socket was closed with suturing of the adjacent soft tissue. If a primary closure was possible to obtain without raising a flap the socket was closed with suturing of the adjacent soft tissue. If primary closure was not achieved a mucoperiosteal flap was raised with or without a Rehrmann plasty (20) to cover the socket. In all cases where a mucoperiosteal flap was carried out, gauze soaked with tranexamic acid (Cyklokapron®, 1 g tablet dissolved in 10 ml of sterile saline) was placed under the flap for 5 minu-

Table 1. Number and type of tooth removal

Tooth removal	Single/ multiple removal	Surgical/non-surgical extraction
Number of patients (124)	88/36	74/50
Number of teeth (194)	88/106	107/87

Table 2. Number of teeth removed in each tooth group

	Maxilla (teeth)	Mandible (teeth)
Incisor/Canine	38	29
Premolar	37	14
Molar	38	38
In total	113	81

Table 3. Treatment of patients with postoperative bleeding (n=5)

Patient	Gender	INR preoperative	ASA	Teeth removed	Tooth diagnosis	Type of tooth removal	Localisation of bleeding (tooth)	Rehrmann plasty (Yes/No)	Day of postoperative bleeding
1	Male	2.1	No	Teeth 37,12,15	Caries/Apical periodontitis	Surgical extraction	15	No	10
2	Female	2.8	No	Tooth 17	Marginal periodontitis	Surgical extraction	17	Yes	4
3	Female	2.8	No	Teeth 32,33,25,26	Caries/Apical periodontitis	Surgical extraction	25	No	6
4	Male	3.0	Yes	Tooth 28	Caries/Apical periodontitis	Surgical extraction	28	Yes	7
5	Male	2.5	Yes	Tooth 16,24	Caries/Apical periodontitis	Surgical extraction	16	Yes	2

tes before suturing. Twenty-seven patients received a Rehrmann plasty and the distribution of tooth removal and the number of teeth removed in the different tooth groups is presented in Tables 1 and 2.

Consequently, all tooth removals were followed by a complete soft tissue closure of the surgical site.

Postoperative care

The patients were instructed to bite on gauze that was soaked in tranexamic acid for 60 minutes postoperatively. Paracetamol (acetaminophen) was recommended, when needed. The patients left the OMFS clinic after the surgery was completed. Patients were instructed to contact the hospital if uncontrolled bleeding would appear. As review appointments were not compulsory it is possible that minor bleedings might have occurred without being reported to the department of OMFS and consequently such bleedings are not included in this study.

Result

5/124 (4%) (95% CI 1.5-9.3) patients returned with postoperative bleedings. The group consisted of 3 males and 2 females with a mean age of 67 years. The bleedings occurred after 2, 4, 6, 7 and 10 days respectively after tooth removal. Patient number 5, (Table 3,) had 2 postoperative bleedings, the first on day 2 and the second on day 6 after tooth removal. In addition to warfarin two patients also medicated with acetylsalicylic acid.

Characteristics of the patients who returned with a postoperative bleeding are presented in table 3.

All patients with a postoperative bleeding had received a surgical extraction in the posterior part of the maxilla, Table 3. Consequently no patient had a postoperative bleeding in the mandible. Three of the five patients with postoperative bleeding had multiple teeth removed. Furthermore, Rehrmann plasty was performed in 3 patients, where the bleeding in one patient was from the releasing incision.

None of the patients returned to the clinic with a dry socket or postoperative pain. 3/124 (2%) patients returned with postoperative infection that required antibiotic treatment.

None of the patients in the present study had a postoperative bleeding that required hospitalisation, blood transfusions or drug administration. Local hemostatic measures were sufficient to stop the bleeding. No thromboembolic events were reported in any patient.

Discussion

This study supports other studies in the findings that warfarin does not have to be suspended when

Table 4. Examples of variation of different local hemostatic measures and postoperative bleeding

Authors	Type of study design		Patients	Teeth extracted	INR (mean)	Age (mean)	Local haemostatic agent	Sutures	Tranexamic acid	Compression	Bleeding (patients)	Day of postoperative bleeding after dental extraction
Devani et al. 1998	Prospective, CCT	Test group	33	69	2.2-3.9 (2.7)	30-82 (64)	Surgicel	Yes	No	Yes	1 (3.0%)	2
		Control group	32	64	1.2-2.1 (1.6)	32-81 (61)	Surgicel	Yes	No	Yes	1 (3.1%)	3
Zanon et al 2003	Prospective, CCT	Test group	250	525	1.8-4.0	44-88	Spongostan	Yes	For postoperative compression 30-60min	Yes	4 (1.6%)	2
		Control group	250	513	n/a	42-92	No	Yes	No	n/a	3 (1.2%)	2
Evans et al 2002	RCT	Test group	57	Ca 2/pat	2.5 (1.2-4.7)	36-92 (67)	Surgicel	Yes	No	Yes	15 (26%)	n/a
		Control group	52	Ca 3/pat	1.6 (1.2-2.3)	30-93 (66)	Surgicel	Yes	No	Yes	7 (14%)	n/a
Ferrieri et al 2007	Case series	Test group	255	n/a	1.3-5.4	27-89 (68)	No	Yes	In some cases for postoperative compression	Yes	5 (2.0%)	12 hours-5 days
Bacci et al 2010	Prospective CCT	Test group	451	921	1.8-4.0	38-89 (64)	Oxidised cellulose	Yes	For postoperative compression 30-40min	Yes	7 (1.6%)	2-6
		Control group	449	894	n/a	35-92 (66)	Oxidised cellulose	Yes	For postoperative compression 30-40min	Yes	4 (0.9%)	2
Carter et al 2003	Prospective RCT	Test group	43	97	2.7 (2.0-4.0)	21-77 (65)	Surgicel	Yes	4.8% Rinsing 2 days postoperative	n/a	2 (4.7%)	0-2
		Control group	42	104	2.8 (2.0-4.0)	24-86 (66)	Surgicel	Yes	4.8% Rinsing 5 days postoperative	n/a	1 (2.4%)	0-2
Carter et al 2003	Prospective RCT	Test group	26	71	3.0 (2.3-4.0)	24-85	Surgicel	Yes	4.8% Rinsing 7 days postoperative	n/a	0	n/a
		Control group	23	81	3.1 (2.1-4.0)	40-83	Surgicel	Yes	Autologous Fibrin glue peroperative	n/a	2 (8.7%)	3 and 7
Sacco et al 2007	Prospective RCT	Test group	65	511	(2.89)	29-86 (61)	Gelatin/ oxidized cellulose sponges	Yes if indicated	Rinsing for 2 days postoperative	n/a	6 (9.2%)	2-3
		Control group	66		1.5-2.0 (1.77)	29-87 (64)	No	Yes if indicated	No	No	10 (15.1%)	2
Blinder et al 1999	Prospective CCT	Test group 1	50	119	1.5-4.0 (2.38)	40-86 (56)	Gelatin sponge	Yes	No	n/a	3 (6%)	n/a
		Test group 2	50	117	1.5-4.0 (2.7)	35-79 (61)	Gelatin sponge	Yes	Rinsing for 4 days	n/a	6 (12%)	n/a
		Test group 3	50	123	1.5-4.0 (2.19)	40-93 (64)	Gelatin sponge	Yes	Fibrin glue	n/a	4 (8%)	n/a
Salam et al 2007	Retrospective Case series	Test group	150	279	0.9-4.2 (2.5)	33-92 (66)	Surgicel	Yes	No	Yes	10 (6.7%)	n/a
Morimoto et al 2008	Prospective Case series	Test group 1	134	278	1.5-4.0	59.0	Surgicel	Yes	No	Yes	7 (4.4%)	n/a
		Test group 2	49	91	1.5-3.0	62.9	Surgicel	Yes	No	Yes	2 (3.9%)	n/a
		Test group 3	87	144	n/a	61.4	Surgicel	Yes	No	Yes	2 (2.2%)	n/a

patients are in their therapeutic range and require a tooth removal (2,7,12,17,21,22).

The recommended therapeutic INR range in Sweden is 2.0-3.0 for all medical diagnosis. The literature, confirms that the rate of postoperative bleeding after tooth removal in patients on warfarin is low when the INR is ≤3.5 and local hemostatic management are instituted, Table 4. In addition, a number of articles confirm that even a higher INR than 3.5 is possible when a tooth removal is required, Table 4. *Blinder et al.* (3) did not find a statistical significant correlation between preoperative INR value and incidence of postoperative bleeding. *Malden et al.* (13) found a significant difference in INR before and after surgery when multiple extractions and surgical removals were compared with single extractions. The INR is known to fluctuate e.g. in relation to diet habits and medicine intake (14,19).

Regarding the use of local hemostatic procedures, the literature is not homogenous. The majority of published studies use one or several local hemostatics to compensate for the anticoagulant effect of warfarin, and thereby prevent a postoperative bleeding.

The majority of studies on the incidence of postoperative bleeding have used a local hemostatic agent that is placed in the alveolus and all these studies have had a very low incidence of postoperative bleeding, Table 3. However, *Ferrieri et al.* (7) did not use a local hemostatic agent placed in the alveolus and showed a low incidence of postoperative bleeding.

Sutures are mostly used after a surgical extraction but also to hold a local hemostatic agent in place in the alveolus. *Al-Mubarak et al.* (1) investigated postoperative bleeding in 214 patients in relation to INR value and the role of suturing. Only non-surgical extractions were performed. Suturing resulted in a higher incidence of postoperative bleeding compared to when not suturing.

Tranexamic acid has an antifibrinolytic effect and several studies have investigated its clinical effect on postoperative bleeding after tooth extraction in patients on anticoagulant treatment. *Carter et al.* (5) noted that there was no statistical difference in the risk of postoperative bleeding, when patients rinsed with tranexamic acid for 2 days versus 5 days. The drug is used for rinsing or as a solution to soak gauze used for compression postoperative. The use of gauze soaked in a tranexamic acid solution for compression is an alternative for preventing a postoperative bleeding.

Ferrieri et al. (7) only used sutures and compression, with or without tranexamic acid, as local hemostatic procedures with a low incidence of postoperative bleedings.

In the present study, all patients with postoperative bleeding received a surgical extraction in the premolar/molar region of the maxilla. This is in accordance with a review by *Rodriguez-Cabrera et al.* (17). They concluded that there was a tendency for a higher incidence of postoperative bleeding from the maxilla versus the mandible. Four of the 5 patients with a postoperative bleeding had their teeth removed because of caries/apical periodontitis and one because of marginal periodontitis. Blinder et al. (4) concluded that there was a higher tendency of a postoperative bleeding when a tooth diagnosed with periodontitis was extracted. A higher incidence of postoperative bleeding in the presence of an acute inflammation in the surgical region has been verified (14).

Three patients out of 5 had multiple extractions performed but postoperative bleeding only occurred from one site. This is in accordance with *Blinder et al.* (4).

The objective of the peroperative procedure in this study was to achieve complete soft tissue closure of the extraction socket by suturing. When needed a Rehrmann plasty was performed. When primary closure was performed after tooth removal the incidence of postoperative bleeding in this study was 4%. This is in accordance with *Sacco et al.* (18) who at primary closure noted that 9.2% returned with postoperative bleeding. Other articles have shown that the incidence of postoperative bleeding is 0.9%-2.2% when the patient is not using warfarin (2,15,22).

Conclusion

According to the protocol of this study the risk of postoperative bleeding after tooth removal in patients on continued warfarin medication is low. Gentle handling of the soft and hard tissues has to be the standard when performing tooth removals in patients on warfarin. But the minimum measures that have to be taken for sufficient homeostasis has not yet been established. There is a need for prospective randomised controlled trials, where each step has to be evaluated.

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Comparison of diagnostic performance on approximal caries detection among Swedish and Chinese senior dental students using analogue and digital radiographs

William Minston[1], Gang Li [2], Rikard Wennberg[1], Karin Näsström[1], Xie-Qi Shi[1]

Abstract

◎ The objective was to investigate diagnostic performance on approximal caries detection among Swedish and Chinese dental students using analogue and digital radiographs in vitro. Additionally, to compare the diagnostic accuracy of two image modalities for approximal caries detection.

46 extracted premolars and molars were mounted in blocks and exposed with two intra-oral systems, one CCD based digital radiographs and one with conventional films. 10 Swedish and 10 Chinese senior dental students diagnosed the approximal sites of the teeth exposed with the digital and analogue images. A 5 point diagnosis confidence scale was applied for caries registration for all the observers. Subsequently, the teeth were sectioned and histo-pathologically analyzed in order to obtain a gold standard. The data were analyzed in terms of receiver operating characteristic (ROC) curves for evaluation of diagnostic accuracy of the two radiographic methods and for the two groups of students for enamel and dentinal caries detection, respectively.

The area under the ROC curve was significantly higher for dentinal caries detection compared with enamel caries detection for both Chinese and Swedish students and for both imaging modalities ($p<0.001$). The present results indicated that the students' ability for enamel caries detection on approximal surfaces was poor. Neither between the two student groups ($p=0.15$-0.64) nor between the two image modalities ($p=0.34$-0.91) a statistically significant difference in detecting approximal caries was found.

Conclusions: The two different intra-oral x-ray systems were equally accurate. Chinese and Swedish students showed similar outcomes in their performance for approximal caries detection.

Key words

Dental caries, digital radiography, radiographic film, dental students

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Jämförelse mellan svenska och kinesiska sistaårs-studenter på tandläkarutbildningen med avseende på diagnostik av approximalkaries vid användning av analog och digital röntgen

William Minston , Gang Li, Rikard Wennberg, Karin Näsström ,Xie-Qi Shi

Sammanfattning

◎ Syftet med föreliggande studie var att utröna diagnostisk prestation bland svenska och kinesiska tandläkarstudenter med avseende på detektion av approximalkaries vid användning av analog och digital röntgen in vitro samt att jämföra diagnostik av approximalkaries mellan analoga och digital röntgenbilder.

46 extraherade premolarer och molarer placerades i block och exponerades med två intraorala system; en CCD-baserad digital röntgen och en med konventionella dentala filmer. 10 svenska och 10 kinesiska sistaårsstudenter diagnostiserade tändernas approximala ytor genom granskning av de digitala och analoga bilderna. En 5-gradig "confidence scale" applicerades vid kariesregistreringen för samtliga granskare. Tänderna blev sedan snittade och analyserade histopatologiskt för erhållandet av en "gold standard". Resultaten analyserades med hjälp av receiver operator characteristic (ROC) kurvor, vilka möjliggjorde utvärdering av den diagnostiska precisionen beträffande de två röntgenmetoderna samt för de två studentgrupperna vid detektion av emalj- och dentinkaries.

Arean under ROC-kurvorna var signifikant högre för detektion av dentinkaries jämfört med detektion av emaljkaries för både kinesiska och svenska studenter samt för de båda röntgensystemen ($p<0.001$). De aktuella resultaten indikerar att studenternas detektionsförmåga vad gäller emaljkaries vid approximala ytor var dålig. Varken mellan de två studentgrupperna ($p=0.15$-0.64) eller mellan de två röntgenmetoderna ($p=0.34$-0.91) kunde en statiskt och signifikant skillnad skönjas vid detektion av approximalkaries.

Konklusion: De två olika intraorala röntgensystemen var likvärdiga. Svenska och kinesiska studenter uppvisade liknande diagnostiska resultat.

Introduction

Numerous studies have been conducted, comparing diagnostic performance of analogue images with digital images for caries detection. The majority of these studies have concluded that digital technique is comparable to conventional analogue technique for caries detection (1, 17-20). Furthermore, according to recent studies the diagnostic accuracy for caries detection may be influenced by a number of factors such as clinical experience, dental professions, student education and training (3, 6, 10-11, 21).

In the field of dentistry, all regions of the world have not been digitized to the same extent; some countries have, more or less, completely abandoned the analogue radiographs, whereas other countries still have not got accustomed to the digital techniques. The dental schools of Sweden have been completely digitized, and hence the students practice in daily clinical work with only digital radiographs. In China, on the other hand, the conventional analogue technique is still commonly applied at the dental schools. The above mentioned difference in the Swedish and Chinese radiological training gives rise to an essential question; does it influence the students' ability in diagnosing caries applying the radiographic technique with which they are not familiar? Apart from the difference in application of digital technique between the Swedish and Chinese dental schools, the contrast in terms of caries prevalence in the two countries should also be taken into consideration. According to the latest report from the Chinese Stomatology Association (CSA), dental caries in China remains a pressing issue with the caries rate being 66 % for deciduous teeth and up to 88 % for permanent teeth (13), whereas the caries prevalence in Sweden is about 41 % for patients of 19 years of age who receive dental treatment at the Swedish Dental Service according to a report by the Swedish National Board of Health and Welfare (16). Enamel caries was not included in the registration of caries prevalence in both studies and thus it may be higher. There are no national data spanning caries rate among Swedish adults.

The aims of the present study were two folds: first to investigate performance of approximal caries detection between senior dental school students from China and Sweden on an educational perspective; secondly to evaluate whether different image modality would influence students' ability on approximal caries diagnosis.

Materials and Methods

Ethical aspect

The present study is an in vitro study in which human extracted teeth is applied. Since the extracted teeth cannot be associated to individuals no conflicting ethical aspects exist although human biologic material was used.

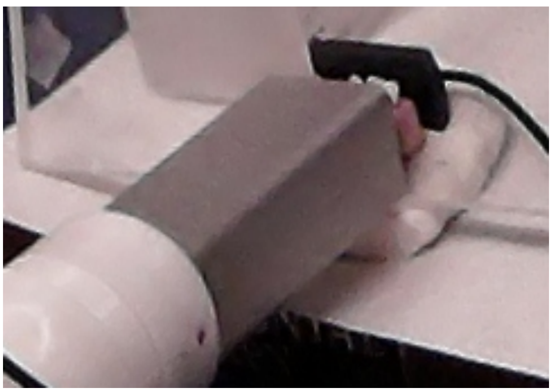
Tooth samples

Fourteen dental clinics within the Swedish Dental Service were contacted and approximately 100 extracted teeth were collected, of which 46 were considered appropriate for the project. The inclusion criteria for the sample collection were molars or premolars without previous fillings on the approximal surfaces. The teeth were mounted in groups of 4 in 11 blocks and group of 2 in 1 block using impression material (Provil©). The teeth were placed as close as possible to simulate their inter-approximal contacts as under in vivo condition.

Digital and analogue radiographs

The 12 tooth blocks were exposed with a CCD based intra-oral system (Dixi, Planmeca oy, Finland) at the Department of Dental Medicine, Karolinska Institutet, Sweden) and with conventional analogue radiographs (Kodak E-speed, Carestream Health Inc., Rochester, NY, USA) at Peking University School and Hospital of Stomatology, Beijing, China. A 10mm thick soft tissue equivalent plastic compound (plexiglass) was applied between the tooth blocks and the collimator to simulate soft tissue for both types of radiographs. Parallel technique was applied at both occasions to obtain images with non-overlapped approximal surfaces (Figure 1). For determining the optimal exposure parameters a sequential test of radiographs was exposed. Based on the default

Figure 1. Set up of image capturing.



exposure parameters at the two clinics, the tube voltage and tube current were kept constant whereas the exposure time varied at 5 exposure levels. The exposure time that yielded the best image quality was selected for this study. The digital radiographs were acquired using the PlanmecaTM X-ray unit. The exposure parameters were set to 66 kVp, 8 mA and 0.16 s with a focus to object distance of 23 cm for all exposures. For the analogue radiographs the Planmeca intra X-ray unit was employed. The corresponding exposure parameters were 70kVp, 8mA and 0.25s with a focus to object distance of 23 cm. The film radiographs were developed in an automatic film processor (XR 25s; Dürr Dental, Bietigheim-Bissingen, Germany) by following the instructions of the manufacturer. All films were processed with fresh Dürr-Automat XR/C chemicals (Dürr Dental).

Viewing and evaluation

Four surfaces were excluded from the study due to inevitable overlapping of approximal surfaces presented in either digital or analogue radiographs. Thus, a total number of 88 approximal surfaces were included. Two survey papers were composed based on the digital and analogue radiographs, where the observers were asked to diagnose the coronal section of the approximal sites in regards to the absence or presence of carious lesions. The two sets of randomized images were viewed under the same viewing conditions, i.e. dimmed light, by 20 senior dental students; 10 from each country. The survey sheets were completed under supervision. Furthermore, no information was provided to the observers in terms of caries prevalence in this study sample. For the analogue images a so-called Mattson-kikare was used, which is a device with a magnification factor of 2 that screens off the surrounding light. The monitors used in the study were pre-adjusted to DICOM setting with built-in Barten curve (2). The Resolution was set to 1,280×1,024 pixels with32 bit colour. The observers were not allowed to adjust the brightness or contrast of the computer screen during viewing. Each observer was instructed to select one of the five ratings to represent his or her level of confidence that a carious lesion was present or not on the approximal surfaces of the teeth. The following scale was used: definitely not caries (1), probably not caries (2), uncertain (3), probably caries (4) and definitely caries (5).

Histopathology analysis

All the 46 teeth were numbered and embedded separately in plastic. Before the sectioning, the mesial and the distal surfaces were registered for each tooth, after which a sequential slice was sectioned in mesiodistal direction taken perpendicular to the occlusal surface for each tooth using a water-cooled diamond saw (Leica SP1600 saw microtome; Leica Microsystems GmbH, Wetzlar, Germany). For each tooth around 5-7 slices were obtained with a thickness of 300 μm per slice. Histo-pathological analysis was carried out applying an optical microscope at a magnification of 16 (Stereomicroscope ZOOM-630E; Changfang Optical Instrument Ltd., Shanghai, China). The lesions were defined by the extension of a whitish decalcified zone or a brown zone in the approximal surface-pulpal direction. The extension of the approximal caries was registered as sound, enamel and dentin caries.

Receiver operating characteristic analysis (ROC)

The registered scores of confidence levels on the presence of caries by the students were evaluated with respect to diagnostic accuracy in terms of ROC analysis using the Statistical Package for the Social Sciences (SPSS). A ROC curve is a plot of sensitivity (y-axis) as a function of [1-specificity] (x-axis) for each possible cut-off. The area under the curve (Az) is the measure that indicates the diagnostic accuracy. The closer the Az value is to 1, the better the accuracy is. If the test is positive or negative just by chance the result will be a diagonal line and the Az value will be 0.5 (4, 12).

ROC analyses were performed for each student and for enamel and dentinal caries detection, respectively. The area under the curve was calculated for each student for both image systems. The Az values between both groups of students were compared using student t-test for enamel and dentinal caries detection respectively.

The A_z values from all the students between the two types of the image modalities were compared using paired T-test for enamel and dentinal caries detection, respectively.

Results

Among the 88 approximal surfaces that were sectioned, 56 were sound and 32 exhibited caries, 16 enamel and 16 dentinal caries, respectively. Table 1 summarizes the mean values and the standard deviations of Az for the two students group and for the two image types . Student t-tests indicated no statistically significant difference between the two groups of students in terms of the Az (p=0.15-0.64) regardless of lesion type.

Table 1. The mean area under the ROC curves and its standard deviation calculated for the two groups of students and for the two types of radiographs. No statistically significant difference was found neither between students from China and Sweden nor between the two types of image modalities

	Digital radiographs						Film radiographs					
	Enamel caries			Dentinal caries			Enamel caries			Dentinal caries		
	SD	Mean	P	SD	Mean	P	SD	Mean	P	SD	Mean	P
Chinese students	0.060	0.52	0.21	0.080	0.74	0.64	0.082	0.52	0.15	0.080	0.78	0.20
Swedish students	0.051	0.55		0.048	0.73		0,049	0.56		0,053	0.74	

P=0.91 and 0.83

P=0.34 and 0.85

Paired t-tests showed no statistically significant difference of the area under curve (Az) between the two types of radiographs for both Chinese and Swedish students regardless of lesion types (p=0.34-0.91).

The diagnostic accuracy for enamel caries detection was poor with both types of images for all the students. The students' ability of detecting dentinal caries on approximal surfaces was significantly higher than that of enamel caries detection regardless of student group and image type ($p<0.001$).

Figures 2-3 show ROC-curves of dentinal caries detection for the two imaging modalities based on the diagnoses of the two groups of students. Notable variation between individual ability for caries detection is observed for the two groups of students.

Discussion

Since the introduction of intraoral digital technique, a number of studies have reported that there is no significant difference in diagnostic accuracy on caries detection between digital and conventional film imaging modalities among dental professionals (1, 17, 18, 20). In the present study the exposure parameters including tube voltage and tube current were determined by the default setting at each clinic for digital and film radiographs. There is a minor difference in tube voltage being 70 kvp for analogue and 66 kvp for digital radiographs. Theoretically, within 60-90 kvp, the lower tube voltage the better contrast in an intraoral image. However the difference of tube voltage is limited and it would not in practice affect students' ability for caries detection (5).

At that time the dental professionals were more familiar with viewing analogue radiographs than digital radiographs and thus the factor of previous perceptual experience could not be excluded when comparing two types of radiographs. Our present study chose senior dental school students from two universities to ensure that the observers have comparable experience in caries diagnosis and at the same time the two groups of students had no previous experience in viewing either digital or analogue image depending on which university they were studying at. There were minor differences in mean Az values between the two groups of students for the two different intra-oral x-ray systems, which should be deemed trivial. Hence, it was confirmed that both film and digital radiographs had similar diagnostic performance for approximal caries detection. It was expected that the Chinese students would have higher diagnostic accuracy when viewing film radiographs than digital radiographs and vice versa for the Swedish students. However, this trend was not observed in the present study. One possible explanation could be the fact that the duration of the student radiology training and the amount of radiographs scrutinized at dental schools is limited. Therefore the type of image modality may not be a critical factor for caries detection for dental students. It could also be concluded that previous perceptual experience on an unfamiliar image did not seem to influence the students' ability on approximal caries detection.

Caries diagnosis is important since the treatment that is opted for is based on how extensive and progressive the operator interprets the carious finding. Swedish dental students are trained to address initial lesions confined to the enamel with prophylactic care, while invasive treatments are to be applied on lesions that have reached to the dentin. Naturally, it is of great significance to distinguish sound teeth from those which have been demineralised so that therapies are not planned where there is no such indication. The present study showed that Az value for enamel caries detection is just above 0.5 indicating

Figure 2a and 2b. ROC-curves for dentinal caries diagnosis using digital and analogue radiographs for Chinese students.

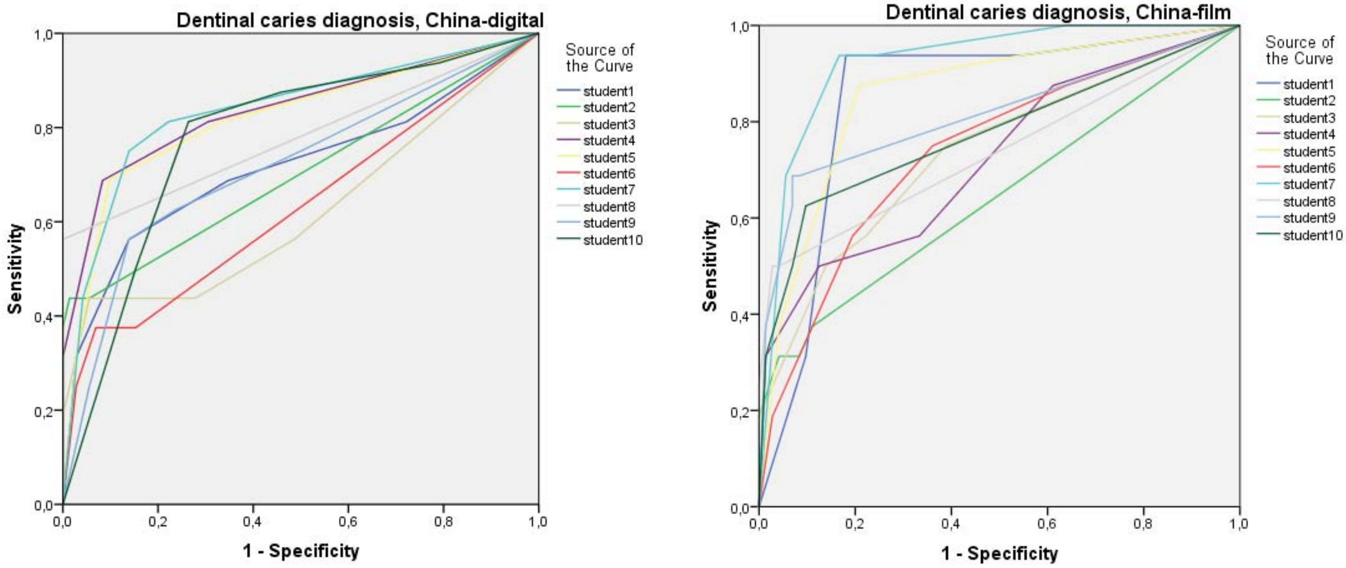
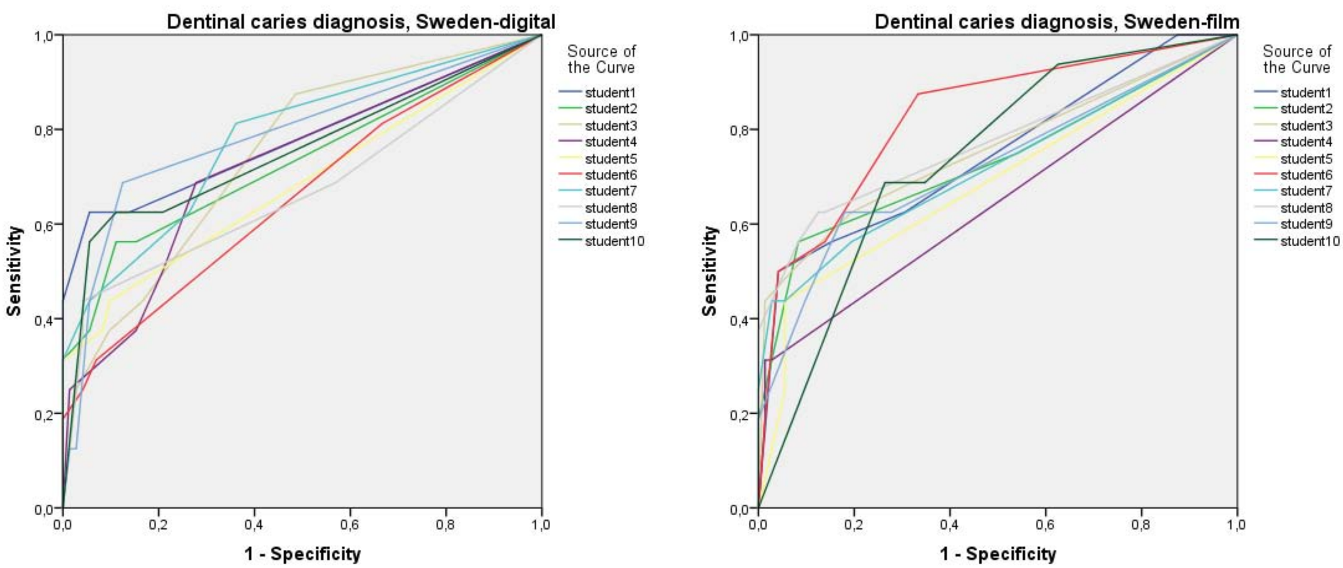


Figure 3a and 3b. ROC-curves for dentinal caries diagnosis using digital and analogue radiographs for Swedish students.



that the students have poor ability on initial caries detection. This may due to the combination of poorer diagnostic experience of students and the "well known" low diagnostic accuracy in diagnosing initial caries (8). That fact is alarming as it denotes that initial caries is easily missed. Consequently preventive care may not be considered when there is a need for it. Other alternative diagnostic methods shall be considered to overcome the intrinsic feature of radiographs (7, 9, 14, 15).

In fact, it has been shown in other studies that it is common with inconsistency between and within dentists (17). In our study a notable variation in Az values was observed for both groups of students regardless of image types (Figures 2-3).

In conclusion a perceptible difference between analogue and digital radiographs in diagnostic performance for caries detection could not be verified. The two different intra-oral x-ray systems were equally accurate. Chinese and Swedish students showed similar outcomes in their diagnosis. Both groups of students had poor diagnostic accuracy in enamel caries detection on approximal surfaces.

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The prevalence and alterations of furcation involvements 13 to 16 years after periodontal treatment

Karl-Johan Johansson, Carin Starkhammar Johansson, Nils Ravald

Abstract

◎ The aim of this study was to evaluate the long term outcome of furcation involved molars in a population treated for periodontal disease.

Initially, the study sample was 147 referred periodontal patients. Periodontal treatment consisted of oral hygiene instructions, supra- and subgingival scaling and periodontal surgery. After treatment 99 patients participated in a two year study on root caries. The patients got maintenance treatment every third to fourth month during 2 years. At the end of that study the patients were periodontally healthy and were referred back for supportive treatment to the referring dentist. Thirteen to 16 years after periodontal treatment 81 patients were still alive and 64 accepted a re-examination.

At the start of the observation period the remaining 64 patients had in total 1537 teeth. During the 13 to 16 year follow up 217 teeth were lost. The number of molars at baseline was 361. The number of furcation involvement with different degrees were; 267 (0), 67 (I), 25 (II) and 2 (III) respectively. Totally 69 molars were lost during follow up. The proportion of molar loss according to the degree of furcation involvements 0 to III at baseline were 15%, 29%, 40% and 100% respectively. It was a significant greater risk of loosing an initially furcation involved molar than a single rooted tooth ($p<0.0001$). The risk of loosing an initially furcated molar increased with the degree of furcation involvement (degree I; $p<0.05$, degree II; $p<0.01$).

In conclusion: During a long term observation period molars with furcation involvements are more frequently lost than not furcation involved molars. However, two thirds are still in function 13 to 16 years after treatment which indicate that molars with furcation involvements might survive long after periodontal treatment.

Key words

Furcation defects, tooth loss, retrospective studies, treatment outcome, follow-up-studies

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Förekomst och förändringar av furkationsinvolveringar på molarer. En retrospektiv studie 13 till 16 år efter inledande parodontal behandling

Karl-Johan Johansson, Carin Starkhammar Johansson, Nils Ravald

Sammanfattning

◎ Syftet med studien var att göra en långtidsuppföljning av förekomst och förändringar av furkationsinvolverade molarer hos patienter som behandlats för parodontit. Från början bestod studiegruppen av 147 patienter som remitterats till specialistklinik för parodontologi. Behandlingen bestod av munhygieninstruktion, supra- och subgingival scaling och parodontal kirurgi. Efter behandlingen deltog 99 av patienterna i en två år lång rotkariesstudie. Under studieperioden fick de stödbehandling var tredje till fjärde månad. Vid studiens slut var patienterna vid god parodontal hälsa. Fortsatt stödbehandling sköttes av ordinarie tandvårdsteam. Efter 13 till 16 år erbjöds de 81 kvarvarande patienterna ny undersökning varav 64 deltog i studien. Antalet tänder, parodontalt status inklusive grad av furkationsinvolvering hos kvarvarande molarer registrerades.

Vid ursprungsundersökningen hade de 64 patienterna 1537 tänder. Totalt 217 tänder förlorades under uppföljningsperioden. Antalet molarer var vid ursprungsundersökningen 361. Antalet molarer med furkationsinvolvering 0-III var 267, 67, 25 och 2 . Sextionio molarer förlorades under uppföljningsperioden. Andelen extraherade molarer med hänsyn till grad av furkationsinvolvering 0-III vid ursprungsundersökningen var 15 %, 29 %, 40 % och 100 %. Det var en signifikant högre risk att förlora en initialt furkationsinvolverad molar jämfört med en enrotig tand ($p<0.0001$). Risken att förlora en initialt furkationsinvolverad molar ökade med grad av furkationsinvolvering (grad I; $p<0.05$, grad II; $p<0.01$).

Sammanfattningsvis visade studien att förekomst och grad av furkationsinvolvering är avgörande för molarers överlevnad i ett långtidsperspektiv. Trots furkationsinvolveringar är 2/3-delar av molarerna i funktion 13 till 16 år efter behandling vilket visar att de kan överleva lång tid efter parodontal behandling.

Introduction

Epidemiological studies have shown that molars are the most frequently missing teeth among people in the late middle-ages and among the elderly (18). *Paulander et al. (29)* found in a prospective 10-year study in 50-year-olds that the incidence of tooth loss was highest among mandibular molars and that the presence of furcation involvement increased the risk of losing the tooth three to six times. A prospective study on disease progression in periodontally untreated individuals showed that molar sites more frequently increased probing attachment loss during a 24 month observation period (24).

Proper instrumentation of the infected root surface is crucial in the treatment of periodontal disease. One explanation why molars have a worse long-term prognosis may be that local factors adversely affect treatment outcome. The furcation areas of molars are complex and contain numerous small ridges, peaks, and pits, forming a mixture of convexities and concavities (38). The extent of periodontal destruction and the anatomy of the furcation area determine what treatments are possible. Initially furcation involved molars (degree I – II) may be treated successfully by oral hygiene measurements and scaling procedures (2). Deeper defects can successfully be treated by surgical and resective treatments e.g. tunnel preparation or resection of roots (6, 7, 8, 15, 21). Long-term studies on root resection therapy show that although periodontal disease is treated, teeth are extracted for other reasons such as root fractures and endodontic infections. Results from different studies show a large variation of success. This indicates that root resection therapy is a technique-sensitive procedure.

Another approach to treat furcation-involved molars is regeneration of the lost periodontal tissue. Guided tissue regeneration as a supplement to open flap debridement in the treatment of mandibular degree-II and buccal maxillary degree-II furcation defects improve clinical conditions (13, 19, 22, 31, 33). Other studies report unfavorable results of guided tissue regeneration therapy in interproximal degree-II furcations of maxillary molars and degree-III furcations in both jaws (27, 32, 34).

The prognosis of available treatment options does not appear to be predictable in the treatment of all types of defects in all molar positions. Numerous studies that address tooth loss in patients treated for periodontal disease account for furcation-involved molars (9, 10, 12, 14, 16, 20, 25, 26, 30, 37, 41, 42). The studies show great heterogeneity. *Hamp et al.* (14) reported no loss of furcated molars over a period of 5 years while a study of *Hirschfeld & Wasserman* (16) showed a loss of 32% of furcation involved molars during an observation period exceeding two decades. More recent publications report losses of less than 10% of furcated molars over an observation period of nearly 10 years (9, 10).

The aim of the present study was to evaluate the long term outcome of furcation-involved molars in a population treated for periodontal disease 13 to 16 years earlier.

Material and Methods

Study Population

Initially, 147 patients referred to the Department of Periodontology, Public Dental Service, Linköping were randomly selected for a study on root caries in patients in need of periodontal treatment (35). Forty-eight individuals were lost before initiation of a clinical trial due to lack of interest to participate (n=20), repeated missing appointments (n=13), removal from the area (n=6), uncompleted periodontal therapy (n=5), death (n=3) and one toothless patient after initial therapy. After active periodontal treatment, 99 patients participated in a 2-year longitudinal study on root caries (36). Thirteen to 16 years (mean 14.8, SD: 0.7) after periodontal treatment all the 81 surviving patients were called for a new examination. Sixty-four patients, 29 males and 35 females, with a mean age at the final examination of 64 years (SD: 8.7; range 49–91) accepted to participate. The drop-out of patients was due to death (18 patients), 5 could not attend due to illness, 4 had moved from the area and 8 were not interested to participate. The study protocol was approved of the Ethics Committee of the University of Linköping, Sweden, and the patients gave their informed consent to participate in the study.

Clinical Examinations

Clinical examinations were performed before and after active periodontal treatment and after 13 to 16 years. The initial examination was performed in a dental chair by one periodontist (NR) and the final examinations were performed by two experienced and calibrated periodontists (NR and CSJ). During the study the patients were independently registered by the examiners. In case of furcations difficult to assess and classify a consensus was adopted by the two examiners. The clinical examinations included recordings of number of teeth, periodontal conditions (23), bleeding on probing (1) and plaque scores

(28). The horizontal extent of furcation involvement was assessed according to *Hamp et al.* (14).
Degree I: Horizontal loss of periodontal support within the furcation area less than one-third of the tooth's buccolingual dimension.
Degree II: Horizontal loss exceeding one-third of the tooth's dimension but less than the total width of the furcation area.
Degree III: Horizontal "through and through" destruction of the periodontal tissue in the furcation.

Full-mouth intra-oral radiographic examinations using standardized parallel technique were performed at the initial and the follow-up examinations (11).

Treatment

Active periodontal treatment comprised oral hygiene instruction, supra- and subgingival scaling, and in 56 patients, selective periodontal surgery in one or more quadrants. In two patients regenerative surgery was performed in totally three mandibular degree II involved molars with GTR-technique. After completion of active periodontal treatment (baseline in the present study), all patients in the prospective study group received 2 years of maintenance treatment every third to fourth month by dental hygienists at the Department of Periodontology. Thereafter the patients were referred back to their regular general dentists and hygienists for continued check-ups and supportive periodontal therapy.

Data collection

Data were analyzed from the examination after active treatment and the final follow-up examination. Information about smoking and dental care habits were recorded from questionnaires filled out at the final examination. The total number of teeth and molars, number of molars in each position, and degree of furcation involvement were recorded. When various degrees of furcation involvements occurred within the same tooth, the most severe furcation defect was used in the data analysis. Based on clinical and radiographic findings the severity of periodontal disease was classified in 5 categories according to the criterias outlined by *Hugoson & Jordan* (17):
Group 1. Healthy or almost healthy gingival units, normal alveolar bone height, and ≤ 12 bleeding units in the molar-premolar regions.
Group 2. Gingivitis, normal alveolar bone height, and > 12 bleeding gingival units in the molar-premolar regions.
Group 3. Alveolar bone loss around the majority of the teeth not exceeding 1/3 of normal bone height.
Group 4. Alveolar bone loss around the majority of the teeth ranging between 1/3 and 2/3 of normal bone height.
Group 5. Alveolar bone loss around the majority of the teeth exceeding 2/3 of normal bone height and presence of angular bony defects and/or furcation defects.

Statistical analysis

For descriptive analysis of the patient characteristics the mean and standard deviations (SD) of the variables were calculated. To investigate if there was a significant difference between proportions of lost teeth during follow-up a normal test with continuity correction was used. Intra-group comparison between baseline and final examinations were analyzed by a paired t-test. To test the correlations between single variables and molar loss, Pearson product-moment correlation test was used. One-way analysis of variance (ANOVA) was used to test the significance of differences among groups when the variable was measured on an interval scale. In all tests a p-value <0.05 was considered to be statistically significant.

Results

Periodontal variables and patient characteristics

The number of teeth and the periodontal status of the 64 patients at baseline and the final examination are shown in Table 1. At final examination the study sample had a mean of 20.8 teeth, including 4.6 molars and 1.2 molars with furcation involvement. Thirty individuals were former smokers, 20 current smokers and 14 never smokers. Fifty-eight individuals (91%) reported that they visited dentists 1-2 times a year and 45 (71%) visited dental hygienists 1-4 times a year. The severity of periodontal disease expressed as the severity index by *Hugoson & Jordan* (17) is shown in Table 2.

Prevalence of furcation involvements

At baseline there were totally 361 molars, 182 maxillary and 179 mandibular molars (Table 3). Out of these 190 were first and 171 second molars. No clinical furcation involvements were scored on 267 molars (74%). The prevalence of degree I, II, and III furcation involvement was 67 (18%), 25 (7%) and 2 (1%) respectively.

Alterations of furcation involvements

The prevalence and alterations of furcation involve-

Table 1. Total number of teeth and molars with furcation involvements (Mean and standard deviation, SD), plaque score, bleeding on probing score and periodontal probing depths in the study group at baseline and final examination (n=64)

Variable	Baseline		Final examination		
	Mean	SD	Mean	SD	p-value
Teeth	23.4	4.8	20.8	6.7	0.0001
Molars	5.6	2.5	4.6	2.7	0.03
Molars with furcation involvements	1.5	1.8	1.2	1.7	ns
Plaque index (%)	23	23	39	26	0.02
Bleeding on probing (%)	17	18	21	19	ns
Probing pocket depths 4-6 mm (no)	13	12	13	8	ns
Probing pocket depths >6 mm (no)	2	6	1	2	ns

Table 2. Distribution of patients according to the severity of periodontal disease index according to Hugoson and Jordan (17)

Severity of periodontal disease experience	No of patients*	No of lost molars*
Group 2	1	0
Group 3	27	7
Group 4	27	46
Group 5	8	15

*One molar lost in one patient was not classified due to technical failure

Table 3. Number of molars at baseline concerning jaw, position and extent of furcation involvement (degree 0-III)

Furcation involvement	Maxillary molars (n = 182)				Mandibular molars (n = 179)				Total no.
	first		second		first		second		
	right	left	right	left	right	left	right	left	
0	34	37	33	37	32	30	37	27	267
I	10	8	8	4	14	11	4	8	67
II	3	5	2	1	1	3	3	7	25
III	0	0	0	0	1	1	0	0	2
Total number	47	50	43	42	48	45	44	42	361

Table 4. Alterations of furcation involvements and number of lost molars during follow-up

Furcation involvements at baseline	Furcation involvement at follow-up examinations 0	I	II	III	Extracted molars	Total number
0	155	60	7	6	39	267
I	21	20	5	3	18	67
II	5	3	5	2	10	25
III	0	0	0	0	2	2
Total number	181	83	17	11	69	361

ments and the number of lost molars during the total observation period are shown in Table 4. Among molars initially with no furcation involvements, 155 were unchanged and 60 progressed into degree I, 7 to degree II and 6 to degree III. Out of molars initially disclosing degree I furcation involvements, 20 were unchanged, 21 improved, and 8 deteriorated. Among molars initially diagnosed to have degree II furcation involvements, 5 were unchanged, 8 improved, and 2 increased to degree III. The two molars with initially degree III involvements were both extracted during the observation period.

Loss of molars

At baseline the number of teeth was 1537 including 361 molars. During the follow-up 148 non-molar and 69 molar teeth were lost (Figure 1). Out of the 69 molars lost during follow-up, 52 were lost due to periodontitis, 4 due to endodontic lesions and 4 due to caries. The reason for loss of 9 molars could not be determined.

Loss of molars in relation to baseline furcation involvement degree 0-III, were 15%, 29%, 40% and 100% respectively. There was a significantly greater risk of loosing an initially furcation involved molar degree I-II than an initially not furcation involved molar during the follow-up period (degree 0 vs. I; $p<0.05$, degree 0 vs. II; $p<0.01$). The risk of loosing an initially furcation involved molar (degree I-III) was significantly higher than loosing a single rooted tooth ($p<0.0001$) or an initially not furcation involved molar ($p<0.001$).

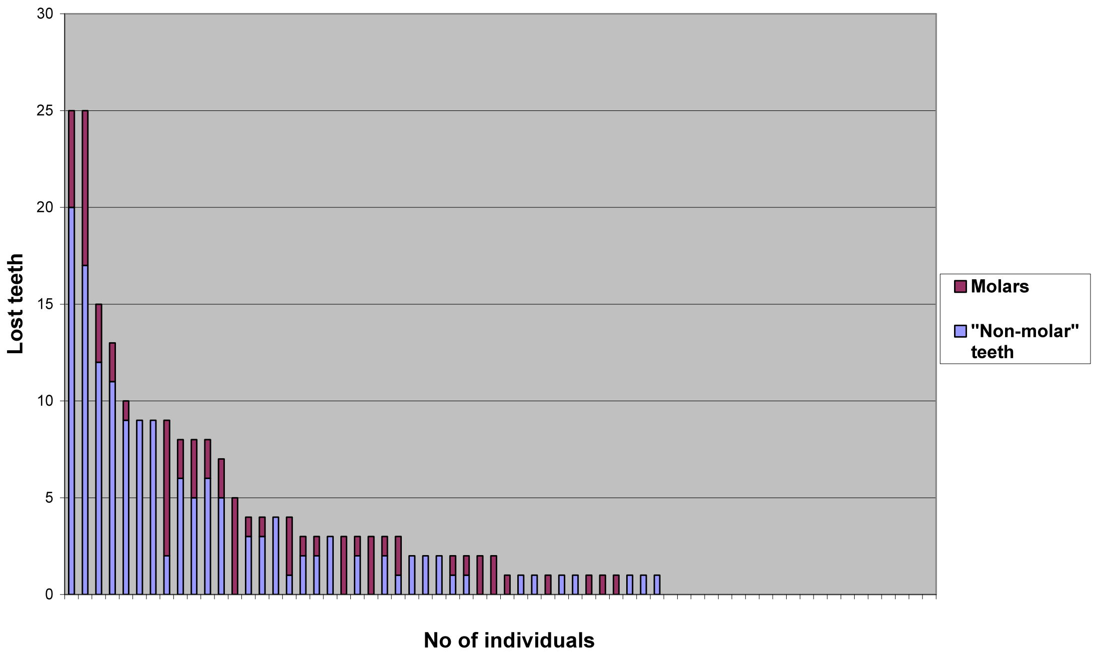
Loss of molars during the observation period was significantly higher in males than in females ($p=0.022$). Smoking was a significant cause for tooth loss ($p<0.01$) but loss of molars was not significantly correlated with smoking or previous smoking. A significant correlation was found between loss of molars and probing pocket depths >3 mm ($p=0.045$) at the final examination. Further, loss of molar teeth was significantly correlated with the severity of periodontal disease according to *Hugoson & Jordan* (17) ($p=0.018$).

Discussion

In the present study 26% of molars were furcation involved at baseline. This observation is in agreement with previous findings in periodontally treated patients (12, 16, 25). In untreated periodontal patients *Svärdström & Wennström* (39) found in 30–39-year old individuals a prevalence of 35% of class II-III furcation involvements and a prevalence of more than 50% in the age groups over 40 years. *Dannewitz et al.* (10) presented in a retrospective analysis of patients treated for periodontal disease that 60% of the molars in the studied group showed some degree of furcation involvement at baseline.

A number of studies report higher proportion of furcation involved molars in the maxilla than in the mandible (10, 16, 25, 39). In the present investigation we found the number of remaining molars and prevalence of furcation involvement equally distributed in the maxilla and mandible. However our result might be influenced by the fact that more maxillary molars were extracted during the active periodontal treatment before baseline (14 vs. 6).

Figure 1. Distribution of lost teeth during follow-up in the 64 patients



In the present study 58% of the molars initially diagnosed without furcation involvements were unchanged over the observation period while 27% deteriorated into a degree I-III furcation defect and 15% were extracted. Among the molars initially diagnosed with degree I-II furcation involvement 11% progressed into deeper defects. This is in agreement with findings of *Becker et al.* (5) who retrospectively followed 95 periodontally treated and maintained patients during a mean time of 6.5 years. Out of initially not furcation involved molars 78% remained stable while 22% developed furcation involvements. Of the 237 molars that initially had furcation involvement, 12% showed increased involvements. In a later study by *Becker et al.* (4) 44 patients treated for periodontal disease without a supportive postoperative programme were reexamined after 5 years. Sixty-nine percent of the molars remained stable while 31% showed furcation involvements. Out of the 84 molars that initially had detectable furcation involvement, 22% showed further deterioration which is in line with our findings.

An interesting finding in the present study is that 32% of the molars initially diagnosed with degree I-II furcation involvement improved over time. Improvement might be attributed to a reduced penetration of the periodontal probe due to decreased inflammation in the furcation area after periodontal treatment. Considering the difficulties in reaching the interproximal furcation areas of maxillary molars, some improvement might be due to variance in clinical recordings. A recent radiographic CBCT-investigation of furcation involved maxillary molars show that involvements degree II often are underestimated in the clinical situation (40). In mandibular degree II furcations, the successful outcome of guided tissue regeneration, GTR, or other regenerative procedures should be considered (19, 33). However, in the few cases treated by the GTR-technique in the present study no beneficial effect was noted.

The relatively high number of tooth loss in the present study could be explained by the studied population with previously high periodontal disease prevalence and the uncertain nature of the supportive therapy after the first two years of maintenance at the Department of Periodontology. In addition, one might speculate that the indications for tooth extractions were wider in general dental practice. The patients had a mean plaque score of 31% at the end of active periodontal treatment and a mean of 41% at the final examination which is higher than reported e.g. by *Axelsson et al.* (3). In their study plaque scores were generally low (< 20%). During 30 years of maintenance 257 patients lost only 173 teeth out of which approximately 50% was molars. The importance of supportive therapy and plaque control seems to be determining factors.

In the present study, 19% of all molars and 32% of molars with furcation involvement were lost during follow up. These figures are similar to those reported in previous long term studies in private clinics on periodontally treated patients (12, 16, 30). Studies conducted at university clinics report more favourable results (9, 10, 14, 20, 26). For example, *Hamp et al.* (14) reported no loss of molars in a 5-year prospective study on multi-rooted teeth with furcation involvements. Explanation for this result might be that a strict protocol was adapted during active periodontal treatment which aimed to eliminate all inflammatory lesions in furcation areas. Molars with severe destruction in the apical portion of the roots and molars without strategic value were extracted before onset of the study. Extractions were also performed when furcation treatment did not result in an area that was easily cleaned by the patient. In their study 44% of the molars were extracted during presurgical treatment or during subsequent surgery. In our study only 22 molars (6%) were extracted during initial periodontal treatment which indicates that a more conservative approach was applied.

Fifteen percent of molars initially diagnosed without furcation involvements were extracted during follow-up, which indicates that factors other than periodontal destruction in the furcation area influence loss of molars. Caries and endodontic infection have been identified as prevalent causes of loss of molars. *Ross & Thompson* (37) reported a low incidence of molar loss compared to other studies. They claimed that their favorable results were due to a conservative treatment approach with few complications and little need for caries and endodontic treatment. Accordingly, *Dannewitz et al.* (10) reported few lost molars due to periodontitis during maintenance. In their study endodontic failures dominated molar loss. In contrast, in the present study 75% of the molars were lost during follow-up, were lost due to periodontal disease. This is in line with other studies (9, 25, 42) which reported continued periodontal breakdown as the main reason for tooth extraction during supportive therapy.

A relatively small proportion of the patients lost many teeth during the observation period which is in accordance with previous studies (9, 10, 12, 16, 25, 26, 30, 42). Other factors i.e. general health, medication, lifestyle, social factors and smoking have been reported to influence the outcome of periodontal treatment. In the present investigation, proportions of present smokers, former smokers, and never smokers were 31%, 47%, and 22%, respectively which is in accordance with *Dannewitz et al.* (10). Smoking was a significant cause for tooth loss but loss of molars was not significantly correlated to smoking or previous smoking which indicate that other factors e.g. the degree of furcation involvement is a more significant risk factor for molar loss.

In conclusion, during a long term observation period molars with furcation involvements are more frequently lost than not furcation involved molars. However, of initially degree I-II involved molars two thirds are still in function 13 to 16 years after treatment which indicate that molars with furcation involvements can survive long after periodontal treatment.

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Molar position associated with a missing opposed and/or adjacent tooth: a follow up study in women

Birgitta Lindskog-Stokland[1], Magnus Hakeberg[2], Ken Hansen[1]

Abstract

◎ The purpose of the study was to assess (i) the degree of overeruption of molars lacking opposed teeth and (ii) the inclination of molars with a mesial edentulous space and also to study (iii) changes during a 12 year period. The subject sample originated from the prospective population study of women in Gothenburg, Sweden where scanned panoramic radiographs taken with an interval of 12 years were analysed.

Tipping as well as overeruption were scored on the two images according to a five-level scale. Sixty-seven subjects fulfilled the inclusion criteria at baseline and were referred to as "the non-extraction group". Further 35 subjects had lost the opposed and/or the adjacent tooth/teeth during the 12-year follow-up period: "the extraction-group". These groups were studied separately and a comparison between these groups was performed.

The prevalence of molars tipped more than 15 degrees at baseline was 17.1 % in the upper jaw and 44.3 % in the lower jaw, in the non-extraction group. At baseline overeruption was seen in 25 % of the unopposed upper molars and none of lower molars in the non-extraction group. The prevalence of tipping and overeruption was statistical significant less in the extraction group (P<0.01), than in the non-extraction group at baseline, but at follow-up no statistical significant group differences existed.

In conclusion:

- The prevalence of tipped molars facing a mesial edentulous space and overerupted unopposed molars increased in adults during the 12-year period but the changes were small.
- Overeruption and tipping is most pronounced immediately after extractions.

Key words

Overeruption, elongation, tipping, adult

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Molarers position i samband med förlust av antagonister och/eller granntänder: en uppföljningsstudie på kvinnor

Birgitta Lindskog-Stokland, Magnus Hakeberg, Ken Hansen

Sammanfattning

◎ Avsikten med studien var att mäta (i) graden av elongation hos molarer som saknar en antagonist och (ii) tippning av molarer med en mesial tandlucka samt även att studera(iii) förändringar under en 12 års period. Materialet bestod av panoramaröntgen från kvinnor i den prospektiva populationsundersökningen av kvinnor i Göteborg, där de scannade röntgenbilderna som tagits med ett intervall av 12 år analyserades.

Tippning liksom elongation uppmättes enligt en femgradig skala. 67 individer uppfyllde inklusionskriterierna initialt och refererades till som ”icke-extraktionsgruppen”. Ytterligare 35 individer hade förlorat en eller flera antagonister och/eller granntänder under den 12-åriga uppföljningsperioden ”extraktionsgruppen”. Grupperna studerades separat och en jämförelse mellan grupperna utfördes.

Prevalensen av molarer tippade mer än 15 grader vid baseline var 17.1% i överkäken och 44.3% i underkäken i ”icke- extraktionsgruppen”. Vid baseline kunde elongation ses i 25 % av överkäksmolarerna utan antagonist och i inget fall i underkäken i ”icke-extraktionsgruppen”. Prevalensen av tippning och elongation var signifikant mindre i ”extraktionsgruppen” ($P<0.01$), än i ”icke-extraktionsgruppen” vid baseline, men vid follow-up kunde ingen signifikant skillnad mellan grupperna påvisas.

Slutsatser:

- Prevalensen av tippade molarer intill ett tandlöst område och elongation av molarer utan en antagonist ökade under en 12-årsperiod, men förflyttningarna var små.
- Förändringarna var större när extraktionerna utfördes under observationsperioden.

Introduction

Tipped and/or overerupted molars, as a consequence of loss of adjacent and/or opposed teeth, have been proposed to affect occlusal interferences and changes in the dental equilibrium (21, 22, 30).

The tendency of teeth to move in an occlusal direction even in adulthood has been described as continuous eruption (12, 26) hypereruption (22), overeruption (16, 17) , supereruption (6) and supra-eruption (15). The majority of unopposed teeth tend to move more in an occlusal direction than opposed (5, 6, 16, 17, 24) . Maxillary unopposed teeth move more than mandibular (6, 17), the movements are most pronounced during the first years after the opposed tooth is lost (18) and periodontally affected teeth move more (4, 5, 9, 17). Craniofacial growth and continuous eruption of opposed and unopposed teeth have been observed in adults but mainly below the age of 50 (1, 3, 8, 13, 14, 25-28).

Findings reported in the literature from studies regarding the extent and severity of posterior tooth movements, due to the lack of an adjacent tooth, are partly contradictory. In summary, the degree of tipping of the teeth distal to an edentulous area has been reported to be larger in the mandible than in the maxilla, but with a high degree of variation (7, 16, 20). Only small changes in the edentulous spaces were evident in cases where lost posterior teeth had not been replaced (17, 23). There was a significant mesial displacement and tipping of unopposed molars with no mesially adjacent teeth (4, 16). Teeth mesial to an extraction site have also been shown to have a tendency to tip or migrate distally (7, 15, 31) and the movement of the teeth into edentulous spaces was largest during the first years and thereafter decreased (10, 18, 20). In a previous study based on the same sample (17), changes of tipping and overeruption were studied, however the prevalence of tipping and overeruption were not described. Hence the aim of the present study was, by the use of an index to study (i) the degree of over eruption of molars lacking opposed teeth and (ii) the inclination of molars with a mesial edentulous space and also to study (iii) changes in these teeth's position during a 12 year period.

Material and methods

The subject sample utilized in the present investigation originated from the prospective population study of women in Gothenburg, Sweden, that was initiated in 1968 (2). The study involved randomly selected women in various age groups, out of which the 50-year age group at the initial examination was selected to be included in the current study. Out of the 390 women in this age group, 292 had been re-examined after 12 years and had panoramic radiographs of the jaws available from both examinations.

The panoramic radiographs of the 292 subjects were examined with regard to presence of:

- a molar in the upper or lower jaw with a mesial edentulous space area due to missing tooth/teeth and/or
- an unopposed molar in the upper or lower jaw.

The set of teeth of the selected patients should not have been subjected to extensive restorative therapy between the examinations and the distortion on the panoramic radiographs should be limited. The distance between intercuspal position and edge-to-edge position has also been taken into account and only unopposed molars with a comfortable margin of at least one molar width were included in the study. Based on the initial radiographic examination 67 subjects fulfilled the inclusion criteria at baseline and was referred to as "the non-extraction group". Additional 35 subjects had lost the opposed and/or the adjacent tooth/teeth during the 12-year follow-up period: "the extraction-group". Thus the total sample included 102 subjects with 169 molars that fulfilled the inclusive criteria (Table 1 and 2).

Radiographic assessments

The following assessments were made on scanned digital images of the panoramic radiographs (Agfa Snap Scan 1236 scanner; resolution of 600 dpi) (Figure 1). The measurements, on the two images, were performed at the same occasion on two different computer screens.

Molar inclination was measured as the angle between the long axis of the tooth and a line perpendicular to the occlusal plane (6, 16). The inclination was scored and classified as (Figure 2):

- distally tipping
- no tipping
- tipping < 15 degrees
- tipping 15-30 degrees
- tipping > 30 degrees

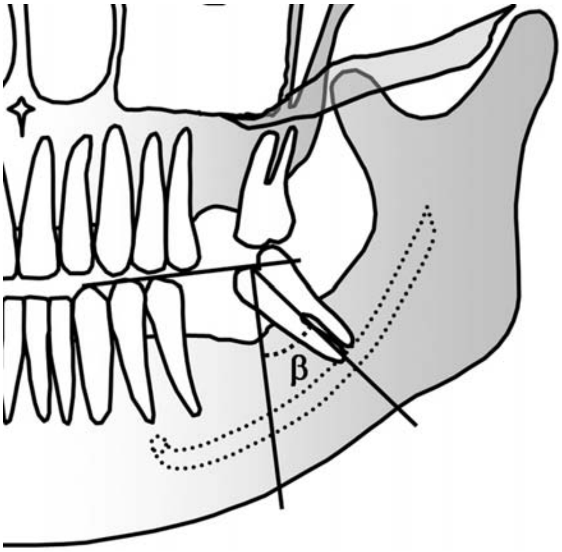
Molar overeruption was measured as the distance between the tip of the most occlusally projecting buccal cusp and the occlusal plane (6, 16). The unopposed molars were scored in five levels in relation to the occlusal plane and classified as (Figure 3):

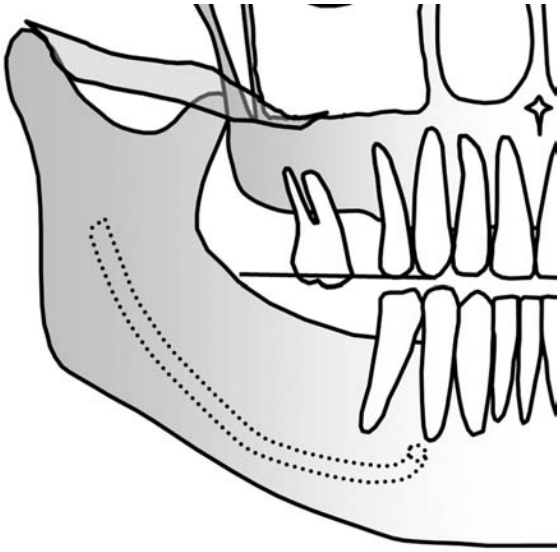
- intrusion
- at the level of the occlusal plane

Figure 1. Assessments were made on scanned digital images of the panoramic radiographs (Agfa Snap Scan 1236 scanner; resolution of 600 dpi). The measurements were performed at the same occasion on two different computer screens.

Figure 2. Inclination was measured as the angle (β) created by estimating the longaxis of the molar and a line perpendicular to the occlusal plane (16).

Figure 3. Overeruption was measured as the distance between the tip of the most occlusally projecting buccal cusp and the occlusal plane (6, 16). The occlusal plane was constructed between the cusp tips of the canine and the premolar(s) in the same quadrant, the investigated molar was not included in the determination of the plane.





- overeruption but < 2 mm
- overeruption 2-3 mm
- overeruption > 3 mm

Statistical methods

Prevalence of scores was calculated. Differences within groups (overeruption and tipping non-extraction and extraction groups) at baseline and follow-up were analysed with Wilcoxon Signed Ranks Test. Between group differences at baseline and follow-up were analysed with Mann-Whitney Test. The relationship between changes and the initial tipping and overeruption was assessed with Spearman's rank correlation analysis.

Error of the method

All assessments were repeated in 20 randomly selected subjects after 3 months and the intra-observer agreements were assessed by the weighted Kappa (Kw). The weighted Kappa was described in a 5-point rating scale (poor, fair, moderate, good and very good) for strength of agreement (11), which correlates to different values of Kw between 0 and 1.00, where the interval 0.41-0.60 corresponds to moderate strength of agreement and 0.8 -1.0 very good. The Kappa value for tipping was 0.8 (very good) and for overeruption 0.5 (moderate).

Results

Molars with a mesial edentulous space; tipping

The prevalence of molars with a mesial edentulous space was somewhat more common in the lower jaw than in the upper jaw (Table 1).

In the non-extraction group the prevalence of tipped molars, 15 degrees or more, was higher in the lower jaw than in the upper jaw at baseline as well as at follow-up (Table 2). The results also showed that there was a statistically significant ($P<0.01$) increase in inclination of the molars in both jaws during the 12 year examination period i.e. mesial tipping. Furthermore there was a statistical significant ($P<0.01$) negative correlation coefficient between changes in inclination and initial tipping in the lower jaw in the non-extraction group, i.e. the less initial tipping the larger changes in inclination.

In the extraction group no upper and only 1 lower molar were tipped 15 degrees or more at baseline but during the follow-up period 2 molars in the upper and 1 molar in the lower jaw tipped significantly mesially ($P<0.05$) (Table 3).

There was a statistical significant difference in prevalence of tipped molars between the groups for both jaws, when comparing baseline values in the non-extraction with the extraction group ($P<0.01$) with less tipping in the extraction group (Table 2

Table 1. Distribution of molars with a mesial edentulous space in the non-extraction and extraction group.

Tipping	Upper	Lower	Total
Non-extraction group	41	61	102
Extraction group	4	6	10
Total	45	67	112

Table 2. Tipping: non-extraction group

Upper jaw	Baseline	Follow-up
Distally tipping	0	0
No tipping	8 (19.5%)	6 (14.6%)
Tipping< 15 degrees	26 (63.4%)	23 (56.1%)
Tipping 15-30 degrees	7 (17.1%)	11 (26.8%)
Tipping> 30 degrees	0	1 (2.4%)
Lower jaw	**Baseline**	**Follow-up**
Distally tipping	0	0
No tipping	4 (6.6%)	4(6.6%)
Tipping< 15 degrees	30 (49.2%)	21 (34.4%)
Tipping 15-30 degrees	27 (44.3%)	36 (59.0%)
Tipping> 30 degrees	0	0

Table 3. Tipping: extraction group

Upper jaw	Baseline	Follow-up
Distally tipping	0	0
No tipping	2(50%)	0
Tipping< 15 degrees	2(50%)	2(50%)
Tipping 15-30 degrees	0	2(50%)
Tipping> 30 degrees	0	0
Lower jaw	**Baseline**	**Follow-up**
Distally tipping	0	0
No tipping	3(50%)	0
Tipping< 15 degrees	2(33.3%)	5(83.3%)
Tipping 15-30 degrees	1(16.7%)	0
Tipping> 30 degrees	0	1(16.7%)

Table 4. Distribution of unopposed molars in the non-extraction and extraction group.

Over-eruption	Upper	Lower	Total
Non-extraction group	52	6	58
Extraction group	26	8	34
Total	78	14	92

Table 5. Overeruption: non-extraction group

Upper jaw	Baseline	Follow-up
Intrusion	1 (1.9%)	
No overeruption	38(73.1%)	29(55.8%)
Overeruption < 2mm	13(25.0%)	18.(34.6%)
Overeruption 2-3mm	0	5(9.6%)
Overuption > 3mm	0	0
Lower jaw	**Baseline**	**Follow-up**
Intrusion	0	0
No overeruption	6 (100%)	4(66.7%)
Overeruption < 2mm	0	2(33.3%)
Overeruption 2-3mm	0	0
Overuption > 3mm	0	0

Table 6. Overeruption: extraction group

Upper jaw	Baseline	Follow-up
Intrusion	4 (15.4%)	0
No overeruption	21(80.8%)	13(50.0%)
Overeruption < 2mm	1(3.8%)	12(46.2%)
Overeruption 2-3mm	0	1(3.8%)
Overeruption > 3mm	0	0
Lower jaw	**Baseline**	**Follow-up**
Intrusion	0	0
No overeruption	8(100%)	2(25.0%)
Overeruption < 2mm	0	6(75.0%)
Overeruption 2-3mm	0	0
Overeruption > 3mm	0	0

and 3), but at follow-up no statistical significant difference existed (Table 2 and 3).

Unopposed molars overeruption

Unopposed molars were more prevalent in the maxilla than in the mandible (Table 4). There were no molars that were overerupted 2 mm or more at baseline in any of the two groups. At follow up the prevalence of over erupted molars increased significantly in both groups. The difference in overeruption between baseline and follow-up was highly significant ($P<0.001$) in the upper jaw in both the extraction and the non-extraction groups (Table 5 and 6). However, in the lower jaw (Table 6) the difference was only significant in the extraction group ($P<0.05$).

The difference in prevalence of over-erupted molars when comparing the baseline values for the non-extraction and the extraction group was statistical significant ($P<0.01$) showing a higher value for the non-extraction group. However at follow-up no statistical significant difference in prevalence existed.

There was a statistical significant difference in over-eruption during the observation period between the non-extraction and the extraction group, for the upper jaw $P<0.05$ and the 3 molars with the most severe changes (2 scores) were seen in the upper jaw in the extraction group.

A statistical significant ($P<0.01$) negative correlation coefficient between changes in over-eruption and the initial level was seen in the extraction group (for upper and lower jaw together and for upper jaw separately). E.g. the less over-eruption the more changes after extraction of the opposed tooth.

Discussion

Panoramic radiographs taken with an interval of 12 years were used for assessments of elongation and tipping. In a previous study on the same material (17) changes occurring during the follow-up period were studied. In that study, the extraction and non-extraction group were pooled due to the fact that no statistical significant differences were seen between the groups. Precise angular measurement as well as exact relative measurement of over-eruption was performed and advanced statistical methods were used. In the present study however another approach was utilized where an index score of tooth inclination and overeruption, in relation to the occlusal plane, was used to get information about the prevalence at the first examination occasion (baseline) and not only the changes occurring during the observation period.

A limitation of this material was relatively few observations in the extraction group for both jaws with regard to tipping and for both groups in the lower jaw concerning overeruption. Another disadvantage was no information about when extractions were performed during the 12- year period in the extraction group.

In the present study the angle (β) was measured between the long axis of the molar and a line perpendicular to the occlusal plane (16). A measurement error of ± 5 degrees for angular measurements performed in panoramic radiographs has to be accepted (29). Hence, the score was set to a minimum value of 15 degrees.

The prevalence of tipped teeth as well as the magnitude of tipping, in the group with a mesial edentulous space, were higher in the lower than in upper jaw for both the non-extraction and the extraction group, which agree with (16) and (7). Besides that, there may in panoramic radiography be an overestimation of tipping of upper molars and an underestimation of tipping of lower molars (19) which could mean that the differences may be even larger. There was a positive correlation between tipping and extraction performed during the period for the upper jaw. This was not shown in the previous study (17), probably due to the difference in methods of measurement. Index scores is a more crude method which probably gives a smaller variance in the results and by that, a statistical significant correlation may easier be obtained.

The incidence of tipping, during the 12-year period, showed a statistically significant increase in tipping of molars in the upper as well as in the lower jaw in both groups. There was also significant divergence between the groups, when comparing baseline values for tipping in the non-extraction and the extraction group ($P<0.01$) but for the follow-up values no statistical significant difference exists. This indicates that molars tip to a certain degree shortly after the extraction of the mesial neighbouring tooth and thereafter stays fairly stable. The tipping changes were also relatively small and no increase in tipping more than 15 degrees were found during the 12 year interval which was in accordance with the previous study on the same material (17), where the incidence of mesial tipping of ≥ 5 degrees was 18% and more than 15 degrees of tipping was observed only in one case of the 112 molars.

There was a larger negative correlation coefficient between changes in inclination and initial tipping in the lower jaw in the non-extraction group than in the extraction group i.e. the less initial tipping the larger changes in inclination. But when the non-extraction and the extraction group were pooled statistical significance was found in the lower jaw. This might indicate that the risk for tipping in the extraction group actually was larger, than shown by the statistics, due to the small number of molars in the lower jaw in extraction group.

There was no overeruption at baseline in the extraction group independent of jaw, this was also valid for the majority of cases in the non-extraction group. At follow-up no overeruption was seen in 50 - 55.8% of the upper molars and 25.0-66.7% of the lower molars (the lower value representing the extraction group and the higher the non-extraction group). The incidence of more severe changes of overeruption was lower in the present study compared to the results found on the same material in a previous study (17), probably due to the different measurement techniques. There was a positive correlation between changes in overeruption in the upper jaw and extraction performed in the opposed jaw during the 12 year interval. However, the incidence of overeruption changes was less than 2 scores in the majority of cases. The difference between the non-extraction and the extraction group, when comparing baseline values, were statistical significant for tipping of lower molars and overeruption of upper molars. However when the follow-up values were compared, no statistical significant difference was found. Thus it can be concluded that after 12 years the group, where extraction was performed during the 12-year period, was quite similar to the group where opposing or adjacent tooth were missing already before the base-line examination, both regarding tipping in the lower jaw and overeruption in the upper jaw which means that the greatest changes occurred during the first years after extractions which also is in agreement with previous studies (10, 18, 20).

The clinical interpretation is in accordance with the findings in the previous study i.e. if prosthetic rehabilitation is planned, for replacement of an extracted tooth, this should be done in close relation to the time of the extraction, as the need after 12 years is minimal in the majority of cases, due to no or only small changes.

Conclusions

- In cases with molars with a mesial edentulous space, the prevalence of molars tipped more than 15 degrees was more than twice as common in the lower jaw than in the upper jaw
- In cases with an unopposed molar, overeruption was noticed in one quarter part of the molars in the upper jaw but almost in none in the lower jaw
- Molars with a mesial edentulous space tipped mesially and molars without antagonists elongated in adults during the 12-year period but the changes were small
- Overeruption and tipping is most pronounced immediately after extractions

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