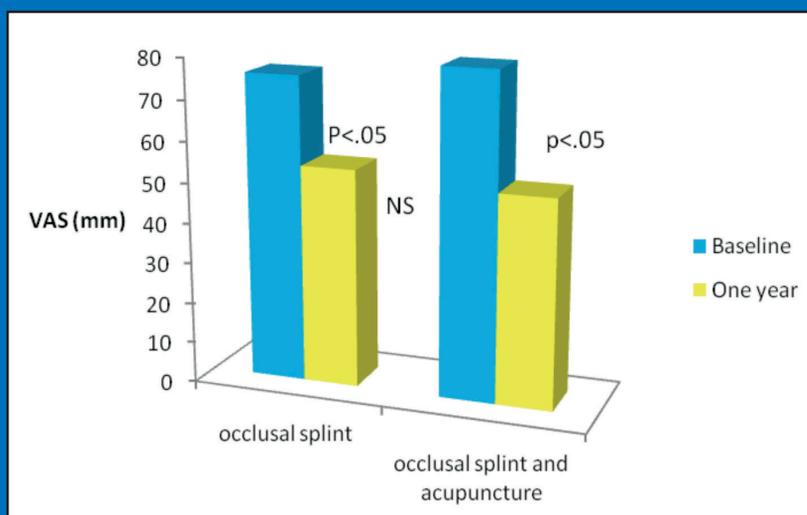


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Management of tinnitus and jaw-muscle tenderness using an intra-oral appliance and acupuncture

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Editorial address
Swedish Dental Journal
Odontologiska Institutionen
Box 1030, SE-551 11 Jönköping, Sweden
Tfn: +46 (0)36 32 46 04
Fax: +46 (0)36 71 22 35

Subscription/business address
Swedish Dental Journal
Box 1217, SE-111 82 Stockholm, Sweden
Tfn: +46 (0)8 666 15 00
Fax: +46 (0)8 662 58 42
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Management of tinnitus and jaw-muscle tenderness using an intraoral appliance and acupuncture

DAN STRÖM^{1,3}, ERIK BEHRENTH¹, KRISTINA EKMAN¹, ANDERS JOHANSSON², LENNART UNELL¹, GUNNAR E CARLSSON³

Abstract

© Associations between signs and symptoms from the masticatory system and tinnitus have been reported. The aim of the study was to evaluate the effect of intraoral splint therapy and acupuncture on jaw-muscle tenderness and tinnitus.

The study comprised 45 patients (24 men, 21 women; mean age 48 ±12 years) with long-standing tinnitus (duration 6.5 ±5.9 years). The patients were referred from the audiology department at the University hospital in Örebro, Sweden, where a complete audiological survey was performed. Jaw muscles were palpated and the subjective tinnitus evaluated on a 100 mm scale (VAS) at baseline and after one year. All patients received stabilization (Michigan type) splints at start of treatment. After 6 months, non-responders (n=25) were subjected to acupuncture (6 sessions with duration of 30 minutes). Standard statistical methods were used. All patients had tender jaw muscles at palpation. Patients reported a significant decrease of the intensity of tinnitus during the observation period (from 78±20 mm to 52±24 mm after one year; $P < 0.001$). Only 6 (13 %) of the 45 patients did not report any improvement of their tinnitus. The number of jaw muscles tender to palpation also decreased significantly from 7.9±5.9 to 4.6±5.3; ($P < 0.001$).

In conclusion, all 45 patients with tinnitus had tender jaw muscles. Intraoral splint therapy and acupuncture had a favorable effect on tinnitus and the jaw muscle symptoms. One year after the start of treatment, all but 6 of the 45 patients reported improvement of their tinnitus. Based on the results it is suggested that many tinnitus patients with jaw muscle tenderness can benefit by a treatment including intraoral splint and acupuncture.

Key words

Masticatory muscle tenderness, Michigan splint, prospective study, temporomandibular disorders

¹Department of Stomatographic physiology, the Post Graduate Dental Education center, Örebro County Council, Örebro Sweden

²University of Bergen, Bergen, Norway

³Institute of Odontology, The Sahlgrenska Academy, University of Gothenburg, Göteborg, Sweden

Behandling av patienter med tinnitus och ömma käkmuskler med bettskena och akupunktur

DAN STRÖM, ERIK BEHRENTH, KRISTINA EKMAN, ANDERS JOHANSSON, LENNART UNELL,
GUNNAR E CARLSSON

Sammanfattning

© Det har rapporterats att det kan föreligga samband mellan tinnitus och symtom och kliniska tecken på käkfunktionsstörning. Syftet med denna studie var därför att hos tinnituspatienter bedöma effekten av bettskena och akupunktur på ömma käkmuskler och tinnitus. Studien omfattade 45 patienter (24 män och 21 kvinnor; medelålder 48 år, SD 12 år) med långvarig tinnitus (duration 6.5 ± 5.9 år). Alla patienterna var remitterade från avdelningen för audiologi vid universitetssjukhuset i Örebro, där en komplett audiologisk undersökning utförts. Tuggmusklerna palperades och patienterna registrerade sin subjektiva uppfattning om svårigheten av sin tinnitus med hjälp av en 100 mm VAS-skala, dels vid undersökningens början, dels ett år senare. Alla patienter erhöll initialt en bettskena av Michigan-typ. Efter 6 månader fick de patienter som inte förbättrats av bettskenebehandlingen ($n=25$) akupunktur (6 sessioner omfattande 30 minuter). Vid utvärderingen av resultaten har statistiska standardmetoder använts.

Alla patienter hade vid första undersökningen en eller flera tuggmuskler som var ömma vid palpation. I genomsnitt minskade den av patienterna angivna intensiteten av tinnitus signifikant under observationstiden (VAS-värden från 78 ± 20 mm till 52 ± 24 mm efter ett år; $P < 0.001$). Antalet palpationsömma käkmuskler minskade också signifikant (från 7.9 ± 5.9 till 4.6 ± 5.3 ; $P < 0.001$).

Sammanfattningsvis befanns alla de undersökta tinnituspatienterna initialt ha en eller flera ömma tuggmuskler. Behandling med bettskena kompletterad med akupunktur hade hos flertalet patienter en gynnsam effekt både på tinnitus och ömheten i tuggmusklerna. Ett år efter behandlingens start rapporterade alla utom 6 (13 %) av de 45 patienterna en förbättring av sin tinnitus. Antalet ömma tuggmuskler minskade också signifikant under observationstiden. Studiens resultat visar att många patienter med tinnitus och ömmande tuggmuskler upplever signifikant minskade besvär genom behandling med bettskena och akupunktur.

Introduction

Tinnitus is defined as a sound in the ear(s) and/or head without external origin and is a serious health concern for millions worldwide (8, 10). A great variety of treatment methods for tinnitus have been tried over the years, often with modest success. This is reflected in the continuing lack of standardized practice in audiology departments treating tinnitus patients (11). Large epidemiological studies have found significant associations between TMD signs and symptoms and tinnitus (2, 3, 14, 19). Observations that patients with temporomandibular disorders (TMDs), also complaining of tinnitus, reported decrease of their tinnitus in parallel with improvement of their TMD symptoms have led to an increased interest regarding the possible comorbidity between tinnitus and TMD. Several studies have shown that treatment of TMD has been accompanied by an improvement of the patients' tinnitus (6, 8, 19, 22, 24). However, no cause-effect relationship between TMD and tinnitus has yet been demonstrated (20, 21). A large longitudinal study concluded nevertheless that signs of TMD are a risk factor for the development of tinnitus (3). Further research in this area is warranted.

There is a great variation in methods used for management of TMD although the superiority of any of them has not been demonstrated (4, 9). Recent studies and systematic reviews have concluded that there is some evidence that two common treatment modalities, viz. interocclusal appliances, especially so-called stabilization or Michigan splints, and acupuncture can be effective in managing TMD symptoms (1, 5, 9, 17).

It was the aim of this study to evaluate the effect of a combination of these two treatment modalities for TMD, an intraoral appliance and acupuncture, on jaw-muscle tenderness and tinnitus. The study was approved at the regional Ethics committee at the Uppsala University, Uppsala, Sweden.

Materials and methods

Subjects

The study comprised totally of 45 patients (24 men; mean age 47 ± 12 years and 21 women; mean age 49 ± 12 years), referred from the audiology depart-

ment at the University Hospital in Örebro, Sweden with a diagnosis of long-standing tinnitus (Table 1). A complete audiological investigation including audiometrical status had been performed. Patients with medical causes of tinnitus (infections, otosclerosis, Meniere's disease) and tumors (acoustic neuromas) were excluded. All subjects had normal hearing with respect to their age according to audiometry. No participants were using antidepressants.

Clinical examination

Jaw muscle pain and tenderness was evaluated during a standardized clinical examination with the participants in a sitting position.

The Research Diagnostic Criteria for RDC/TMD criteria axis I (RDC/TMD) was used for diagnosis of myofascial pain (7). Twelve muscle sites bilaterally were palpated; the anterior and posterior temporal muscles, the deep and superficial masseter muscles, the sternocleidomastoid muscles, the trapezius muscle, the digastric muscles, the medial and lateral pterygoid muscles, the insertion of the temporal muscles, neck muscles in the region of the linea nuchae. The number of muscles showing any reaction of pain or tenderness at palpation was registered at baseline and one year after the start of the treatment.

Subjective tinnitus recording

The patients were asked to record the subjective evaluation of their tinnitus on a 100 mm visual analog scale (VAS) with the end points 0 = no tinnitus, and 100 = worst thinkable tinnitus. The wording of the question was: "How would you summarize the problems with your tinnitus? Please indicate it somewhere on the line from 0 to 100". This registration was performed at baseline and one year after the start of the TMD treatment.

Splint therapy and acupuncture

All patients received a maxillary full coverage hard acrylic resin splint of the Michigan type (18) at baseline. After 6 months, the outcome of the splint therapy was evaluated. Twenty patients were satisfied with the splint-treatment. The remaining 25 patients were not fully satisfied with the outcome so far and were offered acupuncture as an additional treatment to the splints. Acupuncture was given in five to six consecutive sessions with 3 manual stimulations. Each acupuncture session had a total duration of 30 minutes. The local acupuncture points used were Ma5, Ma6, Tu18, Tu19, Tv18, Tv19, Tv22, Gb2, Gb3. Distal point used was Li4 (16). The final evaluation

© Table 1. Age and duration of tinnitus in years (Mean \pm SD) in 45 tinnitus patients

Gender	Number	Age	Years with tinnitus
Female	21	49.2 ± 12.4	5.7 ± 5.3
Male	24	47.0 ± 12.0	7.2 ± 6.4

of all patients was performed one year after the start of the treatment.

Statistics

Standard statistical methods were used: Student's t-test for parametric and Wilcoxon Signed Ranks Test for nonparametric data (SPSS ver.15.0). P-values < 0.05 were considered statistically significant.

Results

The number of tender jaw muscles decreased from 7.9 ± 5.9 initially to 4.8 ± 5.3 after one year ($P < 0.001$). During the same period the subjective tinnitus dropped from 78 ± 20 mm to 52 ± 24 mm according to the VAS registrations at the end of the observation period. In spite of the wide variation of the values reflected in the great SDs, the changes were highly significant ($P < 0.001$). In the splint group (20 patients), the number of tender jaw muscles decreased significantly ($P < 0.05$) after one year in contrast to the 25 patients receiving splint and acupuncture (NS). At the final follow-up no significant changes were identified between the groups. (Fig. 1). The subjective tinnitus decreased significantly in the splint as well as in the combined splint and acupuncture group ($P < 0.05$). At the end no significant differences were found between the groups (Fig. 2).

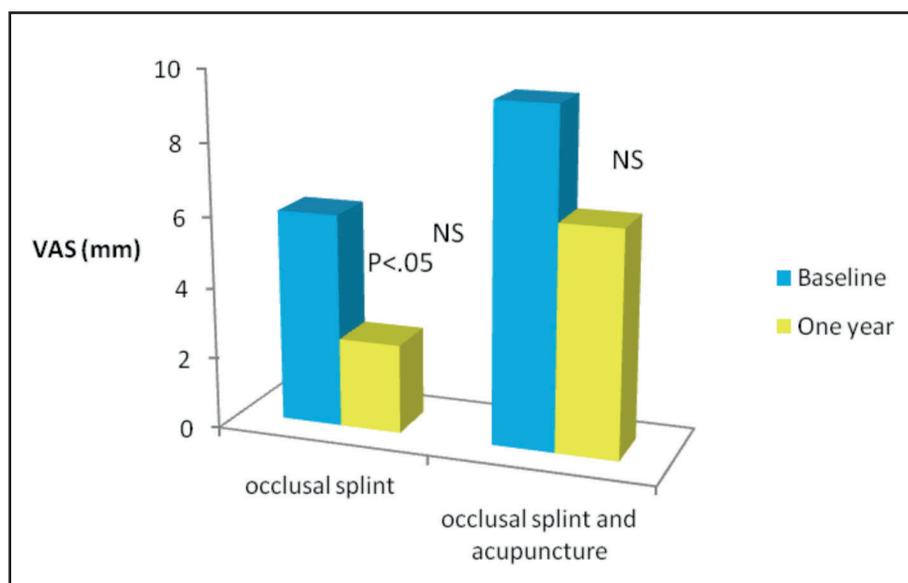
Among the 45 patients, 39 reported reduction of their tinnitus, whereas 2 were unchanged and 4 considered their tinnitus worse after one year. One third

of the patients (15) reported a reduction of 50% or more on their tinnitus evaluation on the VAS scale. Thus only 6 (13%) of the patients did not report any reduction of their tinnitus ($P < 0.001$). The distribution of changes of the number of jaw-muscles tender to palpation was 26 decreased, 7 unchanged, and 11 increased (the data on tender muscles were missing for one patient). $P < 0.01$. There was no significant difference in the outcome between female and male patients.

Discussion

The results of the present study indicated that treatment aimed at reducing jaw muscle tenderness in patients with tinnitus may have positive effects on the tinnitus intensity. The outcome thus corroborated earlier studies with similar results (6, 8, 19, 22, 24). There is still no good explanation for the mechanism behind the favorable outcome of TMD treatment on tinnitus (21). However, the recent finding in a longitudinal population study that signs of TMD increase the risk of developing tinnitus deserves further attention to the relationship between TMD and tinnitus (3). It has been found that TMD patients with low severity of tinnitus, normal hearing, and fluctuating type of tinnitus may experience a reduction of their tinnitus after TMD treatment (19, 22). It has been recommended that a screening for TMD should be included in the diagnostic survey of patients with tinnitus, and that tinnitus patients with

© **Figure 1.** Mean number of muscles tender to palpation in tinnitus patients who received occlusal splints (n=20) and splints followed by acupuncture (n=25).



pain and tension in the masticatory muscles should receive TMD treatment (2, 4). A possible reason why many patients with tinnitus experience an improvement may be the reduction of their jaw muscle problems associated with the treatment. Symptoms related to the jaw muscles belong to the most common findings among TMD patients and a reduction of the jaw muscle pain and dysfunction will certainly increase the comfort in the masticatory system, beneficial also for those affected by tinnitus.

Medical treatment of tinnitus seems to have at most a modest success, and there is a lack of standardized practice in the management of tinnitus patients (11, 12, 23). The positive effects on tinnitus related to odontological treatment of TMD patients also suffering from tinnitus therefore deserve further analyses. Even if most critical systematic reviews of management of TMD emphasize the considerable variation in methodology making definitive conclusions extremely difficult, there is some evidence that splint therapy and acupuncture can be effective in alleviating TMD pain (13, 15, 17). The present results corroborated this conclusion as well as it added further one study to those showing a positive effect on tinnitus in association with treatment focusing on TMD (6, 8, 19, 22, 24).

The design of the present study does not permit any analysis of the specific effect of the splint or the acupuncture on the tinnitus, but the combined treatment was associated with reduction of the tinnitus

in 39 (87 %) of the 45 patients, as reported one year after start of the treatment. For about half of the responding patients the splint alone was successful whereas the remaining patients needed the addition of acupuncture for a significant symptom decrease. With respect to the generally poor prognosis of management of tinnitus it is not surprising that a few patients did not respond to the tested treatment.

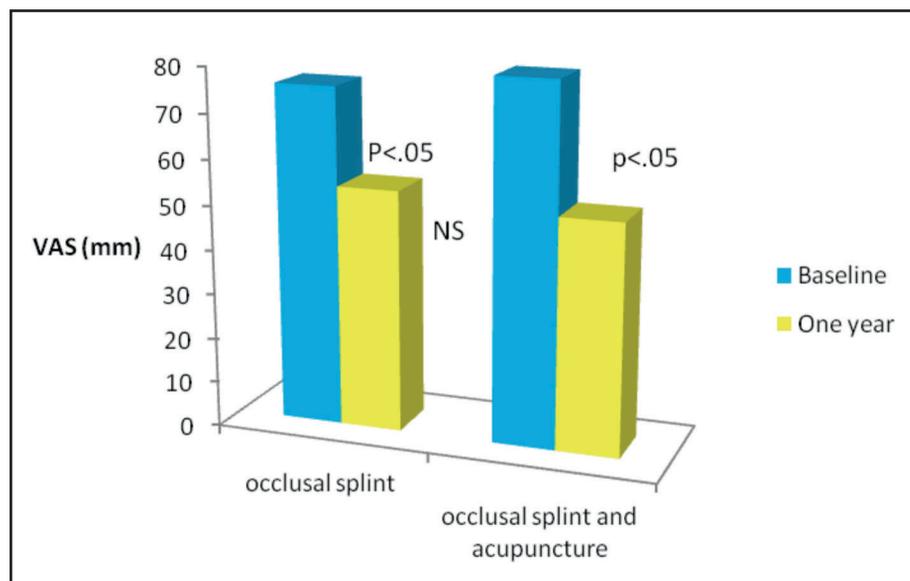
Conclusions

All the 45 patients with tinnitus had tender jaw muscles. Intraoral splint therapy and acupuncture had a favorable effect on tinnitus and the jaw muscle tenderness. One year after the start of treatment, all but 6 of the 45 patients reported reduction of their tinnitus. Based on the results it may therefore be concluded that many tinnitus patients with jaw muscle tenderness can benefit from a treatment including intraoral splint and acupuncture.

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© **Figure 2.** Tinnitus assessment (VAS) in patients who received occlusal splints (n=20) and patients receiving splints and acupuncture (n=25).



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Corresponding author:
 Dr Dan Ström
 Department of Stomatographic physiology, the Post Graduate Dental Education center,
 Örebro County Council
 Örebro Sweden
 Box 1126
 SE-701 11 Örebro Sweden
 E-mail: dan_strom@yahoo.se

Timing of mineralization of homologues permanent teeth – an evaluation of the dental maturation in panoramic radiographs

PIA SAHLSTRAND^{1,2}, AGNETA LITH³, MAGNUS HAKEBERG⁴, JÖRGEN G. NORÉN⁵

Abstract

© Clinically the condition Molar Incisor Hypomineralization (MIH), varies considerably between individuals, where any number of molars, from one to all four permanent first molars, may be affected with different degrees of hypomineralized enamel within the same dentition. An explanation to these variations could be that the start of the enamel mineralization differs between homologues teeth.

The aim of this study was to compare the dental development between homologues teeth in digital panoramic radiographs (PRs), from children aged 7 to 11 years, using the *Gleiser & Hunt* method on second and third molars and to calculate the crown/root ratio for the mandibular premolars. 77 PRs, from individuals between 7.3 and 11.0 years of age, were studied. Differences in developmental stages between homologues teeth (second and third molars) were studied. In 72 of these PRs, the crown/root ratio of mandibular premolars was also compared.

In 31 of the PRs, a difference in development was found between the right and left maxillary second molar. In 22 PRs, a difference in development between the right and left mandibular second molar was found. In 17 of the PRs, a difference in development was found between the right and left maxillary third molars. In 26 PRs, a difference in-between the right and left mandibular third molar was found. In 72 PRs, the crown/root ratio of mandibular premolars was measured and differences were found. All these differences were significant.

A possible explanation to the variations in expressivity of MIH may be a result of differences in the start of mineralization between homologues teeth.

Timing of mineralization of homologues permanent teeth – An evaluation of the dental maturation in panoramic radiographs.

Key words

Age estimation, developmental stage, homologues teeth, MIH, panoramic radiographs, permanent molars, premolars.

¹ Orthodontic Dentistry Special Dental Service, Lidköping, Sweden

² Specialist Clinic for Orthodontics, Public Dental Service, Västra Götaland Region, Göteborg, Sweden

³ Department of Oral and Maxillofacial Radiology, Institute of Odontology at the Sahlgrenska Academy, University of Gothenburg, Göteborg, Sweden

⁴ Department of Behavioural and Community Dentistry, Institute of Odontology at the Sahlgrenska Academy, University of Gothenburg, Göteborg, Sweden

⁵ Department of Pediatric Dentistry, Institute of Odontology at the Sahlgrenska Academy, University of Gothenburg, Göteborg, Sweden

Mineralisering av homologa tänder – utvärdering av mineralisationsgraden i panoramaröntgenbilder

PIA SAHLSTRAND, AGNETA LITH, MAGNUS HAKEBERG, JÖRGEN G. NORÉN

Sammanfattning

⊙ Tillståndet Molar Incisor Hypomineralization (MIH) varierar avsevärt mellan olika patienter där allt från en till fyra molarer kan vara drabbade och då också till olika grad i samma bett. En förklaring skulle kunna vara att homologa tänder startar sin mineralisering vid olika tidpunkter.

Syftet med studien var att jämföra tandutvecklingen mellan homologa tänder i digitala panoramaröntgenbilder (PR), tagna på barn i en ålder mellan 7 och 11 år genom att använda *Gleiser & Hunt's* metod på permanenta andra och tredje molarer, samt beräkna kron-rot förhållandet för underkäkens premolarer. Skillnaderna i utvecklingsstadium mellan homologa tänder i 77 PR, från patienter i åldern 7,3 till 11,0 år undersöktes. Kron/rot förhållandet hos underkäkens premolarer mättes i 72 av dessa PR.

I 31 PR sågs en skillnad mellan höger respektive vänster sidas andramolarer i överkäken. För underkäkens andramolarer sågs en skillnad i 22 PR. För tredjemolarerna var motsvarande siffror 17 respektive 26 PR. Alla skillnaderna var statistiskt signifikanta. Kron-rot förhållandet i underkäkens premolarer uppvisade också statistiskt signifikanta skillnader mellan höger och vänster sida.

En möjlig förklaring till skillnaderna i variationerna till expressiviteten av MIH skulle kunna vara skillnader i när mineraliseringen startar mellan homologa tänder.

Introduction

The condition Molar Incisor Hypomineralization (MIH), hypomineralization of the enamel in permanent first molars and incisors, has a reported prevalence varying between 2.8% and 37.5% (1, 32). There are a number of subjective and objective problems and complications associated with MIH: Dental fear and anxiety, severe loss of enamel, hypersensitivity, increased treatment need and problems in performing proper filling therapy (12, 15, 22). Clinically, it is difficult to estimate the degree of hypomineralization and the risk for loss of enamel. However, it has been shown that there is a relation between hardness values and the color of the hypomineralized enamel, with yellow lesions being softer than white (29).

The etiology behind MIH is still not known and by definition, MIH is a general and chronological disturbance of the enamel mineralization which may be related to the early postnatal period of life (8, 30-31). However, clinically, MIH varies considerably between individuals and anywhere from one to all four permanent first molars may be affected, with different degrees of hypomineralized enamel within the same dentition (6, 32). In a recent article, 52% of the children with MIH had one affected permanent first molar, 29% had two affected molars, while 12% and 7% had three and four affected molars, respectively (6). The variation in number of affected permanent first molars could be explained by the causative factor being non-chronological or by the start of the enamel mineralization differing between homologues teeth. Therefore, it would be of importance to establish the timing for the start of the mineralization of homologues teeth.

One way to study the timing of the mineralization of homologues teeth is to use panoramic radiographs and apply a dental maturity method. The most commonly used method for age estimation is *Demirjian's* (4-5) dental maturity method, which has been widely used and validated (2, 3, 17-21, 25). *Demirjian's* dental maturity method has eight developmental stages of permanent dentition, of which the first four stages is the crown development (4-5). Another dental maturity method is the method according to *Gleiser & Hunt*, comprising fifteen different stages of calcification of the permanent first molar, of which the first seven stages concern the crown development. The latter study was an investigation of calcification, eruption and caries in the right first permanent molar in a group of 25 boys and 25 girls. In most of their cases, lateral jaw radiographs of the right side of the face were taken at

intervals of three months (from birth to 18 months), and at intervals of 6 months (from 18 months to 10 years of age). A row of outline sketches was made of all the radiographic images of the permanent first molar for each child. From these sketches, 15 stages of calcification were arbitrarily chosen and listed as the fifteen different stages of calcification of the permanent first molar (9).

Since the age estimation methods to some extent are rather crude methods, the relative root length or crown/root index may be useful and has been applied on different radiographs (10, 16, 23).

The aim of this study was to study the dental development of homologues teeth in digital panoramic radiographs from children, aged 7 to 11 years of age, using the *Gleiser & Hunt* method on second and third molars, and to calculate the crown/root ratio for the mandibular premolars.

The hypothesis was that there were no differences in dental development between homologues premolars and permanent second and third molars.

Material and methods

Subjects

Panoramic radiographs (PRs), taken at the Clinic of Oral and Maxillofacial Radiology, Public Dental Service, Göteborg, Sweden, were selected from children born in the year 2000. The reason for taking a PR was mainly before orthodontic treatment (96%). The inclusion criterion was visible tooth buds of homologues third molars. Since homologues teeth were compared, PRs with third molars visible only in the maxilla or in the mandible were also included. During the period 20071101 to 20111028 a total of 192 PRs and from these 77 PRs became eligible for the study. The age of the patients when the PR was taken ranged between 7.3 and 11.0 years of age (mean age 9.9 ± 0.8 years, median age = 10.08 years).

Methods

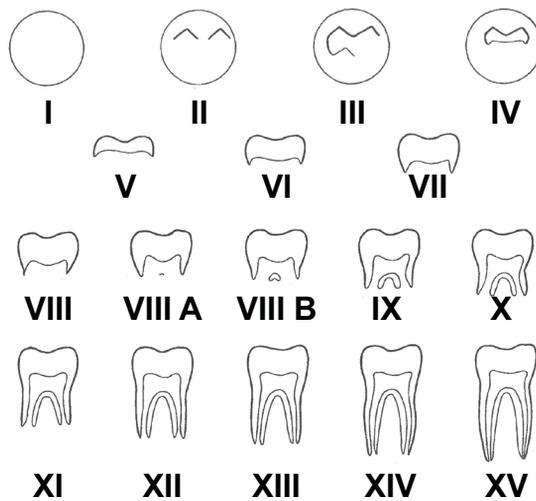
Estimation of dental development

The developmental stages of homologues teeth in the PRs are estimated using the *Gleiser & Hunt* (9) dental maturity method which consists of 15 developmental stages (I-XV).

A brief description of the different stages will be given here (Fig. 1).

In stage I, a tooth bud exists but with no sign of calcification. In stage II, a visible mass of cusp tissue has calcified, the center can be seen on the X-ray as an inverted cone. When a coalescence of at least two centers is visible, stage III is obtained. In stage

© **Figure 1.** Stage of calcification of the mandibular permanent first molar after Gleiser & Hunt (9). (I=No calcification; II=Centers of calcification visible; III=Coalescence of centers; IV=Outline of cusps completed; V=1/2 crown; VI=2/3 crown; VII=Crown completed; VIII=Minimal root formation; VIII A=Cleft minimal; VIII B=Cleft rapidly enlarging; IX=1/4 root; X=1/3 root; XI=1/2 root; XII=2/3 root; XIII=3/4 root; XIV=Divergent root canal walls; XV=Convergent root canal walls).



IV, the outlines of the cusps are completed. In stage V, half of the crown is completed and in stage VI, 2/3rds. The crown is completed in stage VII. When a minimal root formation is visible, stage VIII is obtained, which is divided into two subgroups; subgroup VIII A, where a minimal cleft between the roots is seen and in VIII B, where a rapid enlarging of the cleft can be observed. In stages IX, X, XI, XII and XIII, the root is continuing to develop with 1/4, 1/3, 2/3 and 3/4's of the root completed, respectively. In stage XIV, the root canal is terminally divergent and finally in the last stage, stage XV, the root canal is terminally convergent.

The digital PRs were obtained with a CRANEX Tome® or a Scanora® extra-oral dental X-ray unit (both from Soredex, Orion Corporation Ltd, Helsinki, Finland). For practical reasons the age estimations were performed at the department of Pediatric Dentistry. The digital images were transferred on a USB-stick in Tiff-format without any identification to the a specific patient year and month for when the PR was taken. For the estimation of the developmental stage, the digital PRs were opened in Adobe Photoshop CS5 (Adobe Systems Inc., San Jose, Calif. USA), under the same magnification using a Dell

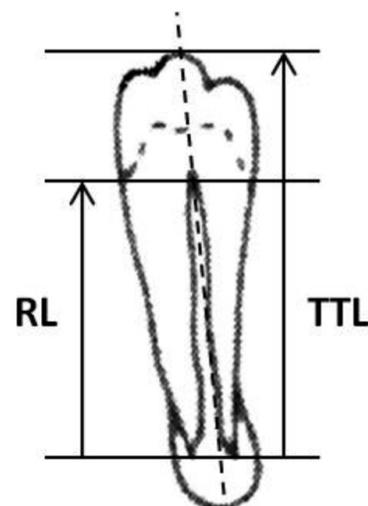
U2311 23" TFT screen (Dell Inc., Round Rock, TX, USA), with a resolution of 1920x1080 at 60Hz.

Before start of the examinations, two of the authors (PSS, JGN) were calibrated concerning estimation of dental maturity of the third molars according to Gleiser & Hunt (9). The calibration, which took place as described above, on 20 PRs included in the study, resulted in a kappa of 0.85. A second estimation of 20 PRs with 114 third molars revealed that the estimation of the dental stage only differed in two cases.

Crown/root measurements

The method described by Lind (16) was applied on the digital panoramic radiographs using ImageJ (Research Services Branch, National Institute of Mental Health, Bethesda, MD, USA), measuring the variables on the computer screen. All values were relative values and the ratio calculated had no unit. The ratios were only compared between homologues teeth. The total tooth length/height was measured perpendicular from the midpoint at the apical part of the root, till the highest midpoint of the crown. The root length was measured from the apical midpoint of the root till the midpoint of the intersection between the mesial and distal points of the enamel-cementum junction (Fig. 2).

© **Figure 2.** Image showing the principle locations for the length measurements of the total tooth length (TTL) and the root length (RL) in the PRs with ImageJ.



Statistical analysis

SPSS version 19 (SPSS Inc. Chicago, IL, USA) was used for the statistical analysis. For the statistical analysis for the dental stage estimation according to Gleiser & Hunt (9), the McNemars's paired test for comparison of proportions was used. For the crown/root ratio comparisons, paired t-test was used. The inter- and intraexaminer reliability were calculated using the kappa statistic and intraclass correlation analysis, respectively (14).

Intra-examiner variation

The intra-examiner validity was evaluated blindly on 20 PRs one month after the first evaluation of the dental maturity, according to Gleiser & Hunt (9). For the crown/root measurements, 17 PRs were evaluated blindly.

There was a non-significant difference between the two evaluations of the dental maturity. The values for the crown/root reliability via intraclass correlation for repeated measurements for 45, 44, 34 and 35 were 0.97, 0.99, 0.98 and 0.92, respectively.

Ethical considerations

All PRs were digitalized with only the year and date of birth available for the examiners, wherefore no individual patient or gender could be identified.

Results

Maxillary second molars

In all 77 PRs, the maxillary second molar tooth buds were present and the crowns and roots were under development.

In 46 PRs there were no differences in the development between the right and the left second molars (Fig. 3a). In 31 of the PRs, a difference in development was found between the right and left second molar. In 15 of these, the right second molar was more developed than the left and in 16 cases, the left molar was more developed than the right. The difference in development between the left and right maxillary second molars was statistically significant ($p < 0.001$).

Mandibular second molars

In all 77 PRs, the mandibular second molar tooth buds were present and the crowns and roots were under development.

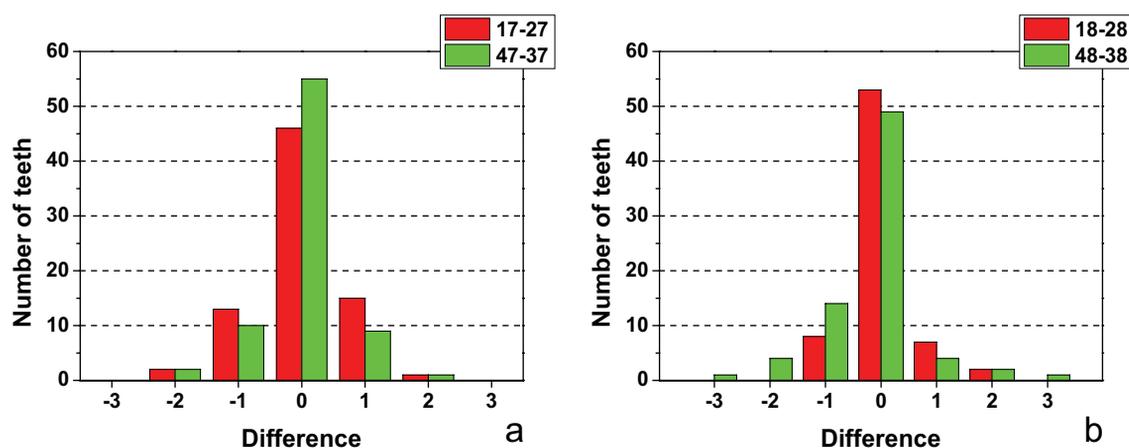
In 55 PRs, there were no differences seen in development between the right and the left second molar (Fig. 3a). However, in 22 PRs, a difference in development between the right and left second molar was found. In 12 PRs, the right second molar was more developed than the left and in 10 cases, the left molar was more developed than the right. The difference in development between the left and right mandibular second molar was statistically significant ($p < 0.001$).

Maxillary third molars

In 70 of the 77 PRs the maxillary third molar tooth buds were present. In 69 of the PRs, the crowns were under development and in one case, root development had started.

In 53 PRs, there were no differences in development between the right and the left third molars (Fig. 3b). In 17 of the PRs, a difference in develop-

© Figures 3a, 3b. Difference in developmental stage between homologues second permanent maxillary and mandibular molars, respectively (9). Difference in developmental stage between homologues third permanent maxillary and mandibular molars, respectively (9).



ment was found between the right and left third molars. In 8 of these, the right third molar was more developed than the left and in 9 cases, the left molar was more developed than the right. The difference in development between left and right maxillary third molars was statistically significant ($p < 0.001$).

Mandibular third molars

In 75 of the 77 PRs, both of the mandibular third molar tooth buds were present. In 68 of the PRs, the crowns were under development and two cases, the root development had started.

In 49 PRs, there were no differences seen in development between the right and the left third molar (Fig 3b). However, in 26 PRs, a difference in-between the right and left third molars was found. In 19 PRs, the right third molar was more developed than the left and in 7 of these, the left molar was more deve-

loped than the right. The difference in development between the left and right mandibular third molars was statistically significant ($p < 0.001$).

Figures 4a-b show that the variation in the developmental stage between homologues 1st and 2nd permanent molars is more marked than the variations between the corresponding molars in the four quadrants.

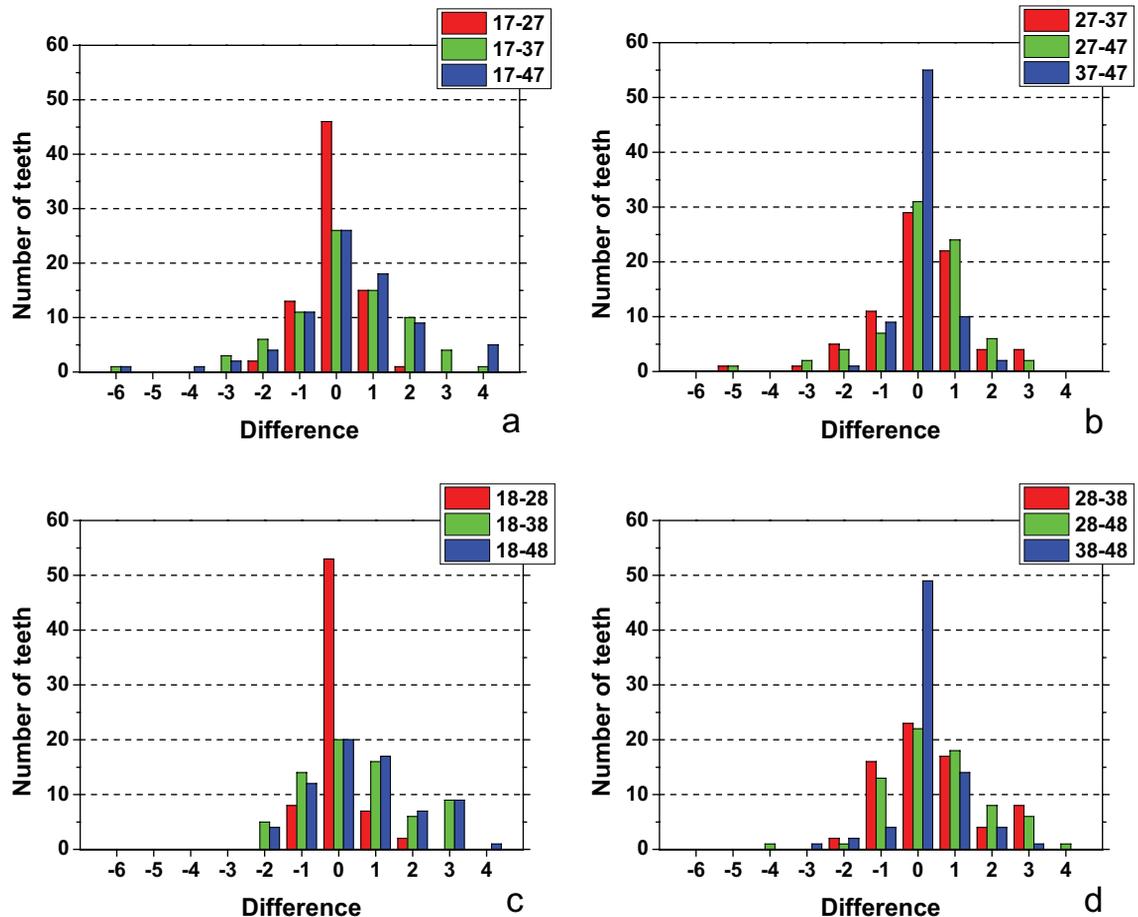
Differences in calcification

A difference in calcification of 17-27, 47-37, 18-28 and 48-38 was found in 40%, 29%, 24% and 35%, respectively, with at least one stage unit.

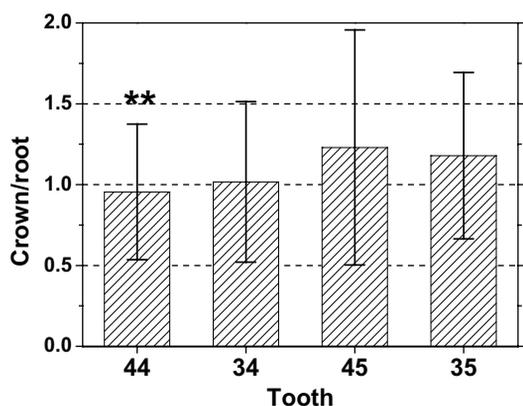
Mandibular first premolars

In 72 PRs it was possible to measure the crown and root lengths of 44 and 34. The average crown/root ratio and standard deviation regarding 44 was

© Figures 4a, 4b, 4c, 4d. Difference in developmental stage between the second permanent molars, respectively (9). Difference in developmental stage between the third permanent molars, respectively (9).



© **Figure 5.** Difference in crown/root ratio between homologues first mandibular premolars.



0.95±0.42 and for 34, 1.02±0.50, respectively (Fig. 5). The difference in the crown/root ratio was statistically significant ($p < 0.007$).

Mandibular second premolars

In the same 72 PRs as for the mandibular first premolars, the crown/root lengths were measured and the crown/root ratio calculated. The mean value for the crown/root ratio and the standard deviation regarding 45 was 1.23±0.73 and for 35, 1.18±0.51 (Fig. 5). The difference in the crown/root ratio was not statistically significant.

Discussion

This study has shown that there are statistically significant differences in dental development between homologues mandibular second premolars and maxillary and mandibular permanent 2nd and 3rd molars evaluated on panoramic radiographs, using the *Gleiser & Hunt* dental maturity method (9) and measurements of the crown/root ratio in premolars. The selection PRs without any identification to a specific individual did not make it possible to analyze any differences between genders, however, the number of girls and boys among the original 192 patients was approximately the same. Further, when discussing the results in relation to MIH its prevalence is given for both genders together.

In order to compare the tooth development stages of homologues teeth in digital panoramic radiographs, the PRs should have been taken during the time when teeth are under mineralization. The first permanent molars, the most common teeth to be affected by MIH, start to mineralize around birth and the crown is completed around three years of

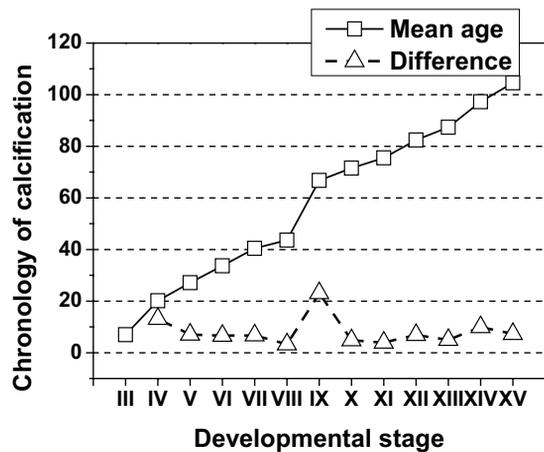
age (26-27). However, exposing newborns or young children to roentgen radiation, without individual indications, is not ethically acceptable (28). Therefore, existing panoramic radiographs from 7 to 11 year-old children, taken on odontological indications, were selected. During this age period, the premolars and permanent 2nd and 3rd molars are under development and may, thus, be used for studying any differences in mineralization of homologues teeth. If the dental development differs between homologues premolars and permanent 2nd and 3rd molars, it is reasonable to believe that the same overall pattern would be the same in homologues first permanent molars.

In order to see as small differences as possible when the crown is under development, a method with as many mineralization stages, especially crown mineralization stages, is a good choice. Of Demirjians eight development stages for molars, only four of them are during crown formation (4). *Moorrees et al.* had twelve development stages where six of the stages concerned the crown formation, which is almost identical to the classification method of the permanent first molar (4, 24). The main difference between these two classification systems is that *Gleiser & Hunt* (9) use one more stage during crown formation, the first stage when a tooth bud is visible but no mineralization is yet visible. Further, they also have two additional root formation stages compared to *Moorrees et al.* (24)

In this study, the classification system according to *Gleiser & Hunt* (9) was chosen since it had the highest number of stages which would better reveal possible differences between the developmental stages of homologues teeth. The *Gleiser & Hunt* system was originally developed for the permanent first molar, however, it may also be used for the second and third molars. Concerning premolars, there is no system that can be used with the same number of stages as in the *Gleiser & Hunt* system. Therefore, it was decided to use the crown/root ratio for the premolars, however, only for the mandibular premolars since the maxillary premolars are, in general, more difficult to discern in PRs.

The estimation of the developmental stages and measurements of the crown/root ratio showed only minor variations between two measurements carried out with an interval of two months. In the present study, the result in relation to the chronological age had little relevance since the aim was only to compare the developmental stage of homologues teeth.

© **Figure 6.** Chronology of calcification of the permanent mandibular first molar in months and difference between the stages in months according to Gleiser and Hunt (9). (Mean age=mean age in months; Difference=difference between developmental stages).



Statistically significant differences between homologues teeth were found for the 2nd and 3rd maxillary and mandibular molars and in the crown/root ratio for the mandibular 2nd premolar. There is no reason to believe that the same pattern would not be applicable also for the first permanent molar.

Gleiser & Hunt presented a table of the chronology of calcification of the permanent mandibular first molar with mean age values for the different calcification stages (9). In order to estimate the difference in calcification between homologues teeth, a figure, based on the data from Gleiser & Hunt, was constructed (Fig. 6). The mean age difference in chronology between the stages is 6.8 months (the difference between stage VIII and IX excluded since no values are given for the stages VIII A and VIII B). The difference in calcification of homologues permanent mandibular and maxillary second and first molars, with at least one stage unit, would thus explain that a factor, limited in time, which potentially could disturb the function of the ameloblasts, would therefore only have an impact on those teeth that are under mineralization. This is in concordance with the expressivity of MIH found where 1, 2, 3 or all four permanent first molars are affected (11, 13, 30-31).

A recent study of etiological factors behind MIH suggests that a possible time period is limited to around the first 6 months of life, which also is supported by histological studies (7-8). Therefore, it can be concluded that the variations in expressivity of MIH may be a result of differences in the start of

mineralization between homologues teeth and also between the same groups of teeth.

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Corresponding author:

Dr Jörgen G. Norén

Department of Pediatric Dentistry

Institute of Odontology at the Sahlgrenska Academy

University of Gothenburg

Box 450

SE-405 30 Göteborg

Sweden

E-mail: jorgen.noren@odontologi.gu.se

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An interview study of persons who attribute health problems to dental filling materials – part two in a triangulation study on 65 and 75 years old Swedes

KATRI STÅHLNACKE¹, BJÖRN SÖDERFELDT²

Abstract

© Dental materials are perceived as a health problem by some people, although scientists do not agree about possible causes of such problems. The aim of this paper was to gain a deeper knowledge and understanding of experiences from living with health problems attributed to dental materials. Addressed topics were the type of problem, both as to general and oral health, perceived causes of the problems, their experienced effect on life, and reception by health professionals.

Persons, who in a previous large questionnaire study had answered that they had experienced troubles from dental materials and also agreed to answer follow-up questions, were contacted with a request to take part in an interview study. Eleven individual interviews were held. The interviews were transcribed verbatim and the material was analysed according to the Qualitative Content Analysis method. Meaning units were extracted and condensed into a number of codes, which were combined into subcategories, categories, and themes.

Four themes were identified: 1) Long-term oral, mental, and somatic difficulties of varying character, caused by dental amalgam. 2) Problems treated mainly by replacement of dental material in fillings. 3) Powerful effects on life, mostly negative. 4) The reception by health professionals was generally good, but with elements of encounters where they felt treated with nonchalance and lack of respect.

In conclusion, people who attributed their health difficulties to dental materials had a complex range of problems and the perception was that amalgam/mercury was the cause of the troubles. The reception from health professionals was perceived as generally good, although with occasional negative experiences.

Key words

Dental amalgam, interviews, qualitative content analysis, oral health

¹ Örebro County Council, Örebro, Sweden

² Dept of Oral Public Health, Malmö University, Malmö Sweden

Hälsoproblem relaterade till dentala material – en intervjustudie

KATRI STÅHLNACKE, BJÖRN SÖDERFELDT

Sammanfattning

⊙ Att dentala material upplevs som ett hälsoproblem av vissa personer är ett välkänt faktum. Vetenskapen har däremot inte varit, och är fortfarande, inte överens om vad som orsakar dessa personers problem. Amalgam/kvicksilver är det material som vanligast lyfts fram som orsak till upplevda besvär. Antalet personer i Sverige som upplever dessa besvär uppskattas till mellan 70 000 – 300 000. Personer med besvär från dentala material upplever sig ofta dåligt bemötta, både från sjukvårds- och tandvårdspersonal.

Syftet med denna studie var att söka en djupare förståelse för upplevelser av att leva med hälsoproblem relaterade till dentala material. Typ av problem, allmänna-/orala hälsoproblem, orsaker till upplevda problem, effekter på livet och bemötandet från vårdpersonal har studerats.

Personer som i en tidigare genomförd enkätundersökning hade svarat att de upplevt problem från dentala material och samtidigt accepterat att svara på följdfrågor, kontaktades brevlades med en förfrågan om deltagande i en intervjustudie. Elva enskilda intervjuer genomfördes, transkriberades och analyserades enligt metoden kvalitativ innehållsanalys. Ur textmaterialet har meningsbärande enheter lyfts ur som sedan kondenserats till ett antal koder som förts samman till sub-kategorier, kategorier och teman.

Fyra teman identifierades: 1) Långvariga orala, mentala och somatiska besvär av varierande karaktär, orsakade av dentalt amalgam. 2) Besvär åtgärdade med i huvudsak byte av dentalt material i fyllningar, resulterande i ingen till påtaglig förbättring. 3) Stark påverkan på livet, till allra största delen negativ men även ett drag av stärkande påverkan. 4) Som helhet ett övervägande gott bemötande från sjukvårds- och tandvårdspersonal men de allra flesta hade varit med om enstaka möten som upplevts som nonchalanta och respektlösa.

Sammanfattningsvis hade de personer som relaterade hälsobesvär till dentala material en komplex besvärsbild. Samtliga intervjuade ansåg att det var amalgam/kvicksilver som var orsaken till upplevda besvär. Bemötandet från sjukvården och tandvården ansågs i det stora hela ha varit bra men där enskilda möten stod för negativa upplevelser.

Introduction

It is a well-known fact that dental materials are perceived as a health problem by some people. Scientists, on the other hand, have not been, and still are not, in agreement about what causes these people's problems (4, 13, 17, 25). Amalgam is usually the material that is considered to cause the problems, but metals such as gold and titanium have also been singled out, amalgam is mostly a mixture of silver, copper, tin, and mercury. For many years it was believed that amalgam did not affect the rest of the body.

In Sweden in the 1970s, a debate began about the suitability of using amalgam as a filling material. People felt that they had become ill as a result of amalgam, with a condition that was called "oral galvanism". In the 1980s, the Swedish National Board of Health and Welfare recommended that amalgam should not be used on pregnant women, and since 2009 it is prohibited to use amalgam as filling material.

It has been pointed out that people with health problems attributed to dental replacement materials often feel that they do not receive a good reception from staff in medical and dental care (19). The Swedish National Board of Health and Welfare has heeded these complaints, and published general recommendations in 1998 about how to handle this group of people (20).

In two Swedish counties, Örebro and Östergötland, all persons born in 1932 and 1942 were surveyed in a questionnaire study in 2007 (7, 11, 21, 23, 24). The study population has, inter alia, been investigated for the occurrence of health problems attributed to dental materials (23). The results showed that about 10 % reported some form of trouble from dental filling materials and roughly 5 % had asked dental staff about the side effects of dental replacement materials. This is one way to look at a problem, to see to what extent the problem occurs, how common it is in a specific group or a population, and to study relations to given factors, e.g. socioeconomic. To broaden the knowledge and understanding of the problems requires other additive study methods. One way of doing that is to use qualitative research methods, like interview studies.

The aim of this study was to gain a deeper knowledge and understanding for experiences of living with health problems attributed to dental materials. The study considers the type of problem, general and oral health problems, causes of the problems,

their effect on life and the reception by health professionals.

Material and method

Study group and procedure

In the above described questionnaire study the total number of respondents was 9813. More information about the questionnaire study has been presented in earlier works (7, 21, 22, 23).

Two of the items in the questionnaire were used for selecting informants. The questions were: "Do you think that you have trouble from material in dental fillings?" and "Have you asked anyone in dental care during the past year about the side effects of dental replacement materials?" To the first question 863 persons (10%) replied that they felt, to some degree, that they had trouble from material in dental fillings and the second question elicited the answer yes from 439 persons (5%).

In the questionnaire, there was also the question "Do you allow us to return with follow-up questions?" Almost 79% (7360 persons) replied "yes" to that request. Those who consented to this and also answered "yes" to either of the two above-mentioned questions were asked if they were willing to take part in an interview study. Information was provided about the purpose of the study and contact details. The request was accompanied by a response envelope and a form, which could be signed and returned to give informed consent, if they were interested in taking part. Each person was then contacted by the investigator by telephone to arrange a time and place to hold the interview. A consecutive procedure was used. A few requests were sent at a time, and interviews and analyses proceeded in parallel. The process for the collection of interview data from the first to the last interview took a total of approximately six months. An interview diary was kept throughout the course of the work.

Interviews

Eleven individual interviews were held. As part of the method, in order to get as much information as possible, variation in the study group was endeavoured between gender, counties, and the two age groups. Six interviews were conducted in the county of Östergötland and 5 in Örebro. Seven women and four men took part; only one person was born in 1932, the rest in 1942.

It was not decided in advance how many interviews would be held; instead we carried on until a sense of information saturation was reached, no

more new information was added. All interviews were conducted by the same investigator (KS), a dental hygienist and doctor of odontology who had no previous relationship to any of the informants. On all occasions it was the first meeting between the interviewer and the informant. The interviews were mostly (7 instances) held in a private room at the public library in the respective place, while 2 interviews were held in the local parish hall and 2 in the informants' homes. The interviews took from 30 minutes to just over an hour and were held in a conversational style in which open questions were posed based on the aim of the study. An interview guide with notes of basic domains was used as support. The basic domains were: problems experienced, the causes, effect on daily life, effect on life as a whole, and reception by health professionals.

Questions were asked based on these domains, with follow-up questions and more penetrating questions. On several occasions during the conversations, the interviewer briefly summed up what had been said so that the informant had a chance to confirm or correct.

In order to supplement information arising from the individual interviews and to consider whether

more individual interviews should be held, a digitally recorded focus-group interview was held with people who represented a patient organization "Dental Care Injury Association" (Tandvårdsskadeförbundet). After the focus-group interview was conducted, it was considered that no further individual interviews should be held, since no new information really emerged. It was deemed that information saturation about the questions had been reached.

Data analysis

Content Analysis has developed from having been solely a quantitative method so that it also can be used as a qualitative research method (10). Analysis of a text or an observation is always dependent on a subjective understanding and interpretation. Reality can be interpreted in different ways. To achieve credibility in an analysis, it is important to give a detailed account of how the data were collected and how the analysis was performed. The process of analysis can take slightly different forms but follows mostly the same pattern (6, 8, 10).

The interviews were recorded on a digital recorder and transcribed verbatim by an experienced medical secretary. Three of the individual inter-

© Table 1. Examples of meaning units, condensed units, codes, subcategories, categories and themes

Meaning unit	Condensed meaning unit	Code	Subcategories	Categories	Theme
and I felt so bad, it was almost as if I didn't want to live any longer	Almost did not want to live	Depression	Depression	Mental problems	Long-term problems of varying character
And terrible pressure in my head, couldn't remember, couldn't read anything, everything got blurred	Could not remember, could not read, everything got blurred	Memory problems	Memory/concentration problems		
began to feel sore in all my joints, in small ones, not the knee but in small joints	Sore joints	Joint pain	Joint/muscle problems	Somatic problems	
I had migraine, but I kept going	I had migraine	Migraine	Headaches	Oral problems	
feel sores and have so many, many blisters in my mouth	Blisters in the mouth	Blisters	Problems with oral soft tissues		
reacted badly to cold and heat and it was really really difficult	Problems with heat and cold	Shooting pains	Tooth problems		

views were not transcribed but analysed solely via the recordings. These three informants turned out to experience not so clear trouble from dental replacement materials, why only parts of the interview contributed to the analysis.

The analyses were performed as the interviews proceeded, and the interview questions were continually developed on the basis of previously obtained results. The analyses were done by both authors (KS and BS), who continuously checked their findings against each other. All the interviews have been listened through over and over again, and the transcribed text has been read repeatedly. Meaning units from each interview have been picked out and condensed to clarify the content. Codes were created on the basis of the condensed meaning units and were then grouped in subcategories and categories, finally yielding themes (see Table 1).

Ethical aspects

Ethical requirements were satisfied by obtaining informed consent and guaranteeing confidentiality. Informants can only be identified in recorded material, written transcripts and in presentations through a code key that is stored in Örebro County council data server, accessible only by the researcher. Contact was made in advance with representatives of psychiatry in case any psychological assistance would be needed in connection with the interviews. Ethical approval for the study was obtained from the Regional Ethical Review Board in Lund (Reg. no. 2009/343).

Results

Meaning units were extracted from the text and condensed into a number of codes combined into subcategories, categories, and themes (see Table 2).

Theme – Long-term problems of varying character caused by dental amalgam

All the informants had long-term problems behind them. For some, it felt like a lifelong suffering. The type of trouble varied greatly, and all the informants thought that the cause of the problems was the mercury in dental amalgam.

Oral problems

As a whole, oral problems were not the major difficulty. Only a few informants said that they have or had any great problems from the mouth. One person had a problem with contact allergy (oral lichen), but otherwise, it was dry mouth and blisters

that some mentioned, and problems with the teeth, as a general expression.

- *“you feel sore and have so many, many blisters in the mouth, I had, you know.”*
- *“have had, got problems with my teeth or with the fillings, you could say.”*

Somatic problems

Somatic problems were a much greater source of difficulty, as regards both the type and the scope of the problems. More diffuse problems were described, such as a general sense of illness, pains in the body, joint/muscle problems, and dizziness/balance problems, as well as more distinct problems, such as headaches, skin complaints, and eye problems. Tiredness was a common difficulty in this group. The informants said that they were badly affected by these problems.

- *“that it might have some connection with my teeth that I was often so terribly tired, had pains in my body and felt dizzy and nauseous, had problems roughly like what you think of if you get the flu.”*

Mental problems

Mental health and mental functions were affected in most of the informants. Depression and difficulties in remembering and concentrating were mentioned by some people. Some said that sleeping difficulties were a major problem.

- *“one aspect of it all is that you have a tendency to get terribly depressed.”*
- *“and if I’m tired I don’t remember anything, I couldn’t remember that Stockholm is our capital, you know.”*

Causes of the problems – Dental materials

All the informants thought that their problems were caused by the mercury in dental amalgam, sometimes in combination with other metals.

- *“that there could be a link with the mercury in the amalgam, and so I began to look into this and then I started talking to doctors and dentists and so on, that I was a textbook case of amalgam, eh, mercury poisoning.”*
- *“first of all they were able to measure the mercury vapour that was still there. I had so much vapour that it was roughly half of what is permitted for working in a workshop.”*

Duration – Long-term problems

In most cases the problems had persisted for a long time. A couple of informants described it as lifelong.

© Table 2. Results. Subcategories, categories and themes based on the different domains.

Domains	Subcategories	Categories	Themes
Problems	Various oral problems	Oral problems	Long-term problems of varying character caused by dental amalgam
	Problems with oral soft tissues		
	Tooth problems		
	Headaches	Somatic problems	
	Joint/muscle problems		
	Pains in the body		
	General sense of illness		
	Problems in ear/nose/throat		
	Tiredness		
	Gastrointestinal problems		
	Dizziness/balance problems		
	Skin problems	Mental problems	
	Eye problems		
	Hypersensitivity		
	Depression		
	Memory/concentration problems		
Sleeping problems			
Anger/disappointment			
Anxiety			
Cause	Amalgam/Mercury	Dental materials	
Duration	Lifelong problems	Long-term problems	
	Lasting problems		
Measures	Change fillings	Odontological treatment	Problems treated mainly with change of dental material in fillings resulting in anything from no improvement to noticeable improvement
	Psychiatric treatment	Medical treatment	
	Polyp operation		
	Other treatment	Alternative medical treatment	
Result of measures	No improvement	Varying results of measures taken	
	Some improvement		
	Noticeable improvement		
Effect on life	Working life affected	Life restricted	Powerful effect on life, mostly negative but also some strengthening effects
	Social life affected		
	Own strength increased	Life strengthened	
	Greater humility		
	No great effect	Not affected	
Reception	Nice reception	Pleased with reception	Good reception from health professionals on the whole. Isolated encounters were often the cause of the negative experiences
	Receiving confirmation and being listened to		
	Good information		
	Not seen or listened to	Displeased with reception	
	Distrusted, misunderstood		
	Unpleasant reception		

One informant claimed to have been affected even in the womb by his mother's amalgam fillings.

- "so these problems had actually been with me since birth because my mother had huge problems with her teeth and had many amalgam fillings."

Theme – Problems treated mainly by change of dental material in fillings, resulting in anything from no improvement to noticeable improvement

Odontological treatment

All the informants had had their amalgam removed, apart from the three who at the time of the interviews stated no problems that they attributed to dental materials. Some had had the fillings changed at public expense, while others had paid for it themselves. Several described how they became sicker during the amalgam removal, and some told what they had done to reduce the problems during the process.

- "I said I want you to take out all the amalgam but I already had problems with the ones that I have, I have read about that, understood that you could get really sick."
- "I had all the amalgam removed and my dentist said, you have to get rid of it, you won't get better before that, he said."

Medical treatment

One informant said that a serious polyp growth was a type of problem caused by amalgam. Another informant had severe depressions that were treated with drugs, psychological therapy and ECT (electroconvulsive therapy).

- "then I asked the doctor for ECT because I thought perhaps it could help against this too, and the fact that I was depressed and that. So I went, I had four, four ECT treatments."

Alternative medical treatment

Many of the informants had chosen to have alternative forms of treatment, both to ascertain the cause of the problems they experienced and to find solutions to them.

- "I have met a doctor in Stockholm who has helped me through this using millimetre wave therapy and breathing assistance which I believe in, millimetre wave therapy, and it's frequency medicine, you know, that you can go in and reprogram millimetre waves in the body."
- "a scan that is very special and you can't have it here in Sweden, it's called cavitation, no, cavital scan, and it lets you see the infections in the dentin."

Results of treatments –

The most frequent treatment was amalgam removal. The results turned out to vary from no improvement to noticeable improvement

- "I can still feel a little now but I've become much better, but it probably took, once all the amalgam was away, it took about two years."
- "and the migraine got slightly better but I had it every day all the same, I suppose I thought I would get much better."

Theme – Powerful effect on life, mostly negative but also some strengthening effects

Life restricted

Both working life and social life had been affected to some extent for all the informants. For some, the problems had led to long-term sick listing and early retirement. Somatic problems such as joint/muscle pain had restricted their ability to engage in leisure activities, because the body could not cope with physical exertion. The problems had also led some people to socialize less with others.

- "I felt so bad that I didn't have the strength for any social life."

Life strengthened

Even if the effect on life was mostly restricting, there were also some features that served to strengthen people.

- "I'm happy for every day I can be here, and it doesn't matter, I have lived a wonderful life."

Not affected

All the informants felt that the problems had affected their life negatively in some way. Some of them said that there were aspects of life that had not been affected, at least not as much.

- "I didn't feel like giving in to this, so I had this great thirst for life, plus that I had, I was out, even if I didn't have the energy to be out walking, not everybody has had the strength to do that."

Theme – Good reception from health professionals on the whole. Isolated encounters are often the cause of the negative experiences

Pleased with reception

The majority of the informants were generally satisfied with the manner in which they had been treated by the staff in both medical and dental care. Some even said that the reception had been very good or fantastically good. The main features of a good encounter were "being listened to", "taken seriously",

“receiving affirmation” and “being shown consideration”.

- “I got affirmation, she told me a lot about the disease, she told me exactly how to act and, and what, what was important to do.”

Displeased with reception

Experiences of poor reception almost always consisted of encounters with one specific person. Common features of this kind of bad encounter were “merely being sent on to somewhere else all the time”, “lack of interest in the problems”, “being ignored” and “a sense of being distrusted”.

- “I’ll send this over to a specialist, when they say this is not my department.”
- “met a doctor who didn’t listen to me one second but just asked about the divorce and wanted to prescribe nerve tablets and the like for me.”

Discussion

The main findings were that the problems varied in character, usually were protracted and mostly having a serious effect on life. The cause of the troubles, as stated by the informants, was dental materials, by mercury poisoning from amalgam. Most informants had undergone amalgam removal, with varying results. Many had also tried different kinds of alternative medicine.

As regards the reception they received from health professionals, the general impression was mainly positive, a sense of having been treated with respect, being listened to and helped. Several, however, had experienced isolated encounters with a therapist – either a doctor or a dentist – as a source of dissatisfaction.

Method discussion

In work with interview studies, important concepts are validity and reliability. To achieve this requires great care in the data collection, preferably transcribed interviews to facilitate the analysis, and that more than one person should perform the analysis (6, 8, 10). Additionally, in qualitative studies it is important to gain access to informants who can give as much information as possible. Despite the selection from persons previous having had claimed to have problems with dental fillings materials, it turned out that three informants after all, did not have that obvious problems, revealing a problem in informant selection from questionnaires. Further, when selecting informants, it is customary to aim for as large variation as possible regarding e.g. age and gender. A

disadvantage in this study is that all the informants who were potential participants came from two older age groups, born in 1942 or 1932. Results could possibly have been different if the informants had represented a greater range of ages.

The number of persons to interview is an important question. Few interviewees entail the risk of losing information, while a large number of interviews can cause difficulties in the analysis. In this study, it was felt that saturation was achieved after 11 individual interviews and a focus-group interview. The interviewer is also important in interview studies, for example if he or she already has some relationship to the interviewee or not, or if he or she is a professional in the sphere or not. In this case, the interviewer (KS) had no previous relationship with the informants, but did belong to the profession. It is possible that a person outside the odontological world would have elicited different answers but on the other hand, the interviewer had knowledge of the context and settings.

Results discussion

Many informants had a combination of several problems, which agrees with earlier reports (2, 3, 12). Several studies have investigated the association between the occurrence of amalgam and various states of illness, without being able to draw any unambiguous conclusions (5, 25, 26). Some studies have found that the problems cannot be attributed to amalgam but are in fact the result of somatization, a process by which mental disturbances or strains find expression in physical symptoms (2, 3, 9). All the informants who experienced problems in this study stated amalgam/mercury as the cause. No one wondered about other causes or factors influencing their problems. Amalgam removal is of course a common measure for people who believe that amalgam is the cause of their problems. The outcome of replacing all amalgam fillings thus varied in this study group, from no change to a good improvement. Other studies likewise show varying results: in their study Lindh *et al.* (14) found that 70% of the patients experienced a significant improvement, while Nerdrum *et al.* (16) conclude that their results do not support the hypothesis that amalgam removal brings an improvement back to a normal state of health.

Whatever the cause of the problems, these are highly tangible ailments that cause great suffering. A natural reaction is to look for the cause of the problems, and it is not unusual for people to use other sources of information than traditional medicine or

odontology; examples of this are mediums and natural healers of various kinds. One problem with this is that such methods have not undergone any testing or supervision. People who seek other than traditional sources of information can, at worst, end up in the hands of someone who makes their condition worse. This is yet another reason why both medical and odontological staff must take good care of people with this type of problem. A poor reception can leave deep marks on a person, and the memory can often persist for a long time. It has been shown that a good reception alone can have a positive effect on health. People who feel that they have been given a good reception feel less ill and get well quicker (18).

For several of the informants, the problems had led to long-term sick listing and their social life had been affected. It is interesting that some of the informants told of how they had battled against their difficulties and had not let them take over. The factors making some people able to live their lives and manage their jobs and their private life despite serious problems leads one's thoughts to *Antonovsky's* studies of factors of significance for health, what can make people healthy, salutogenesis (1). His answer was that it is a person's sense of coherence that is the explanation. In the interviews, however, this aspect was not specifically considered, but a salutogenic perspective ought to be included in continued research

This study has been conducted as part of a larger project, the first part of which consisted of a quantitative study with data material from a questionnaire study. It was found there that people who experienced problems from dental material also felt that they had poorer general health and oral health than the group who had no problems from dental materials. The group with problems had also had their fillings changed more often than the group with no problems, and they felt that the behaviour of dental staff towards them was worse and they were generally less satisfied with their dental care (23). The present study (which included people from the first study) followed up those findings by investigating the types of difficulties experienced. The results of the first study were confirmed here in that all the informants felt a negative effect on their health. The increased frequency of amalgam removal was also confirmed. On the other hand, this interview study yielded partly different results about the quality of the encounter with health professionals. A more positive picture emerged in the interviews than in the questionnaire study. A possible explanation is that

in a questionnaire item, there is often just one possible response alternative. It is not possible to give nuances or elaborate on an answer as one can during an interview. Perhaps an isolated bad encounter can overshadow a larger number of good encounters, and the isolated case is what the informant refers to when no other alternative is given.

To sum up, this interview study confirms previous findings showing that people who attribute their health problems to dental materials have a complex picture of symptoms – somatic, mental and oral – with the first two types dominating. All the informants believed that it was amalgam/mercury that was the cause of the problems they experienced, and they had all had their amalgam fillings replaced, with varying results. They felt that the reception they received from dental and medical staff was generally good, but most of them had experienced isolated encounters when they were not treated with respect and consideration.

Continued research is needed, both to ascertain any shared properties among people who attribute their health problems to dental materials, and what makes certain people with these problems cope with their lives better than others, despite similar problems. A salutogenic perspective could then be important.

Although problems with amalgam as filling material will disappear in Sweden over time, since it is now prohibited to use amalgam, there will probably still be people who attribute health problems to dental materials. The Dental Care Injury Association is talking about both present and future problems with gold, titanium and dental composites. The best thing that society can do must be to engage more in preventive work, chiefly among children and adolescents, to prevent, as far as possible, damage to teeth that requires filling material.

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Corresponding author:
Dr Katri Ståhlacke
Dental Public Health
Örebro County Council
Box 1126
SE-701 11 Örebro, Sweden
e-mail: katri.stahlacke@orebroll.se

Patients' choice of payment system in the Swedish Public Dental Service – views on dental care and oral health

ANNA-LENA ÖSTBERG^{1,2}, BIRGITTA AHLSTRÖM², MAGNUS HAKEBERG¹

Abstract

© The aim of this study was to generate new knowledge of considerations and factors having impacted the patients' choice of payment system and their views on oral health. Moreover, their later attitudes to the prepaid risk-related payment system, having been enrolled or not, were explored.

A qualitative design was chosen and data was collected through semi-structured interviews. Twenty patients in the Public Dental Service (PDS) in western Sweden were strategically sampled with reference to gender, age (older/younger adults), residence (rural/urban), and choice of payment system: fee-for-service or capitation plan. The interview guide covered areas concerning the payment systems, patient considerations before choosing system, views of their own oral health and experiences of received dental care within the chosen system. The analysis was performed according to basic principles of qualitative content analysis.

The results revealed two themes expressing the latent content. In the theme "The individual's relation to the PDS", expectations of the care, feelings of safety and aspects of responsibility emerged. The theme "Health-related attitudes and perceptions" revealed that views on health and self-assessment of oral health influenced the patients' considerations. Moreover, the perceived influence on oral health and risk thinking emerged as important factors in this theme.

The conclusion was that the individual's relation to the PDS together with his/her health-related attitudes and perceptions were the main factors impacting the choice of payment system in the PDS. A health promotion perspective should be applied, empowering the patients to develop their risk awareness and their own resources.

Key words

Capitation plan, dental care, fee-for-service, patient perspective

¹ Dept. of Behavioural and Community Dentistry, Institute of Odontology, Sahlgrenska Academy, University of Gothenburg, Göteborg, Sweden

² Public Dental Service, Region Västra Götaland, Göteborg, Sweden

Patienters val av försäkrings- och behandlingssystem i svensk folktandvård – syn på tandvård och oral hälsa

ANNA-LENA ÖSTBERG, BIRGITTA AHLSTRÖM, MAGNUS HAKEBERG

Sammanfattning

☉ Syftet med studien var att skapa kunskap om vilka överväganden och faktorer som påverkat patienters val av behandlingsmodell och deras syn på munhälsa. Ett ytterligare syfte var att utforska vilka attityder de hade till abonnemangstandvård i svensk folktandvård, det vill säga ett Frisktandvårdssystem, oavsett om de valt att gå med eller ej.

Studien hade kvalitativ design och ett strategiskt urval gjordes bland folktandvårdspatienter i Västra Götalandsregionen med avseende på kön, ålder (äldre/yngre vuxna), bostadsort (landsbygd/större stad) och val av betalningssystem (Frisktandvårdsabonnemang/ taxetandvård). Data samlades in genom semi-strukturerade intervjuer med tjugo individer. Huvudsakliga områden i intervjuguiden var patienternas syn på betalningssystemen och hur de upplevt den information de fått om Frisktandvården, vilka överväganden de gjorde innan de valde betalningssystem, hur de såg på sin egen munhälsa samt hur de upplevt vården inom det betalningssystem de hade valt. Analysen gjordes med kvalitativ innehållsanalys.

Resultaten sammanfattas i två huvudteman. I temat "Individens relation till folktandvården" framkom förväntningar på vården, vikten av att känna trygghet i vården och olika perspektiv på ansvar. Temat "Hälsorelaterade attityder och uppfattningar" visade att synen på hälsa och uppfattning av den egna munhälsan påverkade patientens överväganden. Viktiga faktorer i detta tema var också hur man uppfattade möjligheten att påverka sin egen munhälsa och risktänkande avseende både hälsa och ekonomi.

Slutsatsen är att individens relation till folktandvården samt hälsorelaterade attityder och uppfattningar är huvudfaktorer vid val av betalningssystem i Folktandvården. Det är viktigt att tandvården har ett hälsofrämjande perspektiv för att stödja patienten till att vara riskmedveten och utveckla sina egna resurser.

Introduction

In Sweden, there are two main payment schemes for adult patients to pay for their dental care. The predominant and traditional way is fee-for-service (FFS) payment, where the patient pays per unit of provided treatment. In the early 1990's a capitation model for dental care in the Public Dental Service (PDS) was tested in Göteborg, Sweden, showing positive attitudes to the model among both the enrolled patients and the dental staff (38). In 1999, an alternative payment method was introduced in the Swedish National Dental Insurance, a dental care subscription scheme (17). This involves a capitation plan (CP), where the patient pays a fixed amount of money, a "premium", and then receives dental care without additional costs. The dental care is partly subsidized by the government in the dental insurance, irrespective of payment system (29). The patient can make use of the so called "general dental care allowance" to partly pay the premium however, other subsidies are reserved for the FFS patients, f.i. a high cost protection scheme (29). The subsidy/patient share ratio has varied over time. Today, the PDS in all Swedish county councils offers the possibility of a dental care subscription scheme.

The CP involves a contract between the patient and the dentist/dental hygienist concerning payment and dental care behaviour. The amount of money is based on an individual risk assessment made by the dental professional on the basis of the patient's oral health status, together with i.a. general and oral medical history and previously received dental care. Specially designed computer programs have been developed for the purpose. The patient is then offered a choice between a CP and the FFS system. If the CP is chosen, a contract of mutual undertakings is signed. The service provided by the PDS includes basic dental care, preventive measures and regular examinations, while the patient commits to recommended dental self-care and health habits. Thus, both the dental professional and the patient are influenced by the system: the dentist/dental hygienist when offering and providing the care and the patient in choosing a system and adhering to the contract.

When new organizational systems are implemented in health care, there is a need for evaluation from a range of perspectives. Quantitative studies, including health outcomes and health economy issues are necessary (13). However, the patient perspective is crucial; for instance, as measured by self-perceived oral health, satisfaction and oral health-related quality of life (18). The patient's reasons for choosing a

particular payment system is vital information when changes and improvements to the systems are considered. The decision of the patient will be influenced by obvious and visible factors, but also by more concealed factors. For instance, the beliefs and goals of the individual may play a role (3). Also, a person's views on oral health and perceived disease risk are of interest for instance being shown to impact individuals' seeking of dental care (11, 31). Studies on decision-making in medicine and dentistry are mostly related to diagnostics and choice of therapy (2, 8). The patient perspective has been investigated in health service research (26). In dentistry, these factors have not been explored.

Thus, the aim of the study was to generate new knowledge of considerations and factors having impacted the patients' choice of payment system (CP or FFS) and their views on oral health. Moreover, their later attitudes to the prepaid risk-related payment system (CP), having been enrolled or not, were explored.

Methods

Setting and design

The study was carried out in Västra Götaland, a region with 1.5 million inhabitants situated in the western part of Sweden. Most of the region is rural and there is one large city (Gothenburg) with half a million inhabitants. The PDS provides dental care for the majority of children and adolescents in the region. Of the adult population, 40-50 per cent has chosen the PDS for their dental care (35). Since 2007, the patients are offered the CP option as an alternative to the traditional FFS payment system. Based on the risk assessment, the patients are classified into ten premium groups, from the lowest to the highest estimated risk with correspondingly increasing charges. The contract period is three years, with an optional extension after re-examination and a renewed risk assessment (27).

A qualitative design was used to gain an in-depth understanding of the adult PDS patients' experiences and perceptions of the payment systems in the PDS.

Informants

The informants were recruited by a purposive sampling from the data record system used in the PDS, related to gender and choice of payment system (CP or FFS). The sampling also strategically aimed at a range in age (older/younger adults) and residence (rural/urban) to achieve heterogeneity of infor-

nants. The purpose was to generate diversity with regard to experiences and statements within the field investigated; i.e., to optimize the variation in these, not to compare groups. The CP patients were first randomized and the FFS patients were then matched according to the sampling criteria. The inclusion criterion was to have undergone a full dental examination in the PDS during the past three years.

Twenty informants were included in the study: age range 22-70 years, 10 in the CP (5 women, 5 men) and 10 in the FFS system (5 women, 5 men). A distribution of residence was achieved: four informants came from urban Gothenburg, three from the extended urban region and the rest from different places in the rural parts of the region. Originally, another 74 persons were invited; however, 21 of these could then not be reached by telephone. Ethical considerations prevented us from asking for their reasons not to participate, and for 24 persons this is unknown. Seventeen people declined, spontaneously declaring “lack of time” or other practical reasons, such as studying or working far away at the time. Six individuals had moved from the region. One person stated health reasons for not wishing to participate. Two persons cancelled and three did not show up for the interview.

The Ethical Review Board of Gothenburg University approved the study (reg.no. 220-10) and all participants provided informed consent.

Data collection

Data were collected through a series of semi-structured individual interviews. The second author (BA), a coordinator (non-dental profession), conducted 13 interviews (5 CP patients, 8 FFS patients) and the first author, a dentist (ALÖ), the remaining seven (5 CP, 2 FFS). The purpose was to achieve a greater variation of statements. The background of the interviewer was known to each informant.

The selected individuals were invited by ordinary mail. After about one week they were contacted by telephone and asked whether they agreed to participate. The interviews were performed locally at premises unconnected with dental care. At the beginning of each session, information about the aim of the study, confidentiality, and the voluntary nature was repeated. The interviews lasted 25-45 minutes.

Interview guide

The interview guide was thematic and covered areas concerning the payment systems in the PDS, specifically the CP, patient considerations before having chosen system, views of their own oral health and experiences of received dental care within the chosen system. It also included health issues, health habits and changes in these over time. The main entrance question was: “Which were your main reasons when choosing payment system?” The following entry questions initiated the subsequent dialogue: “How did you get information about the payment systems? How do you perceive the dental care provided, once having made your choice? Would you make the same choice again? Can you describe what you mean by oral health? Have you changed your health habits in any way lately?” Starting from these issues, discussions were held and the interviewer followed up with other questions. The informants were also given the opportunity to bring up their own concerns.

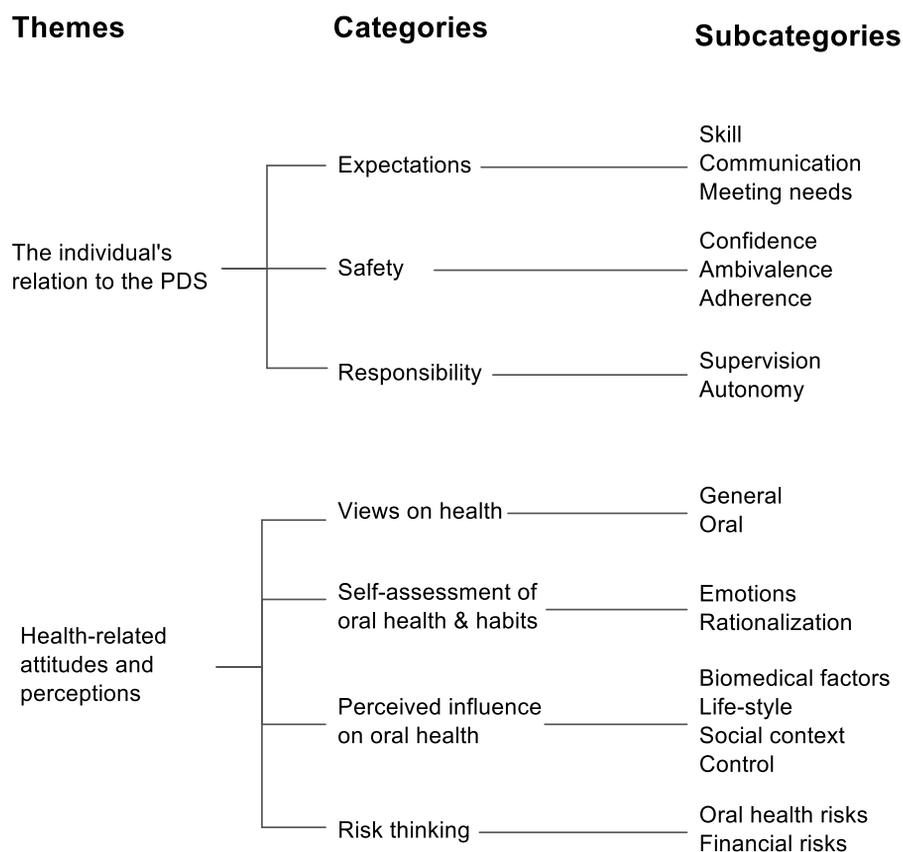
Data analysis

The interviews were audio taped and transcribed verbatim. The analysis was performed according to basic principles of qualitative content analysis (12). Both the manifest content (visible and spoken statements) and the latent content (interpreted underlying meanings) were explored. Firstly, meaning units in the text were identified; that is, words or statements with related content (19). The essentials

© **Figure 1.** An example of the analysis from codes of condensed meaning units to the labelling of a category.

Codes condensed from meaning units	Sub-categories	Category
Examine properly and assess professionally	Skill	Expectations
Find out what’s wrong and attend to it		
Tell what it looks like and what I shall do	Communication	
Listen to my opinion		
Offer painless treatment	Meeting needs	
Provide support		

© Figure 2. Two themes with categories and subcategories describing the content in patient's views of payment systems in the PDS.



of these meanings were then expressed in shorter phrases, called condensation, into condensed meaning units. These were abstracted to form content areas, labelled codes. The next step in the analytical process was to create categories, with content that shared commonality. In Figure 1, an example is shown of the analytical process, from the condensation of meaning units into codes and then to inclusion in a category.

The first stages in the analytical process were carried out consecutively during the data collection to allow for revision of the interview guide. However, only small amendments were made to the guide and then only after discussion between the two interviewers. The main interpretative analysis was performed after the completed data collection. The interview protocols were read repeatedly by the whole research group. The first author (A-L Ö) created the

interpretation model. Constant comparisons were made between the informants' statements and the analytical model. The model was discussed and confirmed in the research group.

Results

Based on the analytical process, with coding and developing of categories and subcategories, two themes expressing the comprehensive latent content, i.e. underlying the patient's choice of payment system, in the interviews were identified: "The individual's relation to the PDS" and "Health-related attitudes and perceptions". A model of the analytical content is shown in Figure 2. The themes, including categories with mainly manifest content and subcategories on varying levels of abstraction, are presented below. The citations chosen to illustrate the results represent all interview protocols.

The individual's relation to the PDS

In the analysis of possible factors impacting the choice of payment system, the categories discovered regarding the participants' relation to the PDS were "expectations", "safety" and "responsibility".

Expectations

The informants expected a high degree of professionalism in the encounter with the dental care service. This concerned both technical proficiency and the attitude of the staff (Fig 1 & 2). Professional **skill** was repeatedly mentioned as important and mostly taken for granted, regarding the technical part:

"I expect a proper examination and a professional assessment"

The dental staff could be seen as well educated experts. This was expected from both dentists and dental hygienists:

"I expect them to be properly qualified and trained"

When visiting the dental clinic, the patient wants to be met and seen as a person. Thus, the attitude of the staff was emphasized. The statements of the informants revealed a great desire for **communication** about what is revealed through the examination and the information given must be truthful. Self-care instructions should be clearly communicated:

"They should give me the instructions I need..., if there is something else that I need to do"

Moreover, the dentist/dental hygienist should have a listening attitude and be prepared to listen to the patient's opinion. If not, he or she may be questioned:

"Then I will ask questions and state my point of view"

According to the informants, their main source of information about the payment systems was the dental staff in connection with the dental visit and any advertising was only vaguely recalled. Some had been recommended the CP by others, mainly their family members, and raised the issue themselves at the dental visit. However, on the whole, the informants were uncertain about the details of the contents of the CP, indicating a need for better communication on this matter. Combined written and verbal information may be easier to understand:

"When someone tells you what's in the brochure, it is easier to understand it than when you read about it yourself"

The **meeting of needs** emerged as important in the interviews, both regarding the clinical dental care and the organisation of the care, specifically the payment systems. Some informants expressed

dental anxiety openly and the provision of painless treatment was stressed. Having their need for support met, for instance when undergoing different treatments, was desired. The dental care received, including prevention activities, was largely perceived as similar to that obtained before the introduction of the new payment system, both by CP and FFS patients. Emergency appointments were also offered when needed, regardless of payment system. However, a few individuals in the CP felt that the time between check-ups was too long and expressed a need for alternative periods between check-ups.

Safety

Feeling safe was seen to be essential, and was expressed in various ways. Regular dental visiting habits generated overall feelings of safety, which could also be a reason to stick to the traditional FFS scheme. The safety of dentist/dental hygienist continuity was important, particularly for those with large treatment needs or anxiety. The patients who had chosen the CP discussed the safety aspects of the system, for instance, that there was opportunity to call between scheduled visits without additional costs.

Confidence in the dentist/dental hygienist emerged as essential to the sense of safety. However, patients have difficulties with judging the risk assessment made by the dental professional and the care given. You are "in their hands", and their judgement is simply accepted: "I have no reason to question anything"; however, the latter informant also stated that if something was perceived as strange, it should be called into question. The attitude of the dental care staff might strengthen the feeling of trust:

"...what you trust in could of course differ from patient to patient, but I have been well received and there haven't been any problems"

Thus, certain **ambivalence** towards the PDS was obvious. The economic interests of the dentist/dental hygienist could decrease the patients' trust, according to the informants; however, there was uncertainty as to whether such interests were present. For instance, there was some speculation about where unused money put into the CP had gone. Nevertheless, the reliance on being correctly treated was considerable. The participants in the study had all chosen the PDS for their dental care, and on the whole, their **adherence** was high. One informant stated that he had always been a "member" of the PDS. It could also just be by force of habit: "it is an old tradition", but in most cases it was a deliberate choice. The perceived quality was raised by a number

of informants. To be checked by both a dentist and a dental hygienist was seen as "quality assurance". On the other hand, some informants had experience of other caregivers than the PDS, which had resulted in conflicting examination results and a perceived poorer quality of care of that dentist.

Responsibility

The responsibility of the individual for her/his own oral health was recognized by the informants regardless of chosen payment system. The shared responsibility by the individual and the dental care service was stressed and discussed:

"...still, the greatest responsibility lies within the individual, but being checked and examined is the job of the dental service"

The responsibility of the individual was thus clearly remarked upon, including carrying out self-care and showing up for dental visits. The shared responsibility could, however, be seen in various ways; for instance, one informant talked about "buying a little help to keep up with looking after my teeth".

The **supervisory** task of the PDS was clearly pointed out by the informants, with the dentists and the dental hygienists "setting the policy" for self-care. Mostly "the stick" was mentioned, and less often "the carrot". The informants often expressed a need and desire for check-ups, as they seemed to be hesitant about their own ability to take care of their own oral health. One individual compared the dental check-ups to school exams:

"If you never get a real assessment through the exams, you cannot improve either"

However, the patients' way of reasoning differed, and one informant stated: "It isn't necessary for me, I know what to do," referring to the CP contract, and another patient commented that "they can't be there in my bathroom and check what I do".

The **autonomy** of the individual was important to most informants. This included the optional choice of payment system but also, which dentist/dental hygienist to visit. The choice between payment systems was sometimes perceived as tricky and the dentist/dental hygienist appears to be influential. This was obvious with regard to the content of the information, but also whether information was given or not. Some of the informants had not been offered the choice between the CP and FFS, and the attitude among these patients varied from slight resentment to resignation: "they made the choice for me... perhaps they thought that I didn't fit in". The dentist's/dental hygienist's role includes a balancing

act between providing unbiased information and offering the dental subscription scheme. The importance emerged of allowing time for the patients to reflect and not force the choice. One informant emphasised: "This was my choice".

The choice of payment system may also be perceived as an obligation, among a series of other choices that have to be made in modern society: "Perhaps you are unprepared for what they talk about, then you must find out and you don't understand. It's difficult...".

Health-related attitudes and perceptions

Reference to own health-related attitudes and perceptions appeared as the other main theme underlying the choice of payment system in the informants' reasoning. The categories were "views on health," "self-assessment of oral health and habits," "perceived influence on oral health," and "risk thinking".

Views on health

Two main approaches to **health** could be discerned in the interviews, one bio-mechanistic and one more holistic view. Thus, some informants compared maintaining a healthy body to attending to a machine or a car in expressing a bio-mechanistic view: "it is like leaving your car to the garage". However, the link between general health and oral health was repeatedly emphasized in holistic approaches to the body: "If you don't have good oral health it can result in other diseases ... or the other way around...", and "if you feel well in general, then your teeth feel well". Likewise, the mouth was included in the body regarding health habits by some: "It's like taking a shower every day". The different national health insurance systems for general and oral health care in Sweden were often spontaneously mentioned and the informants felt that these systems should be equal, specifically regarding the share of the cost for the patient.

Oral health was discussed with regard to a number of aspects: functioning, symptoms, psychological, and socialising aspects. You should be able to chew without "being afraid that something will break". "No holes" but also healthy gums were mentioned as indicators of oral health. One informant expressed his view on oral health like this:

"You don't have any pain anywhere... you still have your teeth and you don't smell"

Freshness and good-looking teeth were mentioned by several informants. The importance of own active health behaviour was pointed out:

"A healthy mouth, that is something you look after;"

germ-free is perhaps not the correct word... but flossing, using tooth picks and brushing your teeth regularly...".

Self-assessment of oral health and habits

When judging their own oral health and behaviour, the informants applied the same criteria as discussed regarding oral health in general. This led to different reactions. There were **emotional** reactions, such as satisfaction or even pride: "I would say that my teeth are fairly good, actually", when referring to having few problems and little need of a CP. The appearance of the teeth was repeatedly used as a basis for the informants' self-assessment of their own oral health, for instance, with comments on whether the teeth were straight or about the colour of their teeth. In those cases, there could be feelings of embarrassment or shame: "I am ashamed of my teeth... I think they are so ugly...". Getting a cavity could also entail feelings of shame: "...that wasn't something you wanted to talk about...". There were also comments related to perceived guilt about the patient's own oral health: "I can only blame myself". One informant spontaneously recognized the teeth to be part of the personality.

Some informants judged themselves to be thorough when it came to their own oral health self-care, while others thought it was difficult to keep up a good standard. According to the informants, habits are difficult to change, whether good or bad. This was compared with other health habits, for instance, physical exercise. The agreement signed by the patient in the CP was specific regarding dental self-care to be performed at home. The agreement seemed to influence patient behaviour to some degree and some of the informants were more aware and active than before:

"I clean my teeth more often now, because of the agreement"

Some pointed out that the agreement was influential; however, not always easy to comply with.

The patients' reasoning about their own oral health habits included **rationalization**. You "try the best you can", and this was often judged to be good enough even if it did not correspond to the recommended dental self-care, specifically the CP contract. One informant referred to having read somewhere that using dental floss did not produce "fantastic results" (implying that this is the message of the dental profession). Another person had bought an electric toothbrush, and said: "I thought flossing wouldn't be as necessary then". Thus, own habits by some were considered to correspond to an acceptable standard.

Perceived influence on oral health

The factors influencing oral health were regarded as manifold, but the informants were often uncertain in their reasoning. **Biomedical factors**, i.a. possible genetic influence and general diseases, were raised in the interviews. The dental care received, including restorations, orthodontics, prosthetic rehabilitations and extensive filling therapy, was mentioned as influential. Also, **lifestyle** issues typically included in oral health education, such as tobacco use, eating and drinking habits together with dental self-care, were discussed. However, the more latent content revealed underlying factors.

The **social context** appeared as important, in particular the role of parents for establishing healthy habits at a young age. This was raised by informants of all ages, also by older individuals. Younger informants could also be influenced by their parents in choosing payment system. **Control** over their own oral health was a central issue in the informants' reasoning. The perceived influence by dental professionals at dental check-ups was frequently referred to: "They keep a check on you". The locus of control was then externally located that is, the person interpreted that her/his dental health depended on extrinsic factors, like powerful other persons. However, the informants generally revealed both external and internal control in different parts of the interview protocols; i.e., they recognized the contributions of both the dental professionals and themselves. Some informants expressed a sense of their oral health not being controlled, and that it is only a matter of chance. This feeling was expressed as follows by one informant:

"They (the dental service) do what they can and if that doesn't help – what can you do?"

The different influencing factors perceived by the patients were considered in the choice of payment system.

Risk thinking

Own perceived **oral health risk**, whether low or high, was stated as the most influential factor when choosing payment system. The patients discussed the risk of future oral health problems in relation to the cost of dental care. For oral health, the perceived risk versus the "true" risk was discussed, both regarding diseases and **financial risks**. One individual who had joined the CP expressed it in this way:

"You must consider the cost in relation to what you would have to pay if you hadn't joined (the CP)..."

and if you have poorer oral health you will have higher costs, so it's always a matter of balancing the pros and cons”.

This balance was brought up by most of the informants. However, the calculated benefits, with preferably a greater output (received dental care) than input (premium charges), were often raised:

“As soon as you get something done, you've profited from the plan”.

However, one informant believed that you always have to pay in the end, in one way or another: “You never get anything for free”. Some made careful considerations; discussing the precise sums they had spent versus the premium they had been offered to pay. Others made more general considerations, similar to this informant who did not choose the CP:

“I haven't got very many problems with my teeth... so perhaps it is worth taking a chance for three more years”.

However, the risk of future oral disease and problems was often perceived as uncertain. The grounds for the risk assessment made by the dental professionals were unclear to most of the informants, as was the allocation to a certain CP premium class. Sometimes, the assessments were perceived as recurrent warnings of events that never occurred. A few patients in the CP admitted to taking higher risks; for instance, by eating more sweets, on the grounds that the cost of oral problems was covered by the plan.

All the informants were asked to reflect on how to handle risks through insurance schemes in general. The regular insurance premiums to be paid were contrasted with the gain of being helped when needed. On the other hand, the premium charges were sometimes seen as unpleasant expenses, if the patient feels that he or she never makes use of the insurance. This was the case regarding the CP for some informants who were hesitant about whether the CP payments would really be of use to themselves. On the other hand, the distribution of the costs over time in the CP was repeatedly brought up as a reduction of the financial risk. The payment of a fixed smaller sum each month involved both managing the expense and avoiding a major financial “blow”. A young informant said:

“Firstly, you don't have to pay everything in one go, and secondly, if something happens you can go to the dentist without feeling that you can't eat the rest of the month”.

Discussion

The qualitative information generated in this study

revealed two themes that are essential factors when patients choose between dental payment systems. The first of these two themes, “The individual's relation to the PDS”, emphasized the importance of creating good relationships between dental professionals and patients. The communication between the dentist/dental hygienist and the patient shall be open, specifically with regard to risk assessment and oral health goals. The need to empower the patient and the promotion of positive health behaviour emerged from the other main theme, “Health-related attitudes and perceptions.”

Qualitative methods are useful to explore the meaning of different phenomena, as experienced by the persons themselves (21), especially those that have been little investigated before. Thus, it was deemed appropriate to explore the new payment system in the PDS through qualitative interviews. The sampling was purposeful and, thus, only individuals using the PDS were contacted (19). This might be questioned as, for instance, people using private dental caregivers could have completed the data with other and varying perspectives. However, their experiences with regard to this particular research question might have been scanty. The interviewed sample varied in terms of gender and age, representing both rural and urban contexts in Sweden's most densely populated region (Västra Götaland). The findings could be regarded as transferable and of benefit to a broader Swedish context.

The construction of the interview guide was directly related to the payment systems recently introduced in the PDS however, also based on previous research showing the importance of views on health in dental utilization (1, 31). Still, the choice of research question and entry questions in the interviews might mirror the preconceptions of the researchers (20). As the interviewer is the main instrument for gathering data, two interviewers with different backgrounds were used to counteract interviewer bias (20). Also, to increase the trustworthiness of the process, regular discussions were held in the research group, both during the data collection process and in the data analysis. The reflexivity achieved by this triangulation enabled the researchers to share preconceptions and to agree on interpretations. Quite a few of the invited persons chose not to participate, often stating lack of time or not giving any reason. This might be an indication of the level of interest in the topic, but also that the research question could be perceived as unpleasant (23). Dental care may instil feelings of unpleasantness and the prevalence of

dental anxiety among adults is estimated between 10 and 20 percent of a population (14, 25).

The main consideration stressed by the informants when choosing payment system was perceived own oral health risk. Thus, their attitude to the prepaid payment system in question was stated to be impacted by perceived need, earlier shown to be related to satisfaction with dental care and self-perceived oral health (11, 10). Economic reasons were emphasized as an important issue, and costs were balanced versus gains. However, the contents in the CP were not much brought out. As a whole, the informants appreciated the opportunity to choose a payment system, even if the choice was perceived as difficult. In an American study, the enrollees were satisfied with their dental benefit plans; however, the basis for their decision was not asked after (6). Participation in decision-making regarding dental treatment options might be more familiar to patients than to choose payment system however, not always the standard (4, 24). According to some informants, they had not been offered the choice between a CP and the FFS. Apart from possible memory bias among the informants, this should be considered by the dental care organization.

Another important issue concerning active choices, especially when we sign a contract, we tend to perceive an obligation or responsibility towards our choice. To maintain the consistency in our self-image to correspond with the choice done, critical reflections can be repressed. Thus, the commitment towards the contract influences how we regard both our choice and its consequences (5). This might have influenced the CP informants' reasoning however difficult to discern in open statements. Still, it is important to consider this possibility having impacted the results.

The expectations of the dental service were high among the informants. The importance of clear and interactive communication was revealed, which also has been recognized as a vital component in health education (37, 33). For instance, the findings indicated a need to make patients understand the grounds of the risk assessment and the recall intervals in the CP. This is of vital importance, as the risk assessment is the basis for the capitation plan system (38). According to *Freeman* (9), the dentist-patient interaction can enable patients both to accept dental care and to take responsibility for their own oral health. The confidence in the PDS was high; however, there were some indications that the care may be questioned by the patients. This further enhances

the need for good communication to improve the patient-provider relationship (33). Today, structured methods for professional dialogue are available (22).

The aspects of oral health identified and discussed by the informants (functioning, symptoms, psychological, social) concur with earlier theories (15). Oral health behaviour was often seen as an aspect of and related to oral health by the informants, consistent with findings in earlier studies (10, 40). This implies a need for dental professionals to talk to patients about their self-care goals. These are important to identify and consider, as the patient's goals do not necessarily coincide with those of the dental staff (33).

Psychological reactions emerged in the interviews, particularly in the appraisal of own oral health and oral health habits. The subjective assessments varied and entailed a wide range of affective reactions, from pride to shame (28). Some defence mechanisms were also recognized. Even if some admitted to deficits in their own oral health habits, they may wish to place their own behaviour in a more favourable light; i.e., rationalization (28). The informants' health locus of control; that is, the perception of whether their own health depended on their own ability and efforts or on other factors, varied as recognized in the theory behind the concept (36). Other factors may be powerful others, as in the present study, where the dental professionals were often considered to "be in control", but it can also be perceived as simply the result of fate or chance in concordance with findings in young Swedish adults (39).

The allocation of financial resources in the health care system was often spontaneously mentioned by the informants. They compared the insurance systems of Swedish general and dental health care and desired greater conformity between the two. Briefly, the difference is more subsidized and fixed prices in general health care, while dental care, to a greater extent, is financed by patient fees (34, 7). There is growing evidence for the link between oral and general health, which could justify the inclusion of the mouth as a part of the body also in financing and payment systems (16, 32, 30). Thus, the prioritization of resources is an important issue in health policy and legislation.

The conclusion was that the individual's relation to the PDS together with his/her health-related attitudes and perceptions were the main factors impacting the choice of payment system in the PDS. A health promotion perspective should be applied, empowering the patients to develop their risk awa-

renew and their own resources.

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Corresponding author:
Dr Anna-Lena Östberg
Public Dental Service
Västra Götaland
Box 7163
SE-402 33 Göteborg
Sweden
E-mail: anna-lena.ostberg@vgregion.se

Porcelain bonding to titanium with two veneering principles and two firing temperatures

PER HAAG¹, MARTIN ANDERSSON², KRISTER NILNER¹, TORE DÉRAND³

Abstract

© Dental literature, as well as dental laboratories, has described problems with ceramic veneering of titanium, while clinical and in vitro studies have reported good results. The objective of this study was to investigate the effect of firing temperature, thermo cycling, and veneering methods on bond strength between porcelain and titanium. Eighty titanium specimens were prepared with one of two methods: a bonding agent firing or an oxidation firing. During veneering, half of the specimens in each group were fired at 30°C above and half at the manufacturer's recommended temperature. In the bonding agent group and in the oxidation group, half of each firing group was thermocycled. Bond strength was calculated in a three-point bending test. Scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS) analyses of the titanium and the porcelain fracture surfaces of one specimen from each subgroup was used in order to study the composition of the interface between titanium and porcelain surfaces after fracture. No significant difference in bond strength was found when firing at a higher temperature compared with firing at the recommended temperature. An oxidation firing before veneering yielded significantly higher bond strength in a three-point bending test than when firing with a bonding agent. SEM and EDS analyses indicated a higher frequency of titanium oxide fractures in the oxidation than in the bonding agent group. The main finding is that firing at 30°C above the recommended temperature does not significantly affect bond strength between titanium and porcelain. SEM and EDS analysis indicate that fractures occur in the titanium oxide layer by oxidation firing and in the interface between titanium oxide layer and veneering material by bonding agent firing. This finding might indicate that three-point bending test is not a relevant method for determining bond strength in this case, since the firing methods might influence the ductility of the samples.

Key words

Bond strength, ceramics, titanium, titanium oxide

¹ Department of Prosthetic Dentistry, Faculty of Odontology, Malmö University, Malmö, Sweden

² Department of Chemical and Biological Engineering, Chalmers University of Technology, Gothenburg, Sweden

³ Deceased

Bindning mellan porslin och titan med två olika påbränningsprinciper och vid två olika temperaturnivåer

PER HAAG, MARTIN ANDERSSON, KRISTER NILNER, TORE DÉRAND

Sammanfattning

⊙ Såväl dental litteratur, som rapporter från dentallaboratorier, har presenterat problem med påbränning av porslin till titan, medan både kliniska och in vitro studier har rapporterat goda resultat. Syftet med denna studie var att undersöka effekten av varierad bränntemperatur, thermocykling och två olika brännmetoder på bindstyrka mellan porslin och titan. Åttio provkroppar i titan behandlades med en av två metoder: 40 med bonding agent bränning och 40 med en oxidbränning. Hälften av provkropparna i varje grupp, 20 stycken vardera, brändes vid 30° C över och hälften vid av tillverkaren rekommenderad bränntemperatur. Hälften av provkropparna i varje undergrupp 10 stycken, belastades med termocykling. Bindstyrkan beräknades med ett trepunktsböjtest i enlighet med ISO 9693:1999. Med hjälp av analyser i Scanning Electron Microscopy (SEM) och Energi Dispersive X-ray Spectroskopi (EDS) på både porslins- och titanytor av de frakturerade provkropparna från varje delgrupp, fastställdes gränssnittets sammansättning. Inga avsevärda skillnader i bindstyrka kunde dokumenteras när bränning vid en 30°C högre temperatur användes jämfört med bränning vid rekommenderad temperatur. Provkropparna med oxidbränning uppvisade dock signifikant högre bindstyrka än vid bränning med en bonding agent. SEM och EDS analyser visade emellertid på en högre frekvens av titanoxidfrakturer i oxidgruppen än i gruppen bonding agent. Den viktigaste slutsatsen är att en höjning av bränntemperaturen med 30°C över rekommenderad temperatur inte avsevärt påverkar bindstyrka mellan titan och porslin vid någon av brännmetoderna. SEM och EDS analys tyder på att frakturer inträffar i titanoxidskiktet vid provkroppar med oxidbränning och i gränssnittet mellan titanoxid och porslin vid bränning med bonding agent, vilket skulle kunna indikera att trepunkts böjtest inte är en helt relevant metod för att fastställa bindstyrka, då brännmetodiken kan tänkas påverka provkropparnas duktilitet.

Introduction

Titanium is an element with documented biocompatibility. It combines low density with high strength and corrosion resistance (2, 5, 15, 16, 20). Pure titanium gets immediately coated with an oxide layer in contact with oxygen. An increase in the thickness of the oxide layer is a critical factor in the problems experienced during the heating process of porcelain veneering of titanium (1, 11). Oxide layer thickness increases with elevated firing temperature, and this is considered a problem in the process of creating sufficient bond strength between titanium and ceramics (1, 11, 13). A compact, well-adhered oxide layer forms at temperatures up to 800°C, while above 800°C, the oxide layer is more porous and adheres less well to the titanium (5)

Adachi & Mackert (1) found that risk of de-bonding grows with increasing firing temperature since fractures within the oxide layer rapidly multiply at temperatures above 800°C. *Kimura* (11) showed how, as the temperature approaches 900°C, the oxide layer thickens with an accompanying decrease in bond strength.

Attempts to minimize the thickening of titanium's oxide layer have been made by firing porcelain in an inert atmosphere, such as one of argon gas. *Atsu & Berksun* (3) found that firing porcelain in an argon atmosphere limited oxide formation compared to firing under normal conditions, hence improving the bond strength between titanium and porcelain. Porcelain systems with a special "bonding agent" that impedes the formation of an oxide layer during firing has demonstrated higher bond strength values than porcelain systems without such a bonding agent (8).

Studies on bond strength between titanium and porcelain often report good results (10), although results of a recent clinical study deviate from such findings (4). Since dental technicians often perceive titanium veneering to be problematic, it could be speculated that the process is not always optimally performed. Delamination, porcelain (chip-off) fractures, and inclusions might, for instance, be caused by incorrect handling of the titanium framework. Lack of precise firing temperature in porcelain furnaces could be another cause, as such defects often

have been shown to indicate too low a firing temperature (9).

Thus, it was considered of interest to test different titanium-ceramic concepts whether varying the firing temperature influences bond strength values. The two different titanium ceramic concepts differed on firing protocol, one having an oxidation firing as first step (Noritake) and the other one (Triceram) has an oxidation inhibiting silica glass application as first step in the firing procedure. *Moormann et al.* (14) found that a decrease in bond strength between titanium and porcelain often occurs when thermocycling is added to the test protocol, so this stress moment was also included in the test procedure.

The aim of the present study was to test, by three-point bending test and SEM/EDS analysis, whether a moderate raise in the firing temperature influence the bond strength between titanium and ceramics, produced with two different firing procedures.

Materials and Methods

Specimen preparation

Eighty specimens of commercially pure titanium, grade 1, according to the American Society for Testing and Materials (ASTM) (Permascand AB, Ljungaverk, Sweden) with dimensions in accordance with ISO 9693: 1999 (10), were prepared for this study. The specimens were adjusted with a hard metal cutter designed for cutting titanium to establish the correct dimensions and verified with a digital slide calliper (Digimatic calibrator; Mitutoyo Corp., Nakatsugawa, Japan). Before veneering, the specimens were blasted with 250- μ m alumina particles (Al_2O_3) under 4 bars of pressure at a distance of 10 cm and an angle of 15° for 15 seconds. After blasting, the specimens were rinsed in an ultrasonic bath containing isopropyl alcohol for 10 min. Thereafter they were dried at 100°C–110°C for 5 min.

Veneering

Within 30 min following cleaning, the specimens were divided into two groups and prepared for veneering. In the oxidation group, (n = 40) specimens were oxidized and in the bonding agent group (n = 40), a bonding agent was applied to the specimens (Table 1). Application of bonding agent and oxida-

© Table 1. Porcelain types, product names and their manufacturers for materials used in this study

Porcelain type	Product name	Manufacturer
Low fired, without bonding agent	Noritake® Ti 22	Noritake Co. Ltd., Nagoya, Japan
Low fired, with bonding agent	Triceram® Triline ti	Esprident GmbH, Ispringen, Germany

tion were carried out according to the manufacturer's instructions.

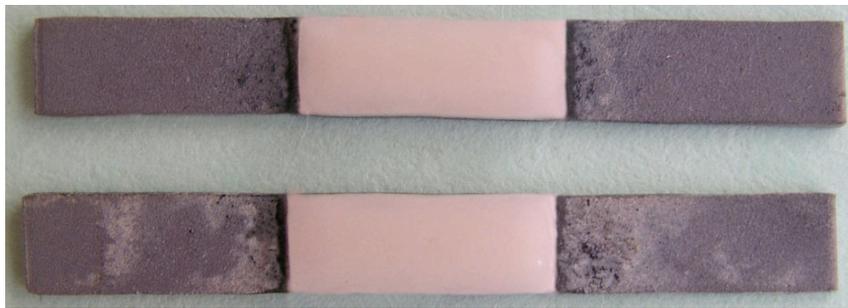
In the oxidation group, veneering was preceded by an oxidation firing, in this case at 800°C, before application of the porcelain (Noritake® Super Porcelain Ti-22; Noritake Co Ltd, Nagoya, Japan) to the titanium specimen. Porcelain veneering of traditional porcelain-fused-to-metal (PFM) alloys and ceramics follows this procedure. In the bonding agent group, no oxidation firing was done. Instead, a glass-containing bonding agent was applied to the titanium before application of the porcelain (Triceram® triline Ti; Esprident GmbH, Ispringen, Germany). The idea is that the bonding agent reduces oxide formation on the titanium surface.

Porcelain firing was done in an Austromat 3001 furnace (DEKEMA Dental-Keramiköfen GmbH,

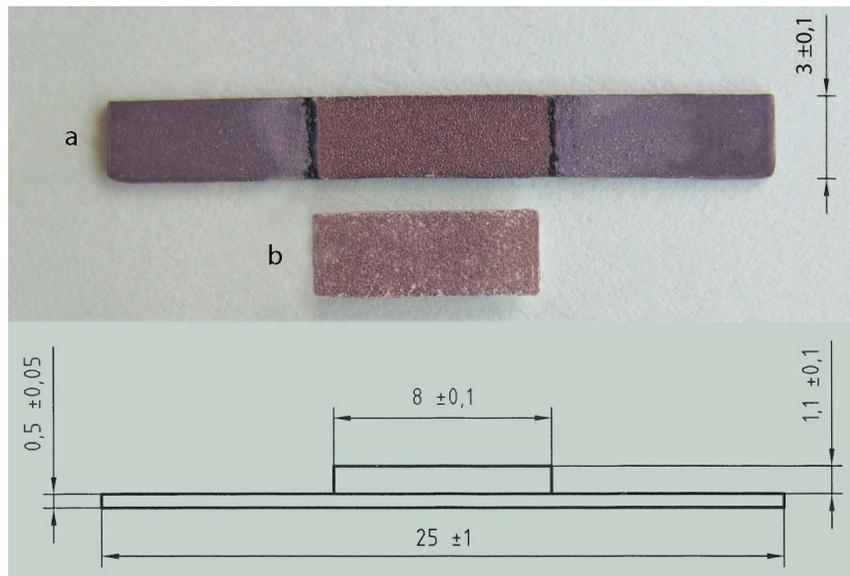
Freilassing, Germany), which had been cleaned with Dentaurum® Carbon chips (DENTAURUM GmbH & Co. KG, Ispringen, Germany) and calibrated as per the manufacturer's instructions before firing. In both groups, the porcelain compound was applied to the titanium surface by aid of a plastic mould (8.0 x 3.0 x 1.1 mm). Twenty specimens in each group were fired according to the manufacturer's recommended firing schedule. The other 20 specimens in each group were fired according to the same schedule, but with a 30°C increase in the recommended firing temperature for dentine.

After firing, total sample thickness of the porcelain layer, including bonding agent, opaque and dentine compound, was 1.1 mm (± 0.1 mm), in accordance with ISO 9693: 1999 (Figures 1 and 2).

© **Figure 1.** Specimen for three point bending test.



© **Figure 2.** Specimen after fracture, showing both a) the titanium side and b) the porcelain side as also dimensions (mm) of the specimen.



Ageing

In each group (in the bonding agent and in the oxidation groups), 10 specimens fired per the manufacturer's recommendations and 10 fired at the elevated firing temperature (+30°C) were subjected to thermocycling (TC). TC comprised 5,000 1-min cycles. Each cycle comprised 30 s in a +5°C and 30 s in a +55°C water bath. The specimens that were not thermocycled (n = 40) were stored in room-tempered water for 3 d.

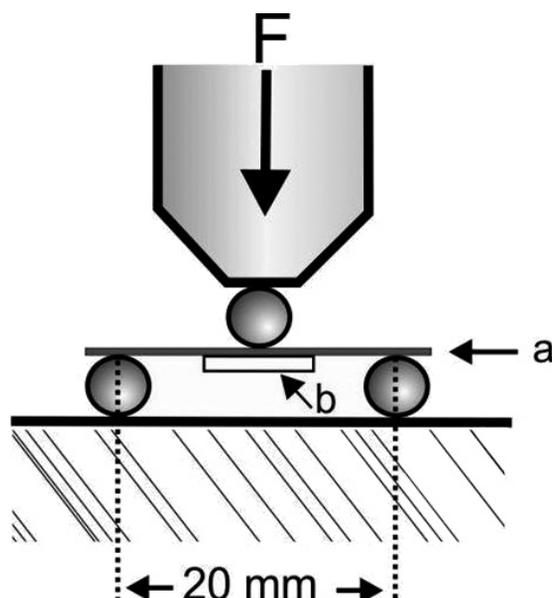
- Group 1 (n = 10): normal firing temperature, no TC
- Group 2 (n = 10): elevated firing temperature, no TC
- Group 3 (n = 10): normal firing temperature, TC
- Group 4 (n = 10): elevated firing temperature, TC

The total material, 80 specimens, thus comprised the bonding agent group and the oxidation group, each with four subgroups of 10 specimens each.

Three-point bending test

The bond strength between the titanium and porcelain was measured in a three-point bending test with an Instron universal test machine (Instron 4465, Instron Worldwide Headquarters, Norwood, MA, USA). Two bearers were placed 20 mm apart and a third bearer, 1 mm in diameter, was loaded at

© **Figure 3.** Schematic illustration of three point bending test. (F= load in Newton, a= titanium part of test specimen, b= porcelain part of test specimen).



the centre of the test body with a crosshead speed of 1.5 mm/min until the titanium-porcelain bond fractured and the porcelain could be removed from the titanium substrate (Figures 2 and 3).

The stress (MPa) that was needed to break the bond was calculated as per ISO 9693:1999 (10)

$$\tau_b = k \cdot F_{\text{fail}}$$

where τ_b is the bond strength in MPa; k is a function of the thickness of the test body, 0.5 mm, and Young's modulus (10), which is 108 GPa for titanium (5), and F_{fail} is the fracture load in Newton.

The standard ISO 9693:1999 (10) prescribes the usage of six samples where four of them must attain a flexure bending strength of 25 MPa, but 10 samples were used in order to establish a more confident statistical evaluation.

Student's t-test determined whether the differences between the oxidation and the bonding agent groups and between their subgroups were statistically significant.

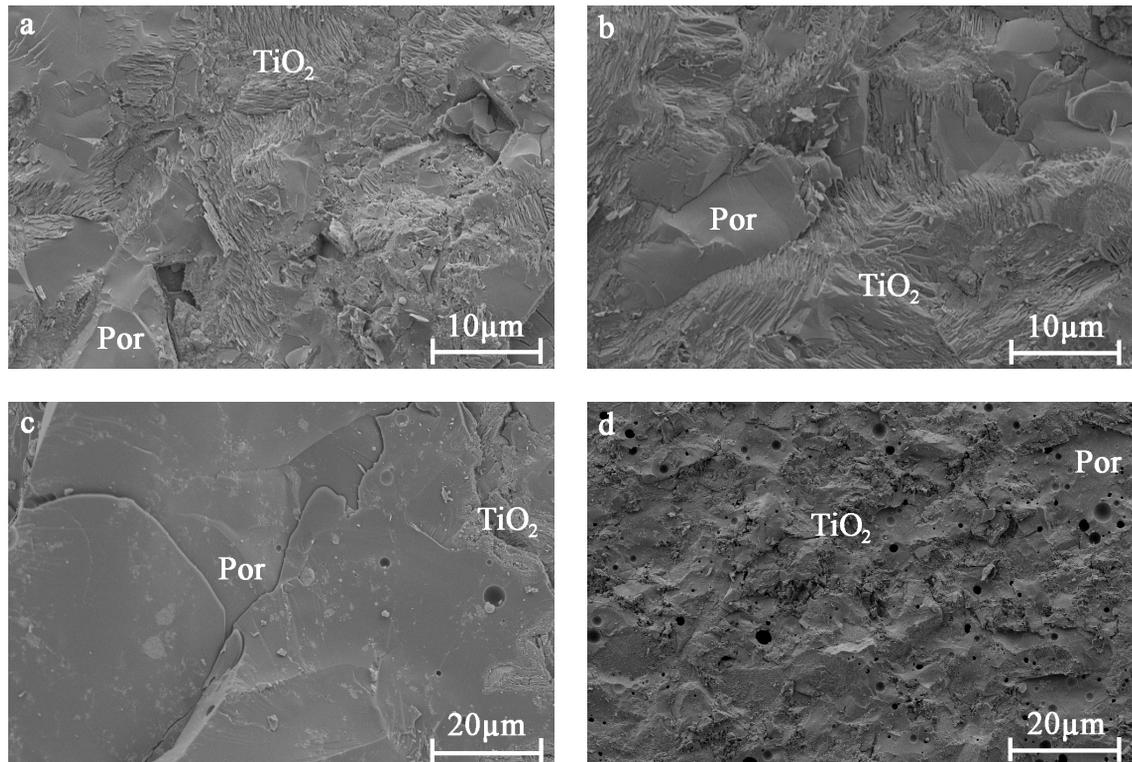
SEM and EDS analysis

Following separation from the substrate, one porcelain and one titanium specimen from each of the eight subgroups was analysed with a scanning electron microscope (SEM) and energy dispersive X-ray spectroscopy (EDS) for visualization and determination of the chemical composition of the fractured surfaces. Both sides of each specimen were analysed, the porcelain surface that had been bonded to the titanium (n = 8 total) and the debonded titanium surface (n = 8 total). The SEM analysis was performed using a Leo Ultra 55 FEG high resolution SEM, operating at an acceleration voltage of 5–10 kV equipped with an Oxford Inca EDS system. The combination of SEM and EDS is used for material determinations.

Results

The three-point bending test caused fractures in the titanium-porcelain bond, which left macroscopic oxide-layer residue on each of the fractured surfaces (Figure 2). The bond strengths of 79 of the 80 specimens achieved acceptable ISO 9693 bond strengths (i.e. ≥ 25 MPa). Table 2 presents the average bond strength in the two groups and their subgroups (Group 1-4), as a whole. Three of the subgroups that had been oxidized before veneering had significantly higher bond strength than the corresponding subgroups that had been fired with a bonding agent. The two not thermo cycled subgroups with elevated temperature did not differ significantly.

© **Figure 4.** SEM-images illustrating fracture pattern after firing including oxidation firing (a) and (b) and after firing with bonding agent (c and d). (a) and (c) are images of the titanium fracture surface of the specimen while (b) and (d) show the porcelain fracture surface. (a) and (b) illustrate fracture in the oxide layer and (c) and (d) in the interface, respectively. (TiO: titanium oxide and Por: porcelain).



© **Table 2.** Results (mean \pm standard deviation as well as ([max min/ values]) and the result of the statistical analyses of the three-point bending test of bond strength (MPa) of the different concepts for firing titanium-porcelain. (Group 1 = prepared according to the manufacturer's recommendations, Group 2 = prepared according to the manufacturer's recommendations but with the dentine firing temperature increased 30°C, Group 3 = Prepared according to the manufacturer's recommendations and thermo cycling, and Group 4 = Prepared according to the manufacturer's recommendations but with the dentine firing temperature increased 30°C and thermo cycling).

Group	Oxidation firing	P	Firing with Bonding Agent
1	40,8 \pm 1,8 [max 43,2 / min 37,3]	P < 0,001	36,4 \pm 3,4 [max 40,9 / min 20,7]
2	38,5 \pm 4,0 [max 43,2 / min 33,6]	P > 0,05	36,5 \pm 3,4 [max 39,6 / min 32,7]
3	43,5 \pm 3,5 [max 47,4 / min 37,3]	P < 0,001	34,8 \pm 3,3 [max 39,1 / min 28,1]
4	41,6 \pm 1,5 [max 44,6 / min 32,2]	0,01 < P < 0,001	38,3 \pm 4,6 [max 45,1 / min 32,2]
Total	40,3 \pm 3,3	P < 0,001	36,2 \pm 4,2

The subgroups within each veneering method group were also compared with each other; only bond strengths in the oxidation subgroups differed significantly, and of these, the higher bond strength was found in the subgroups that had undergone thermo cycling. The bond strength in the bonding agent subgroups did not differ significantly, but higher bond strength, though not significant, could be observed in the subgroups with elevated firing temperature.

SEM images of fractured surfaces are illustrated by Figure 4 a-d, and are demonstrating that in the oxidation group titanium oxide is present on the porcelain part of the specimen indicating a fracture in the thickened oxide layer, while in the bonding agent group the fracture has occurred in the integrated interface, as judged from the amount of remaining elements.

The EDS analysis also demonstrates a higher amount of titanium oxide on the porcelain fracture

surface in the oxidation group, confirming the findings from the SEM picture.

Porcelain components (Si, Al) were found on the titanium fracture surfaces of both specimens (both in the oxidation and the bonding agent groups), but with a higher percentage in the bonding agent sub-groups (Figure 5 a,b).

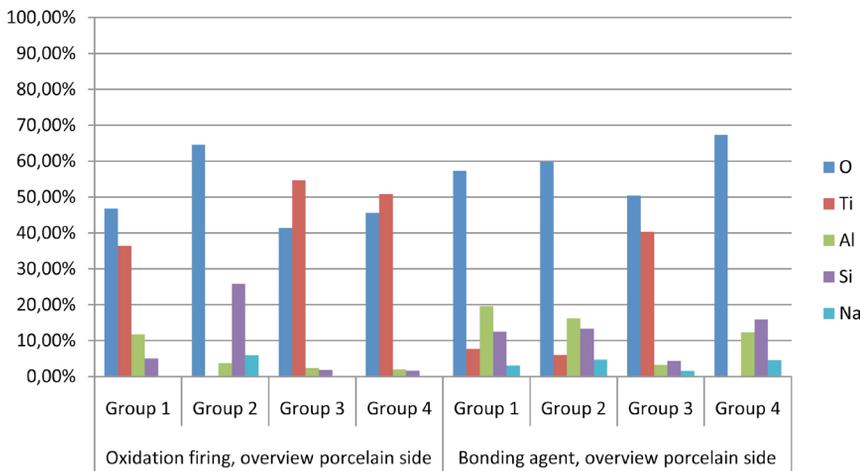
Discussion

Firing of porcelain at the highest possible temperature improves transparency and strength (7), but in the case of titanium, higher firing temperatures approach titanium’s critical oxidation level (1, 11). Thus, it was considered justifiable to test the hypothesis whether oxidizing the titanium surface before applying the porcelain would increase the brittleness of the interface at a higher firing temperature or after thermo cycling.

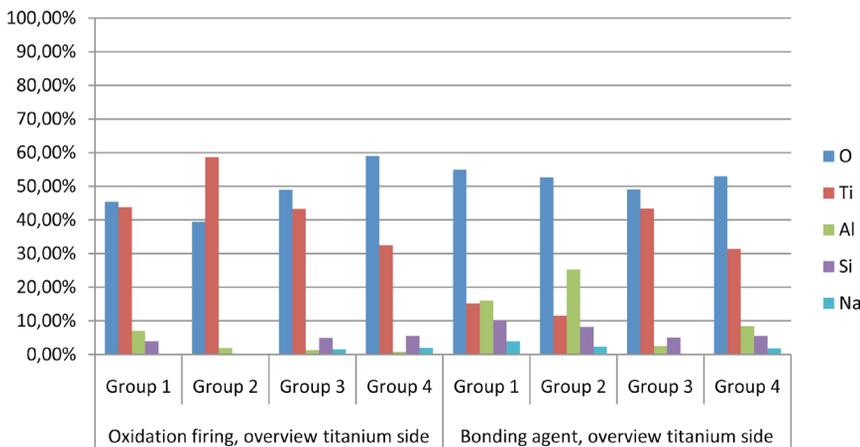
De-bonding between titanium and porcelain in prosthetic restorations has been observed clinically and documented in the literature (4). Porcelain fractures in general have serious consequences for the patient. Consequently, it is important to find a way to minimize such risks of material failure.

Three-point bending is frequently used to determine the bond strength between porcelain and metal (10). To meet ISO 9693:1999 standards, the bonding strength of 4 or more specimens in a sample of 6 must meet or exceed 25 MPa. In the present study, all but one of the eighty specimens tested exceeded this value, so the samples fulfilled ISO requirements. Titanium porcelain is fired at a lower temperature than many furnaces are calibrated for (9), so one cause of titanium-ceramic complications could be firing at an incorrect temperature. This study has shown that firing at 30°C above the recommended

© Figure 5a. EDX analysis of fractured specimen, porcelain side



© Figure 5b. EDX analysis of fractured specimen, titanium side



firing temperature does not affect bond strength, although the oxide layer on the titanium surface may be thicker than at recommended firing temperatures. Inaccurately calibrated furnaces (9) may also cause firing at lower temperatures than recommended, which is always a source of error independent of the type of porcelain used. Such under-firing causes a milky appearance of the fired porcelain and a risk of cohesive fractures in the porcelain (7). Underfiring is therefore more easily detected than firing at too high of a temperature.

Thermocycling could be considered a form of artificial ageing (14) because the difference in the thermal expansion coefficients of porcelain and metal, although small, creates concentrations of strain in the interface between the two materials (6, 7). The three-point bending test was unable to verify this hypothesis. Neither could the risks of an oxidation process at veneering be documented since bond strengths were higher in the oxidation group, the group that underwent oxidation before veneering, than in the bonding agent group, in which the specimens were not fired with an oxidation step in the veneering process. Elevating the firing temperature sooner seemed to enhance bond strength; bond strengths in the oxidation subgroups with elevated firing temperature (TC and no TC) differed nonsignificantly from bond strengths in the bonding agent subgroups with elevated firing temperature, but bond strengths in the groups with normal firing temperature, 1 and 3, (TC and no TC) differed more widely between the oxidation and bonding agent groups. Thus, a 30°C increase in firing temperature caused no significant differences in bond strength in either veneering preparation group, and possibly improved the bond strength in the bonding agent group.

An interesting finding is that aged oxidized specimens showed a significant increase in bond strength. This finding might indicate that the stronger bond strength that was achieved at the higher firing temperature will better withstand the strain induced by thermo cycling than the bond created when fired at the recommended firing temperature. This finding has to be further explored before any valid conclusions can be drawn. *Pröbster et al* (19) and the present study found that bond strength determined according to the ISO test differs significantly between porcelain brands, even when recommended firing temperatures are used. We found the bond strength when firing with oxidation process (800°C) to be significantly higher than when firing with a bon-

ding agent in the case when recommended firing temperature was used. According to other studies, high temperatures up to 800°C result in lower bond strengths because of the greater thickness of the oxide layer compared to when firing at lower temperatures (1, 19) which could not be verified in this study.

EDS analysis of the specimens (Figure 4a-d) might indicate how the amount of titanium oxide on the porcelain fracture surface of the samples tells where the fracture occurs. A higher amount of titanium oxide present on the porcelain fracture surface indicates that the fracture has occurred in the oxide layer. Since the oxide layer created in the firing process is inherent and brittle (1, 11) these samples should logically show lower bond strength.

In the bonding agent groups, less titanium oxide remained on the porcelain side in all groups when compared with the oxidation groups, which indicates an integrated mixture between titanium oxide and porcelain components. Most of the oxidation fired specimens demonstrated higher levels of titanium oxide on the porcelain side, indicating a fracture between porcelain and oxide layers.

These observations are contradictory to the results from the three-point bending test, but the SEM and EDS analysis might more detailed illustrate what happens when the specimens are exposed to the strain of the test, and indicate that further analyses are required to fully elucidate these findings.

The fracture pattern therefore also raises the question whether the three-point bending test is the most relevant test method. Previous studies (12, 13) have demonstrated a change in the ductility of titanium when exposed for heat processing. Oxide firing at 800°C will therefore create less ductile titanium, and since the test method used induces de-bonding by deflection (21), the oxidation firing itself might alters the test situation in an uncontrolled direction. Persson and Bergman (18) questioned the relevance of the three-point bending test and suggested that the forces applied in the clinical situation are better reflected with a test method where the shear forces are applied in a more relevant way. In their study, the bond strength between titanium and ceramics was higher than when traditional porcelain-fused-to-metal alloy was veneered with porcelain. A more recent study (17), using a similar test procedure, supported the findings of Persson and Bergman (18).

Conclusion

- Raising the firing temperature 30°C above recommended did not affect bond strength, neither for

the system using an oxidation firing, nor for the system which was fired with a bonding agent.

- In a three-point bending test a veneering protocol of titanium porcelain, where an oxidation firing was included, resulted in a significantly higher bond strength than with a firing protocol including a bonding agent.
- Analysis of SEM/EDS showed the presence of a high amount of titanium oxide on the porcelain fracture surface of the oxidized specimens, indicating a fracture in the oxide layers, a fact which might limit the clinical relevance of the three-point bending test.

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Corresponding author:

Dr Per Haag
 Department of Prosthetic Dentistry, Faculty of Odontology
 Malmö University
 SE-20506 Malmö
 Sweden
 E-mail: per.haag@mah.se

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Pulp exposures in adults – choice of treatment among Swedish dentists

FREDRIK FRISK^{1,2}, THOMAS KVIST², SUSANNA AXELSSON³, GUNNAR BERGENHOLTZ², THOMAS DAVIDSON^{3,4}, INGEGERD MEJARE³, ANDERS NORLUND³, ARNE PETERSSON⁵, HANS SANDBERG⁶, SOFIA TRANÆUS³, MAGNUS HAKEBERG^{7,8}

Abstract

© This study comprises a survey of Swedish dentists' treatment preferences in cases of carious exposure of the dental pulp in adults. The survey was conducted as part of a comprehensive report on methods of diagnosis and treatment in endodontics, published in 2010 by the Swedish Council on Health Technology Assessment. A questionnaire was mailed to a random subsample of 2012 dental offices where one dentist at each office was requested to answer all questions. Each questionnaire contained one of three sets of questions about endodontic practice routines. Thus around one-third of the subsample received case-specific questions about treating carious exposure. Only general practitioners aged below 70 years were included. The final study sample comprised 412 participants. The dentists were presented with two case scenarios. In Case 1 a 22-year old patient had a deep carious lesion in tooth 36 and in Case 2 a 50-year old patient had a deep carious lesion in tooth 14. The participants were asked to nominate their treatment of choice: pulp capping, partial pulpotomy or pulpectomy. For Case 1, 17 per cent of the respondents selected pulpectomy; the corresponding rate for Case 2 was 47 per cent. Female gender and age group 25-49 years were predictive of selection of less invasive treatment options. However, according to recent guidelines (2011) from the National Board of Health and Welfare, Swedish dentists are recommended to elect pulpectomy prior to pulp capping/partial pulpotomy when confronted with a tooth having a cariously exposed pulp in adults.

Key words

Endodontics, partial pulpotomy, practice guidelines, pulpectomy, pulp capping

¹ The Institute for Postgraduate Dental Education, Jönköping, Sweden

² Department of Endodontology, Institute of Odontology at the Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden

³ SBU (Swedish Council on Health Technology Assessment), Stockholm, Sweden

⁴ Center for Medical Technology Assessment, Linköping University, Linköping, Sweden

⁵ Department of Oral and Maxillofacial Radiology, Faculty of Odontology, Malmö University, Malmö, Sweden.

⁶ Karolinska Institutet, Stockholm, Sweden

⁷ Department of Behavioral and Community Dentistry, Institute of Odontology at the Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden

⁸ Public Dental Service, Region Västra Götaland, Sweden

Pulpablottor hos vuxna – val av behandling hos svenska tandläkare

FREDRIK FRISK, THOMAS KVIST, SUSANNA AXELSSON, GUNNAR BERGENHOLTZ, THOMAS DAVIDSON, INGEGERD MEJARE, ANDERS NORLUND, ARNE PETERSSON, HANS SANDBERG, SOFIA TRANÆUS, MAGNUS HAKEBERG

Sammanfattning

⊙ I samband med arbetet med SBU-rapporten "Rotfyllning" gjordes 2009 en praxisundersökning bland svenska tandläkare avseende deras val av metoder och material vid olika endodontiska kliniska situationer. Ett slumpmässigt urval av svenska tandläkarmottagningar (N=2012) delades in i tre grupper. Tre olika frågeformulär med delvis olika frågeställningar skickades ut till de tre grupperna av tandläkarmottagningar. En tandläkare vid varje mottagning besvarade frågorna. Bakgrundsinformation samlades om ålder, erfarenhet, kön, privat- eller offentlig verksamhet och vilken typ av tandvård man var verksam inom. Svarefrekvensen var 80.1%.

Syftet med den del av undersökningen som presenteras här var att undersöka behandlingsvalet i fall av pulpablotta efter exkavering av djup karies. I denna studie inkluderades allmänpraktiserande tandläkare vars ålder understeg 70 år. Detta resulterade i ett urval på 412 tandläkare som tog ställning till hur man skulle behandla pulpaläsioner i två olika fall. I fall 1 hade en 22-årig patient en djup kariesskada i tanden 36 och i fall 2 hade en 50-årig patient en djup kariesskada i tanden 14. Behandlingsvalen utgjordes av överkappning, partiell pulpotomi och pulpektomi. I fall 1 valde 17% av tandläkarna pulpektomi och motsvarande resultat i fall 2 var 47%. Skillnaden var statistiskt signifikant. Analysen visade vidare att kvinnliga tandläkare och tandläkare i åldersgruppen 25-49 år oftare valde överkappning och partiell pulpotomi än manliga tandläkare och tandläkare i åldersgruppen 50-69 år.

Socialstyrelsens nationella riktlinjer rekommenderar svenska tandläkare att välja pulpektomi framför pulpaöverkappning/partiell pulpotomi. Resultaten visar att de tandläkare som deltagit i studien tenderar att oftare välja pulpaöverkappning/partiell pulpotomi..

Introduction

During excavation of deep caries, exposure of the pulp is not uncommon. The clinician then has two treatment options. If the pulp is deemed to be reversibly inflamed, pulp capping or partial pulpotomy may be considered. Such a procedure is relatively uncomplicated: the exposure is covered with a wound dressing prior to restoration. If the inflammation is assessed as irreversible, the alternative is pulpectomy. This procedure is more invasive and time consuming as it involves complete removal of the pulp and a root filling. In both instances the aim of treatment is to achieve healthy, non-symptomatic conditions. Hence, in the case of pulp capping/partial pulpotomy the objective is the maintenance of a functional, vital pulp, while successful pulpectomy requires the absence of apical periodontitis at follow-up. Treatment of a carious exposure has been the subject of debate since the dawn of modern dentistry, without consensus to this day. With respect to outcome, the report by The Swedish Council on Health Technology Assessment (26) along with a recently published systematic review (1) both concluded that there is a lack of adequate scientific evidence to give preferential support to either treatment approach.

The present study was undertaken in order to investigate how Swedish dentists elect to treat carious exposure of the dental pulp. The investigation is based on a questionnaire associated with preparation of a comprehensive report on endodontic diagnosis and treatment published in 2010 by SBU (26).

Material and method

In 2009, 2012 dental offices were randomly selected from the population of dental offices in Sweden, using a register of addresses from PAR (the Swedish register of postal addresses; PAR AB, Stockholm, Sweden). The selection was weighted so that half of the participants were dental offices from the major urban areas Malmö, Gothenburg or Stockholm. They were divided into three groups. Each group of dental offices was sent a questionnaire with specific but different questions (A, B or C). One dentist at each office was requested to answer all questions. The overall participation rate was 80.1 per cent, resulting in 546 participants in group A, 542 in B and 524 in group C.

Questions about age, gender, workplace (public or private clinic), geographical region, experience (expressed as number of years in practice) and type of dentistry were common to all questionnaires. Each questionnaire had specific sets of questions about

the method and materials the participants would routinely use in a given clinical situation.

The present study concerned only data from questionnaire A, on choice of therapy in case of carious exposure of the pulp. In two clinical cases of deep carious lesions leading to pulpal exposure, the participants were asked whether they would choose pulp capping, partial pulpotomy or pulpectomy. In order to eliminate the subjective interpretation of radiographs, written case histories and drawings of simulated radiographs were constructed. Three factors varied between the cases. In Case 1, patient age was stated to be 22 years and in Case 2, 50 years. Case 1 was a lower molar tooth (36) and Case 2 an upper premolar (14). In Case 1 the carious lesion involved only the mesial portion of the tooth, while in Case 2 the lesion was more extensive (Fig. 1).

Excluded from the study were dentists aged 70 or older, those not practising clinical dentistry, specialists in any field of dentistry and dentists whose practice did not include endodontic treatment. Also excluded were those who failed to respond to the two questions about cases 1 and 2. This resulted in a final study sample of 412 respondents from the initial sample of 546. The dependent variable was type of treatment (pulp capping, partial pulpotomy and pulpectomy). Independent variables were gender, public/private practice, age (20-49 vs. 50-69), years of practice (1-25 vs. >25).

Statistical method

Comparisons between cases were made with the χ^2 -test. Multinomial logistic regression was applied to analysis of factors underlying choice of therapy in each case. A 95% confidence interval was used and the significance level applied was $p < 0.05$.

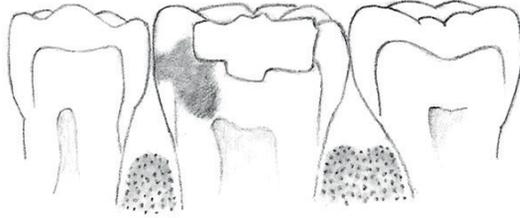
Results

The respondents were predominantly male (61.5 per cent), private practitioners (64.3 per cent), with a minority employed in public dental clinics. The age distribution was skewed; only 8.4 per cent of the participants were under 50 years of age. Accordingly, the number of years in practice was also skewed, with only 15.9 per cent reporting work experience of less than 25 years.

Pulp capping was the most frequent treatment decision for Case 1, selected by 272 (66 per cent) of respondents. In Case 2, pulp capping was proposed by 169 (41 per cent) of respondents. Pulpectomy was selected by 72 (17 per cent) and by 194 (47 per cent) in Case 1 and 2 respectively (Table 1). Only a minori-

© **Figure 1.** Case histories and illustrations for cases 1 and 2.

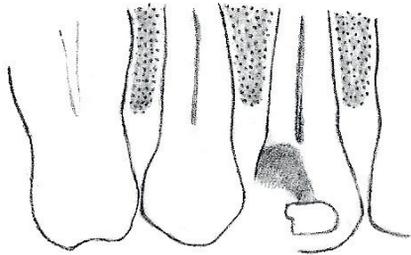
Case 1. During routine examination of a 22-year-old patient you find that 36 has a deep carious lesion (see illustration). The patient has no symptoms and a periapical radiograph shows no pathological changes. While excavating caries from 36 you expose the pulp. The pulp is vital and you consider it to be bleeding normally. **How would you treat this tooth?**



Treatment alternatives

- Partial pulpotomy (according to Cvek)
- Pulp capping
- Pulpectomy (extirpation)
- Other option

Case 2. During routine examination of a 50-year-old patient you find that 14 has a deep carious lesion (see illustration). The patient has no symptoms and a periapical radiograph shows no pathological changes. While excavating caries from 14 you expose the pulp. The pulp is vital and you consider it to be bleeding normally. **How would you treat this tooth?**



Treatment alternatives

- Partial pulpotomy (according to Cvek)
- Pulp capping
- Pulpectomy (extirpation)
- Other option

Illustrations: Michaela Mejäre

© **Table 1.** Choice of treatment in cases 1 and 2, respectively. Frequency distribution in absolute numbers.

	Pulpcapping case 1	Partial pulpotomy case 1	Pulpectomy case 1	Other option case 1	Sum
Pulpcapping case 2	158	7	3	1	169
Partial pulpotomy case 2	7	19	2	0	28
Pulpectomy case 2	101	26	67	0	194
Other option case 2	6	4	0	11	21
Sum	272	56	72	12	412

ty of respondents selected partial pulpotomy as their preferred treatment in the two cases.

Comparison of choice of therapy in the two cases disclosed a statistically non-significant difference for pulp capping vs. partial pulpotomy ($\chi^2=0.75$; $p=0.46$). However, there were significant differences for pulp capping vs. pulpectomy ($\chi^2=79.6$; $p<0.001$) and partial pulpotomy vs. pulpectomy ($\chi^2=41.2$; $p<0.001$). Ninety-three per cent of the respondents who chose pulpectomy in Case 1 ($n=72$) also chose pulpectomy in Case 2. Of those who chose pulp capping in Case 1 ($n=272$), 58 per cent also did so in Case 2, and of those who chose partial pulpotomy in Case 1, 34 per cent did so in Case 2 as well (Table 1).

Multinomial logistic regression analyses were undertaken, using the chosen treatment option, i.e. partial pulpotomy, pulp capping and pulpectomy, as the dependent variable and age, gender, employment, and years of professional experience as a dentist as independent variables. Due to the risk of collinearity between age and years of experience, only age was included in the models.

The results showed that for Case 1, the only statistically significant predictor for choice of treatment between partial pulpotomy and pulpectomy was age group, with an OR of 3.73 (CI 1.09-12.75; $p=0.036$), (Table 2).

For Case 2, dentists in the younger age group were more likely to prefer partial pulpotomy to pulpectomy, with an OR of 2.99 (CI 1.02-8.82; $p=0.047$). Gender was statistically predictive for direct pulp capping versus pulpectomy: female dentists were more likely to choose direct pulp capping, with an OR of 1.69 (CI 1.07-2.67; $p=0.023$), (Table 3).

The analyses indicated that younger dentists and female dentists are likely to choose the less inva-

sive endodontic treatment options pulp capping and partial pulpotomy. However, in Case 1, female gender was not statistically significant in the model, even though the OR:s had a similar tendency (OR=1.55) towards direct pulp capping.

Discussion

This survey was undertaken in order to disclose current decision-making patterns among Swedish dentists with respect to some specific endodontic conditions. Such surveys are important for determining current clinical routines. Follow-up surveys can disclose changes in such routines, e.g. in response to educational development, progress in clinical research and the adoption of new technology. When SBU undertakes systematic reviews of different health technologies, surveys of current practice are included in the assignment.

The study revealed that for the majority of the respondents, the treatment of choice in the two cases of carious exposure of an asymptomatic tooth in an adult patient was direct pulp capping or partial pulpotomy, in preference to pulpectomy. Decisions seemed to be influenced by both the gender and age of the clinician. The analyses further disclosed that male dentists and dentists over 50 years of age did not favour the less invasive treatment to the same extent as female dentists and dentists under 50 years of age.

A majority of the respondents reported to work in private practice. This is probably a result of the selection of dental offices rather than dentists and may also explain the skewed distribution with regard to age and gender (22). Thus, the results should be interpreted with caution. It should also be acknowledged that the case simulation design of the survey

© **Table 2.** A multinomial logistic regression model for Case 1 with the dependent variable treatments partial pulpectomy, direct pulp capping and pulpectomy (Odds Ratio and 95% confidence interval).

Reference category: Pulpectomy vs Partial pulpectomy	OR	95% CI	p-value
Gender	1.37	0.62-3.03	0.431
Employment	1.53	0.71-3.30	0.282
Age	3.73	1.09-12.75	0.036
Direct pulp capping			
Gender	1.55	0.86-2.81	0.145
Employment	1.12	0.62-2.00	0.712
Age	1.65	0.55-4.97	0.369

© **Table 3.** A multinomial logistic regression model for Case 2 with the dependent variable treatments partial pulpectomy, direct pulp capping and pulpectomy (Odds Ratio and 95% confidence interval).

Reference category: Pulpectomy vs Partial pulpectomy	OR	95% CI	p-value
Gender	1.20	0.50-2.90	0.683
Employment	1.57	0.67-3.69	0.299
Age	2.99	1.06-8.82	0.047
Direct pulp capping			
Gender	1.69	1.07-2.67	0.023
Employment	1.42	0.90-2.24	0.132
Age	1.26	0.61-2.63	0.530

simplifies the decision-making task (14). Under true clinical conditions, the decision-making process is likely to be influenced by additional factors. Such factors may be disclosed by qualitative research (16). Also, the prerequisites given in cases 1 and 2 (Fig 1), may have biased the respondents. Normal bleeding is generally considered as a sign of a reversible inflammation and may have influenced the respondents to decide in favour of pulp capping or partial pulpotomy.

Pulp capping or partial pulpotomy was significantly more frequently chosen in Case 1 than in Case 2. This may be linked to the difference in age between the two patients (22 vs. 50 years of age). Several authors (8, 13, 29) have argued that pulp capping and partial pulpotomy are indicated in young patients because of the superior healing capacity of the young dental pulp. However, to date there is no firm evidence from clinical studies to support this claim. The type of tooth may also contribute to the difference, given that there may be a common conception among general dental practitioners that endodontic treatment is more difficult in molars than in premolars. Moreover, the fact that in Case 2 there was a potentially greater need for more extensive restoration may also have contributed to the difference in treatment approach.

Recent guidelines issued by the National Board of Health and Welfare (23) recommend that in cases of carious exposure in adults, Swedish dentists should undertake pulpectomy in preference to pulp capping/partial pulpotomy. The responses to the questionnaire suggest that in routine practice, the respondents frequently prefer pulp capping/partial pulpotomy (Case 1). This may be due to lack of conclusive evidence regarding the outcome of direct pulp capping or partial pulpotomy in adult individuals. Bjørndal et al. (6), in a randomized clinical trial, recently reported a poor 1 year outcome following direct pulp capping or partial pulpotomy (31.8 and 34.5 per cent respectively maintained vitality). In a retrospective study (13), the survival rate declined over time; it was 82 per cent after 5 years and had declined further after 10 years. The survival rate was significantly lower in patients aged 50-79 than in those aged 10-29 years. Mente et al (21), in a retrospective study reported results in favour of MTA (78% survival) in comparison to calcium hydroxide (60% survival). They identified treatment provider (dentist/supervised student), capping material and time span between capping and placement of a permanent restoration to be predictive of pulp survival.

Aguilar & Linsuwanont (1), in a systematic review, concluded that vital pulp therapy should be considered as an alternative to pulpectomy in teeth with carious exposures. They highlighted the lack of evidence supporting age and status of the root apex as predictors of treatment outcome. The SBU report (26) found conflicting results for healing rates after direct pulp capping. Thus, dentists are left to rely on their own judgment and experience and may then be more sensitive to factors such as costs and potentially complicated treatment.

An interesting finding in this survey was that male dentists chose pulpectomy significantly more often than female dentists (Case 2). In recent years there has been increasing interest in the impact of gender on clinical decision-making (19, 7, 11, 4). With respect to the dental profession, the gender of the decision-maker has been disclosed as a significant independent variable (10, 9, 17, 18, 3, 2, 5, 30, 24). In the present survey, female dentists tended to prefer less invasive treatment options (i.e. pulp capping) significantly more frequently than their male colleagues (Case 2). This finding is in accordance with reports that Swedish female dentists are less prone than their male colleagues to recommend both fixed and removable prosthodontics (10, 18), suggesting that female dentists are more conservative in their choice of treatment. Another possible explanation is that like their Danish colleagues, Swedish female dentists have a significantly lower self-estimated level of skill than male practitioners with respect to mechanical root canal preparation and root filling procedures (5). A similar mechanism could possibly explain the finding that the group of younger dentists, compared to older and probably more experienced colleagues, prefer the less complex procedure involved in pulp capping or partial pulpotomy than the sometimes demanding and time-consuming pulpectomy procedure.

It may also be assumed that in the absence of strong scientific evidence, except for a tendency to choose the least invasive and inexpensive alternative, heuristic reasoning plays an essential role in the decision-making process (15, 25,12). The judgemental heuristic principle, referred to as availability, defines the phenomenon whereby people assess the frequency of a class or the probability of an event by the ease with which instances or occurrences can be brought to mind. In this study it may be assumed that if a dentist answering the questionnaire had recently experienced failure of pulp capping, with resultant intensely painful symptoms for the pa-

tient (6) he or she would have a tendency to prefer pulpectomy. In particular, this is to be expected if the case or cases in the questionnaire, in any aspect, resemble the recently failed procedure. Thus, the heuristic principle of representativeness may also be present in the individual dentist's treatment decisions (15). The same type of reasoning, but with the opposite tendency in their answers, may be true for dentists with recent experience of positive outcomes of treatment of pulp exposures by pulp capping or partial pulpotomy. Moreover, the participants' decisions may also reflect their individually perceived rates of success and failure following partial pulpotomy, pulp capping and pulpectomy.

In conclusion, this study indicates that therapeutic decisions of the respondents regarding cariously exposed pulps in adult patients may not be in accordance with the guidelines of the Swedish Board of Health and Welfare (23). The SBU report (26) highlighted the need for further research into a central, unresolved issue in clinical dentistry, namely whether carious exposure of the dental pulp is best treated by measures intended to preserve the pulp, or by pulpectomy and root filling.

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Corresponding author:
 Dr Fredrik Frisk
 Department of Periodontology/Endodontology
 The Institute for Postgraduate Education
 Box 1030
 SE-551 11 Jönköping, Sweden
 E-mail: fredrik.frisk.lj.se

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