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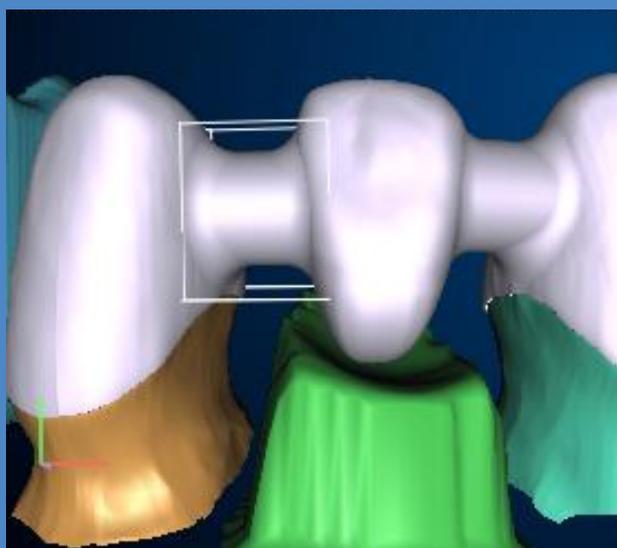
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# Oral infections and their influence on medical rehabilitation in kidney transplant patients

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MAGNUS HAKEBERG<sup>5</sup>, JOHN BRATEL<sup>3</sup>

## Abstract

© Infections seem to be the most common life-threatening complication of long-term immunosuppressive therapy following organ transplantation. Although sparse scientific evidence, potential oral infections are considered to contribute to these complications.

The aim of this study was to examine whether there is an association between oral infections and rejections after kidney transplantation.

A group of 46 kidney transplant candidates was enrolled. The patients were examined clinically and radiographically for dental caries, periodontal disease, mucosal lesions/infections, and general oral health problems. Examinations were conducted the day before transplantation, and one year post transplantation.

Fifteen (32.6%) patients developed acute rejections during the first year. Six of these patients (40%) presented with oral opportunistic infections (candida or herpes infections of the oral mucosa). The number of dental infections and semi-impacted teeth were low. When rejections were related to probing pocket depths (PPDs)  $\geq 4$  mm and apical lesions together, statistical significance was not reached ( $p=0.075$ ,  $OR=3.17$  [0.87;11.55]). Similar results were obtained when PPDs  $\geq 4$  mm, apical lesions, semi-impacted teeth, and opportunistic mucosal infections were compared to rejections.

The results of the present study do not support that opportunistic oral mucosal infections or dental-related infections seem to increase the risk of rejection in kidney transplanted patients.

## Key words

*Candida, mucosal lesions, periodontal disease, immune-suppression*

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## Orala infektioner och deras påverkan på medicinsk rehabilitering av njurtranplanterade

KERSTIN SCHANDER, MATS JONTELL, PETER JOHANSSON, GUNNELA NORDÉN, MAGNUS HAKEBERG, JOHN BRATEL

### Sammanfattning

☉ Infektioner tycks vara den vanligaste orsaken till livshotande komplikationer vid långtidsimmunosuppressivbehandling efter organtranplantation. Trots sparsam vetenskaplig evidens, så anser man att orala infektioner bidrar till den typen av komplikationer.

Målet med den här studien var att undersöka om det finns ett samband mellan orala infektioner och rejektioner efter njurtranplantation.

Materialet bestod av 46 njurtranplantationspatienter. Patienterna undersöktes kliniskt och röntgenologiskt för karies, parodontit, infektioner/lesioner i orala mukosan, och generalla hälsoproblem. Undersökningarna gjordes dagen innan transplantation, och ett år efter transplantationen.

Femton (32.6 %) av patienterna utvecklade akuta rejektioner under första året. Sex av de patienterna (40 %) hade orala opportunistiska infektioner (Candida- eller herpesinfektioner i orala mukosan). Antalet dentala infektioner och semi-retinerade tänder var lågt. När rejektion relaterades till fickdjup (PPDs)  $\geq 4$  mm och apikala lesioner tillsammans nåddes ingen statistisk signifikans ( $p=0.075$ ,  $OR=3.17$  [0.87;11.55]). Resultatet när PPDs  $\geq 4$  mm, apikala lesioner, semiretinerade tänder och opportunistiska infektioner jämfördes med rejektioner erhöles heller ingen signifikans.

Resultaten från studien ger inte stöd för att opportunistiska orala infektioner eller dentala infektioner ökar risken för rejektion hos njurtransplanterade.

## Introduction

Oral infections and their implication on the medical rehabilitation following solid organ transplantation have been discussed ever since the introduction of this treatment modality. In lack of guidelines based on scientific studies, a number of clinical protocols from different transplantation centers have emerged (8, 9). Although there is meager scientific evidence for dental disease as a source of infectious complications after transplantation, most centers recommend preoperative assessment of dental foci and their subsequent eradication (9, 6, 19, 26, 21).

The reason why potential oral infections have been in focus for many years is probably that infectious complications in general continue to be an important cause of post-transplant morbidity and a leading cause of death of renal allograft recipients (22, 18). Bacterial infections are frequently encountered in renal transplant recipients, most of which emanate from the urinary tract and pulmonary tissues. However, most reviews that have dealt with the infectious complication in organ transplanted recipients do not cite dental infections as the source of infection (22, 18, 3, 7, 13, 14, 15, 16, 17, 23, 24). The apparent lack of consensus on the necessity for a pre-transplantation dental evaluation also suggests that dental infections do not appear to be a major concern for the physicians and dentists who are involved with all aspects of organ transplantation. It may therefore be assumed that the few reported cases of oral infections with an impact on the prognosis following organ transplantation (6, 19, 16) reflect a relative rarity of these events rather than a failure to diagnose oral diseases as the source of the infection.

More comprehensive studies are warranted to investigate the consequence of potential oral infections in relation to medical rehabilitation of organ transplanted patients. The aim of this study was therefore to examine whether there is an association between oral infections and rejections after kidney transplantation.

## Materials and Methods

This study was a collaborative effort between the Clinic of Oral Medicine and the Transplant Centre, at the Sahlgrenska Academy, University of Gothenburg, Sweden. The study was designed as a prospective cohort study of donor transplant candidates at the Transplant Centre and the patients were consecutively included during a 2 yr period. The collected data are taken from the medical- and odontological charts and are according to the guidelines at that time. The study followed the Declaration of Helsinki.

Forty-six patients (17 women, 29 men, mean age of  $36 \pm 13$ , range 18-69 yr) were examined in a dental setting for oral mucosal infections/lesions, periodontal diseases, and semi-impacted teeth, the day before renal transplantation and 1-yr postoperatively. A radiographic evaluation was performed with an orthopantomogram at both examinations. The radiographs were used to identify teeth with apical periodontitis, impacted teeth and alveolar bone loss. Apical periodontitis was identified as asymptomatic periapical radiolucency with a loss of lamina dura. A semi-impacted tooth was clinically recognized as a partial penetration of the oral mucosa of the tooth crown. Pocket depth was recorded in mm at four sites per tooth (deepest site mesial, distal, buccal and lingual) with the aid of a color-coded (1 to 15 mm) periodontal probe. Measurements were rounded up to the next whole mm.

Acute pseudomembranous candidiasis was diagnosed as a widespread whitish slough covering the oral mucosa which could easily be removed by a blunt instrument leaving an erythematic area.

Herpes labialis was recognized as newly developed vesicle or crusts on the vermilion border. Intra oral herpes infection presented with multiple, yellow and slightly elevated lesion with a size of 2 to 4 mm in diameter. All diagnoses were established by an experienced clinician trained in oral medicine.

In case of any oral problems during the follow-up after the hospitalization period, the patients were informed to consult with the oral medicine expertise involved in the study. The patients were also asked at the 1-yr follow-up about any dental appointment or oral symptoms during the previous 12 months.

Acute rejection was diagnosed clinically as a rise of serum creatinine, which could not be explained by nephrotoxicity from immunosuppressive drugs or outflow obstruction, or, in a few patients, by transplant biopsy. Data regarding general health of the subjects and underlying disease causing renal failure were also recorded. These data and the number of rejections diagnosed throughout the study were gathered from the medical charts. All medications used before transplantation and at the 1-yr postoperative control were registered.

### Statistical analysis

Mean values and standard deviations were used to describe the patient sample. Frequency distributions were used to obtain an overview of the data. A chi-square test was used to determine if there was any significance between rejection and opportunistic in-

fections, oral lesions, pocket depths  $\geq 4$  mm, apical lesions, age, or gender. A logistic regression analysis was used to evaluate whether age, gender, pocket depth  $\geq 6$  mm or apical lesions, semi-impacted teeth or opportunistic infections had an impact on the risk for rejection. The chosen significance level was  $p < 0.05$  (odds ratio and 95 % confidence interval).

## Results

The causes of renal failure prior to transplantation are presented in Table 1. Before transplantation, 42 of the 46 patients medicated with one or more drugs for hypertension and/or cardiovascular disease. Following transplantation, all patients were given immune-suppressive medication such as azathioprine (Imurel®, Glaxo Smith Kline AB, Mölndal, Sweden) and/or ciclosporin (Sandimmun Neoral®, Novartis Sweden AB, Täby, Sweden) and/or steroids (Pred-

No periodontal or endodontic problems were reported or observed during the hospitalization period. At the follow-up, none of the patients reported to have seen their dentist for dental problems during the last 12 months. The radiographs did not indicate that any of the patients had received endodontic treatment or extractions during the observation time. In one patient, a periapical lesion had decreased in size. In two patients the pocket depth had increased without causing any symptoms. The rest of the patients had no changes with regards to periapical lesions and pocket depths compared to baseline. During the 12-months follow-up, there were no reports of acute pericoronitis related to the semi-impacted teeth.

Thirty percent ( $n=14$ ) of the patients experienced some form of opportunistic infection, i.e. oral candidiasis ( $n=8$ ), herpes labialis ( $n=4$ ) or intraoral

© **Table 1.** Causes of uremia

Diagnosis	Number of subjects
Chronic glomerulonephritis (CGN)	22
Chronic pyelonephritis (CPN)	7
Diabetic nephropathy	4
Polycystic kidney disease (PCK)	2
Hereditary nephropathy	2
Congenital malformation disease	2
Interstitial nephritis	1
Systemic amyloidosis	1
SLE nephritis	1
Renal vascular disease	1
Chronic renal failure, etiology uncertain	2
Other identified renal disorder	1
SUM	46

nisolon®, Pfizer AB, Sollentuna, Sweden), (Table 2). Fifteen (32.6%) patients experienced an acute rejection within the first year after transplantation. All episodes of rejection were successfully treated and there was no mortality.

At the primary examination, the day before transplantation, the patients had a mean (SD) of 26 (6) teeth, and none of the patients were edentulous. Fourteen patients had one or more of the observed periapical lesions, all in association with endodontically treated teeth. Twenty-five patients had pocket depths equal to or exceeding 4 mm and 9 of these patients had one or more pockets  $\geq 6$  mm (Table 3). Twelve of the 46 patients had semi-impacted teeth.

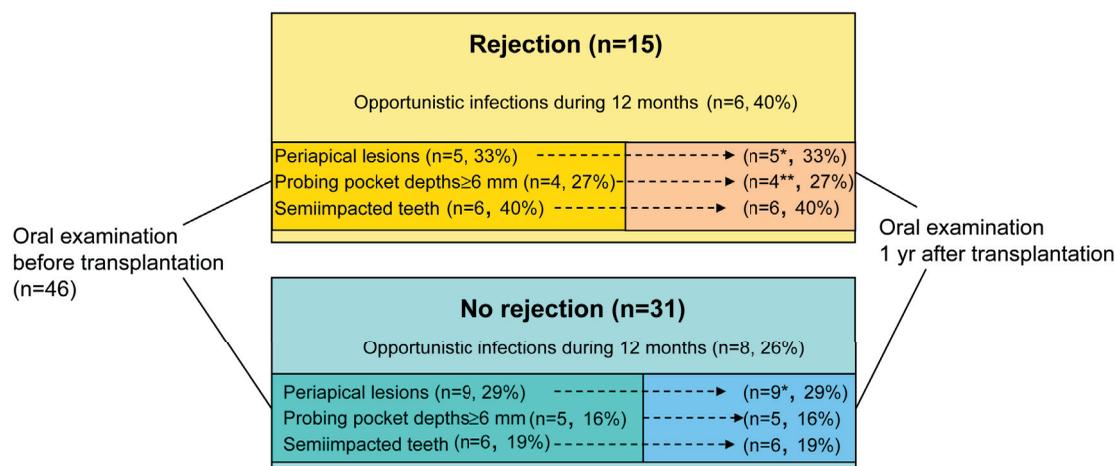
© **Table 2.** Medication before and after transplantation ( $n=46$ ).

Medication	Pre-transplantation	1yr follow up
Beta-blockers	19	9
Ca antagonists	27	30
ACE inhibitors	12	2
Diuretics	19	19
Corticosteroids	6	44
Other immunosuppressive drugs		
Sandimmun Neoral®, Imurel®	0	45

© **Table 3.** Apical and periodontal lesions in kidney transplant patients with acute rejections ( $n=15$ ).

Patients with rejections gender and age	Apical lesions		Pocket depths $\geq 4$ mm		Pocket depths $\geq 6$ mm	
	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
Male 29 yr	N	N	N	N	N	N
Male 48 yr	Y	Y	Y	Y	Y	Y
Male 57 yr	Y	N	N	N	N	N
Male 32 yr	N	N	N	N	N	N
Male 23 yr	N	N	N	N	N	N
Female 21 yr	N	N	N	N	N	N
Female 22 yr	N	N	N	N	N	N
Female 53 yr	N	Y	Y	Y	Y	Y
Male 25 yr	N	Y	Y	N	N	N
Male 31 yr	N	Y	Y	N	N	N
Male 60 yr	N	N	N	N	N	N
Male 60 yr	Y	Y	Y	N	N	N
Male 31 yr	N	N	N	N	Y	Y
Male 36 yr	N	N	N	N	N	N
Male 25 yr	N	N	N	N	Y	Y

© Figure 1.



\* One perapical lesion had decreased in size

\*\* The pocket depth had increased in two of the patients

herpes infection (n=2), during the first postoperative year. When opportunistic infections were correlated with rejections (n=15), no statistically significant difference was found between patients with or without oral mucosal infections (p= 0.09). Six of the 14 patients with opportunistic infections experienced rejection (Figure 1).

When rejections were compared to pockets depths only, there was a tendency towards a greater risk for rejection with pocket depths ≥ 6mm. However, no significant correlation was obtained for probing pocket depths (PPD) ≥ 6 mm (p= 0.10), OR= 3.75 (0.75; 15.15), and PPD ≥ 4 mm (p= 0.88), OR= 0.91 (0.25; 3.34), in relation to rejections. PPD ≥ 4 mm and apical lesions were combined and related to rejections, but no statistical significance was reached; p= 0.075, OR= 3.17 (0.87; 11.55). A similar result was obtained when multivariable logistic regression analysis was performed, including adjustment for age, gender, pocket depth ≥ 6 mm, apical lesions, semi-impacted teeth, and opportunistic infections.

**Discussion**

The present data show that oral opportunistic infections among renal transplant patients are rather frequent. However, these infections should be considered as a consequence of the increased immunosuppressive therapy during the different phases following transplantation. Thus, they do not play a role as a cause of rejections. In addition, dental status

including periodontal and apical conditions did not increase the risk for rejection. Although the study sample displayed a tendency towards a greater risk for rejection in patients with pocket depths ≥ 6mm and in patients where PPD ≥ 6 mm and PPD ≥ 4 mm had been compiled with periapical lesions, no statistical significance was reached. Hence, our results do no support that opportunistic infections or potential dental infections will put kidney transplanted patients at an increased risk. On the contrary, our findings were in agreement with previous observations made on patients with heart transplants (18). In this study, no statistically significant relationship was found between the survival and rejection rates with detected dental infectious foci. However, it should be emphasized that the small sample size and low statistical power in the present study increases the risk of type II error when evaluating the statistical inference testing.

Bacterial infections have been considered to increase the risk of rejection. Anderson (1) found that gram-negative bacteria were the most frequent cause of post-transplant septicemia, and that the oral cavity constitutes a potential source for these microorganisms. Gram-negative bacteria have also been associated with marginal and apical periodontal disease (20). Although no measures were taken to identify active dental infections in the present study, it does not lend support to the role of the oral cavity as a significant source of septicemia of gram-

negative bacteria. However, it should be emphasized that the twenty-four periapical radioluscencies found beneath endodontically treated teeth may only indicate healing processes. Radioluscencies of non-vital teeth, most likely demonstrate chronic apical periodontitis, but such were not identified in the present study. Although no systematic examinations of bleeding on probing or pus formation were conducted, the survey performed could show teeth with increased pocket depths and signs of inflammation. Thus, the absence of exacerbation of potential infections during the immune-suppressive phase is not only due to the lack of ongoing chronic dental infections.

The increased risk to contract infections during the immune-suppressive phase is depending on the nature of the underlying disease and type of immune-suppression. Patients with malignant hematological diseases have an impaired innate as well as an adaptive immune response. As the neutrophil granulocytes have an important function to conquer bacterial infections, neutropenia as part of hematological malignancies and bone-marrow transplantation will reduce the capacity of the innate immune defense. Thus, impairment of the phagocytic capacity of neutrophilic granulocytes seems to have far more serious consequence in relation to septicemia than a primary immune-suppression of T-lymphocytes. *Streptococcus viridans* has been isolated from blood and cerebrospinal fluid cultures and has been suggested to cause septicemia, but only in patients with neutropenia who were undergoing bone marrow transplantation (4). It is therefore important to consider the type of underlying disease and type of immune-suppression before different measures are taken to eradicate potential oral infections.

The dental health status of the patients in this study was well in accordance with that of a comparative general population (5, 10). This may be explained by the fact that the patients had not been on dialysis for an extended period of time and some of the patients had not received dialysis prior to transplantation. There is strong evidence to suggest that prolonged time on dialysis negatively affects the long-term outcome of renal transplantation (11). The saliva composition after renal transplantation shows significant improvement compared with the quality of saliva found during the predialysis and dialysis stages (25). However, this improvement in salivary flow and composition do not seem to have any affect on DMFT, dental plaque, gingival bleeding and periodontal indices comparing dialysis and renal transplant patients (2).

Our results indicate that oral infections are a minor problem for the medical rehabilitation of renal transplant recipients, and that suppression of the cell-mediated immune system does not entail an increased risk for medical complications due to exacerbation and spread of oral infections. Screening for potential dental infections in patients about to undergo renal transplantation has become standard at most centers. The objective of screening is to reduce the morbidity and mortality that may arise from oral complications associated with renal transplantation. This strategy does not gain support from this study, or from the sparse information retrieved from the literature. Furthermore, patients should not be exposed to additional complications from needless dental interventions. Still, it is important to emphasize that the present study has investigated potential chronic infections and opportunistic oral infections, and it is essential that oral examination and treatment are conducted to eradicate acute oral infections. This is particularly important in the time period just before transplantation, when the patient may be most medically compromised. A reasonable strategy must be to conduct dental treatment as early as possible in the medical examination process, when the status of the patient allows conventional treatment planning, dental care and evaluation. An improved communication between internal medicine and dentistry is a prerequisite to fulfill this objective.

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# Full-mouth versus quadrant-wise scaling

## - clinical outcome, efficiency and treatment discomfort

INGELA LOGGNER GRAFF, BARBRO ASKLÖW, HELENE THORSTENSSON

### Abstract

© The aim of this randomized clinical study was to compare full-mouth scaling and root planing (FM-SRP) in two sessions within 24 hours with quadrant-wise scaling and root planing (Q-SRP) in four sessions within 4–6 weeks and evaluate (I) clinical outcome, (II) treatment efficiency, and (III) treatment discomfort of patients and therapists. Twenty individuals, aged 28–65 years, with severe chronic periodontitis were randomly assigned to treatment with FM-SRP or Q-SRP. At baseline and after 6 months, there were no between-group differences in clinical findings, treatment discomfort, or post-treatment body temperature. The therapists, however, felt that FM-SRP was more physically and psychologically demanding than Q-SRP.

Mean effective scaling and root planing (SRP) time was 165.5 min during the two FM-SRP sessions and 202.1 min during the four Q-SRP sessions. FM-SRP's initial time savings of 36.6 min compared with Q-SRP diminished to 30.8 min at the 6-month follow-up due to rescaling needs. Total mean treatment time (comprising SRP and patient reinformation and reinstruction in oral hygiene) during the first 6 months post-treatment was 321.2 min for FM-SRP and 353.0 min for Q-SRP. Thus, mean savings in total treatment time with FM-SRP was 31.8 min compared with Q-SRP.

In conclusion, this study found that both treatment modalities may be recommended for chronic periodontitis patients. Although time saving is possible with FM-SRP, the modality may compromise the therapist's well-being if practiced frequently due to the risk of musculoskeletal problems.

### Key words

*Chronic periodontitis, efficiency, periodontal therapy, treatment experience*

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## Scaling inom 24 timmar jämfört med kvadrantvis scaling - kliniskt utfall, tidsåtgång, upplevelse av behandling och arbetsförhållanden

INGELA LOGGNER GRAFF, BARBRO ASKLÖW, HELENE THORSTENSSON

### Sammanfattning

© Syftet med denna randomiserade studie var att (I) utvärdera den kliniska effekten av scaling i hela munnen utförd under 24 timmar (FM-SRP) och konventionell kvadrantvis scaling med 1-2 veckor mellan behandlingarna (Q-SRP); (II) genomföra kostnadsanalys av de två behandlingsformerna; (III) undersöka patientens upplevelser av behandlingen liksom terapeutens arbetssituation. Tjugo individer i åldern 28-65 år med grav kronisk parodontit slumpades till en av de två behandlingarna. Det var inga signifikanta skillnader avseende kliniska förhållanden mellan de två grupperna varken vid studiens början eller efter 6 månader. Inte heller var det någon skillnad mellan grupperna avseende patienternas upplevelse av behandlingen eller förändring av kroppstemperaturen i samband med scaling. Däremot upplevde terapeuterna den intensiva scalingen genomförd inom 24 timmar som både fysiskt och psykiskt mer ansträngande än traditionell kvadrantvis scaling.

Tiden som ägnades åt enbart scaling inom 24 timmar respektive scaling vid fyra tillfällen var 165,5 minuter (FM-SRP) och 202,1 minuter (Q-SRP), dvs en tidsvinst för FM-SRP av 36,6 minuter. Efter 6 månader hade den initiala tidsvinsten minskat till 30,8 minuter på grund av behovet av rescaling. Total behandlingstid (scaling tillsammans med reformation och reinstruktion i munhygienteknik) under hela 6 månaders perioden var 321,2 minuter (FM-SRP) respektive 353,0 minuter (Q-SRP). Alltså blev den totala tidsvinsten för behandling med scaling inom 24 timmar 31,8 minuter.

Sammanfattningsvis visar studien att både scaling genomförd inom ett dygn liksom traditionell scaling genomförd kvadrantvis med 1-2 veckors intervall kan rekommenderas för behandling av individer med kronisk parodontit. Scaling utförd koncentrerat inom 24 timmar ger viss ekonomisk vinst (uttryckt i minuter) men kan å andra sidan utgöra en risk för att terapeuten utvecklar belastningsskador om denna typ av behandling görs regelbundet.

## Introduction

Periodontal diseases have a multifactorial aetiology involving a susceptible host and interaction between host defence mechanisms and periopathogenic bacteria. Treatment consists of self-performed supragingival plaque control and professional supra- and subgingival scaling to remove pathogenic bacteria from the supra- and subgingival environment. Traditionally, non-surgical mechanical therapy is performed quadrant-wise in four sessions at intervals of 1–2 weeks (3). Complete mechanical treatment of the entire mouth usually takes 4–6 weeks and effectively reduces bacterial load, resulting in clinical improvement (17).

To reduce the risk of untreated periodontal pockets re-infecting treated sites, *Quirynen et al* (15) proposed an alternative treatment to traditional quadrant-wise scaling and root planing (Q-SRP): full-mouth scaling and root planing (FM-SRP) in two sessions within 24 hours. The authors also considered the risk of re-infection from other intra-oral niches such as the tongue and tonsils and included extensive antimicrobial therapy with chlorhexidine – full-mouth disinfection (FMD) – in their treatment. Several studies (4,14,18) found that FMD improved healing compared to Q-SRP. Later, *Quirynen et al* (16) showed that the major part of FMD's treatment effect could be attributed to SRP of all quadrants within 24 hours and not FMD.

*Quirynen et al* (16) reported a rise in body temperature on the second day after FMD and FM-SRP and interpreted this as a possible local Schwartzman reaction – a type of hypersensitivity reaction to antigens from repeated bacteraemia caused by the second FM-SRP session. *Apatzidou & Kinane* (2) and *Koshy et al* (11), however, could not verify this rise in body temperature.

Two recent systematic reviews evaluated FMD, FM-SRP, and Q-SRP in the treatment of adult chronic periodontitis (8,12). Probing pocket depth reduction was significantly greater (0.2 mm) for FMD and FM-SRP compared with Q-SRP. Likewise, clinical attachment levels were 0.2–0.4 mm greater with FMD and FM-SRP (12). Both systematic reviews conclude that all three treatment modalities may be recommended for initial treatment of individuals with chronic periodontitis.

This study compared FM-SRP within 24 hours and Q-SRP within 4–6 weeks to evaluate:

- clinical outcome.
- treatment efficiency.
- patient and therapist treatment discomfort.

## Material and methods

This study is a randomized, controlled, single-masked, parallel group study of 6 months duration and was conducted during 2005 and 2006. Twenty patients who were referred to the Department of Periodontology, The Institute for Postgraduate Dental Education, Jönköping, Sweden for periodontal treatment participated. Inclusion criteria were advanced chronic periodontitis with at least four remaining teeth per quadrant, probing pocket depth (PPD) > 5 mm, bleeding on probing (BOP), and good general health based on a medical history. Exclusion criteria were compromising medical conditions requiring prophylactic antibiotic coverage, poorly controlled diabetes, pregnancy, and ongoing drug therapy that might affect clinical signs and symptoms of periodontitis.

All participants received information about the study and signed an informed-consent form. Before the study began, a dentist from the Department of Periodontology examined each patient and planned treatment. A full-mouth radiographic examination was performed at the Department of Maxillofacial Radiology, Jönköping. Tooth extractions and endodontic and caries treatment were carried out before the start of the study.

Patients were randomized to FM-SRP or Q-SRP. Twenty sealed envelopes, 10 each marked with one of two therapists' names, had been prepared in advance. Each group of 10 envelopes contained five assignments to FM-SRP and five to Q-SRP treatments. An independent person who was not otherwise involved in the study randomised the patients. The seal was broken after the patient agreed to participate.

### Treatment procedures

Treatment was performed by two therapists, one experienced dental hygienist and one dentist from the Department of Periodontology. Each therapist treated five patients with FM-SRP within 24 hours and five patients with Q-SRP within 4–6 weeks. An experienced dental hygienist who was blinded to treatment made all clinical measurements at baseline and 6 months. Before the start of the study, the examiner was calibrated to acceptable accuracy and reproducibility for all clinical assessments.

### Clinical variables

**Plaque score:** Presence/absence of plaque at the cervical part of the tooth, scored by running a probe along the tooth surface.

<i>Gingival index:</i>	Gingival bleeding index, as modified by <i>Ainamo &amp; Bay</i> (1).
<i>PPD:</i>	Measured with a manual HuFriedy H6 periodontal probe (HuFriedy Inc., Leimen, Germany) to the closest lower millimetre at four tooth surfaces.
<i>BOP:</i>	Presence/absence of bleeding within 15 s following pocket probing.
<i>Probing attachment level (PAL):</i>	The distance fixed reference point on the tooth (cemento-enamel junction or the margin of a restoration) and the bottom of the probed pocket.

Scaling began when the patient's plaque index was  $\leq 20\%$ . Local anaesthesia with no time restrictions was used. In the FM-SRP group, the upper and lower quadrants on the right side were treated at the first session and the upper and lower quadrants on the left side at the second session. In the Q-SRP group, scaling was performed clockwise, one quadrant at a time starting in the upper right jaw. Ultrasonic or hand instruments were used for scaling depending on the therapist's preference. Each treatment session ended with polishing with a low-abrasive paste and a fluoride rinse. The patient was instructed to rinse with 0.1% chlorhexidine mornings and evenings for the next 3 days and use a dentifrice without sodium lauryl sulphate.

Five weeks after scaling, patients were recalled for re-evaluation of plaque control and reinforcement of oral hygiene. After 3 months, the teeth were professionally cleaned, oral hygiene and scaling re-evaluated, and reinstruction and rescaling performed if needed. The final examination was made 6 months after scaling.

#### *Body temperature*

Body temperature was measured in the morning of the day scaling was performed and the next two mornings. Patients used a digital thermometer (Terumo®, Terumo Sweden AB, Sweden) according to the manufacturer's instructions and recorded temperatures on a chart.

#### *Questionnaire, patient*

Immediately after the first and last scaling sessions, the patient completed a questionnaire anonymously. Responses were graded on 10-cm visual analogue scales (VAS) with the endpoints "not at all tiresome" and "too long", "not at all painful" and "too

painful", or "treatment time not at all too long" and "treatment time too long". Patients also completed a questionnaire on pain experience and one on use of analgesics on the first and the second days after each scaling session.

#### *Questionnaire, therapist*

After each scaling session, the therapist completed a questionnaire on a 10-cm graded VAS. The questions assessed the therapist's experience of the treatment session; VAS endpoints were "not at all psychologically demanding" and "psychologically demanding", "not at all physically demanding" and "physically demanding", and "treatment session not at all long" and "treatment session too long".

#### *Treatment efficiency*

Treatment efficiency was expressed as total number of min spent on treatment during 6 months. At each patient's visit, treatment time was calculated. This time is expressed as (i) SRP time: time spent in scaling and root planing, including anaesthesia and professional tooth cleaning and (ii) total treatment time: SRP time plus time spent on patient information and instruction at all examinations.

#### *Statistical analysis*

Mean patient values were calculated as a basis for the analysis. Mean values, maximum and minimum values, and standard deviations were calculated.

#### **Results**

Two groups of 10 individuals participated in this study. The FM-SRP group comprised six females and four males with a mean age of 53.1 years (range 28–65). Seven smoked at baseline and five at the 6-month examination. The Q-SRP group comprised nine females and one male with a mean age of 49.6 years (range 35–64). Three individuals smoked.

One male smoker in the FM-SRP group dropped out after the 3-month visit because he moved from the area. One non-smoking male in the Q-SRP group dropped out at the 6-month visit for personal reasons.

#### *Clinical findings*

No teeth were lost during the 6-month study period. Between-group differences at baseline and at the 6-month examination were non-significant. The plaque index was  $<20\%$  at the start of scaling and continued to be low through the whole study period. At the 6-month examination the plaque index

was 18.9 % (SD=11.7) and 10.6 % (SD=7.8) for the FM-SRP and Q-SRP group, respectively. The gingival index improved from 55.4 % (SD=20.0) to 19.0 % (SD=15.0) in the FM-SRP group and from 58 % (SD=15.0) to 14.3 % (SD=9.5) in the Q-SRP group. Table 1 lists number of teeth, BOP, and PPD.

At the 6-month examination, mean PAL gains of ≥ 2 mm were observed in:

- 5.8 % (SD=3.9) of the sites in the FM-SRP group and 6.2 % (SD= 6.1) in the Q-SRP group with an initial PPD ≤ 6 mm.
- 59.6 % (SD=16.6) of the sites in the FM-SRP group and 47.3 % (SD=13.4) in the Q-SRP group with an initial PPD ≥ 7 mm.

*Body temperature*

In the morning of the first scaling session, mean body temperature was 36.5° C (range 36.0–37.1). Between-group differences were non-significant, as were between-group differences on the first and second day following scaling. Mean body temperature post-scaling was:

- on the first day: 36.6° C (range: 35.5–37.1) in the FM-SRP group and 36.7° C (range: 36–37.4) in the Q-SRP group.
- on the second day: 36.6° C (35.8–37.0) in the FM-SRP group and 36.6° C (36.0–37.0) in the Q-SRP group.

*Treatment discomfort, patients*

There were no between-group differences in experience of treatment as tiresome, of long duration, or

© **Table 1.** Means of clinical characteristics at baseline and 6 months in the full-mouth (FM-SRP) and quadrant-wise (Q-SRP) scaling and root planing groups. Number of teeth, percentage of tooth surfaces with bleeding on probing (BOP), probing pocket depth (PPD), and number of teeth with PPD ≥ 6 mm; standard deviations in parentheses.

	FM-SRP		Q-SRP	
	Baseline	6 months	Baseline	6 months
No. of teeth	25.1		25.5	
Min – max	19-32		22-30	
BOP, %	51.8 (14.4)	28.4 (7.4)	48.9(13.3)	19.4 (7.8)
PPD, mm	5.8 (1.4)	3.2 (1.2)	5.3 (1.4)	4.2 (1.7)
PPD ≥ 6 mm, no.	15.6 (7.0)	7.9 (4.9)	20.8 (4.6)	11.1 (3.3)
<i>Single-rooted teeth</i>				
No. of teeth	18.8		19.2	
Min – max	16-20		18-20	
<i>Multi-rooted teeth</i>				
No. of teeth	6.3		6.4	
Min – max	2-12		3-10	

© **Table 2.** Mean visual analog scale (VAS) ratings of treatment discomfort in the full-mouth (FM-SRP) and quadrant-wise (Q-SRP) scaling and root planing groups. VAS endpoints: 0 = not at all; 10 = too much; minimum and maximum VAS ratings in parentheses.

	FM-SRP	Q-SRP
<i>Tiresome treatment</i>		
After the first scaling visit	0.9(0-3.0)	1.3(0-4.8)
After the last scaling visit	1.2(1-5.1)	1.2(1-6.1)
<i>Long treatment time</i>		
After the first scaling visit	1.9(0-4.6)	1.9(0-4.8)
After the last scaling visit	1.5(0.1-3.7)	1.2(0-5.9)
<i>Painful treatment</i>		
After the first scaling visit	0.9(0.2-2.8)	0.6(0-1.1)
After the last scaling visit	1.0(0-4.8)	0.7 (0.1-2.3)

© **Table 3.** Mean visual analog scale (VAS) ratings of treatment discomfort among therapists working with full-mouth (FM-SRP) and quadrant-wise (Q-SRP) scaling and root planing. VAS endpoints: 0 = not at all; 10 = too much; minimum and maximum VAS ratings in parentheses.

	FM-SRP	Q-SRP
<i>Psychologically demanding</i>		
After the first scaling visit	2.1(0-6.5)	0.9(0-3.8)
After the last scaling visit	1.8(0-5.4)	0.8(0-5.6)
<i>Physically demanding</i>		
After the first scaling visit	3.3(0-7.4)	1.4(0-4.5)
After the last scaling visit	3.6(0-7.0)	1.6(0-5.6)
<i>Long session</i>		
After the first scaling visit	4.6(0-9.6)	1.1(0-3.5)
After the last scaling visit	4.6(0.2-6.9)	0.6(0-2.2)

© **Table 4.** Treatment efficiency, expressed as mean treatment time in no. of min in the full-mouth (FM-SRP) and quadrant-wise (Q-SRP) scaling and root planing groups. Treatment time is reported as (i) SRP time: time spent in scaling and root planing, including anaesthesia and professional tooth cleaning and (ii) total treatment time: SRP time plus patient information and instruction at all visits from baseline to 6 months. Range in parentheses.

	Treatment time		Difference
	FM-SRP	Q-SRP	
<i>First scaling session</i>			
SRP	84.8 (50-110)	50.0 (35-60)	
Total treatment	97.7 (65-120)	61.0 (50-75)	
<i>Second scaling session</i>			
SRP	80.7 (50-130)	50.0 (35-70)	
Total treatment	89.0 (60-135)	57.5 (45-75)	
<i>Third scaling session</i>			
SRP		46.9 (30-65)	
Total treatment		55.0 (45-70)	
<i>Fourth scaling session</i>			
SRP		55.2 (35-75)	
Total treatment		62.4 (45-85)	
<i>All scaling sessions</i>			
SRP	165.5	202.1	36.6
Total treatment	186.7	235.9	49.2
<i>5-week visit</i>			
SRP	25.7 (5-45)	24.4 (5-60)	
Total treatment	39.5 (15-55)	38.8 (20-65)	
<i>3-month visit</i>			
SRP	68.3 (20-125)	63.8 (25-95)	4.5
Total treatment	95.0 (45-17)	78.3 (35-115)	16.7
<i>All treatment time</i>			
SRP	259.5	290.3	30.8
Total treatment	321.2	353.0	31.8

painful (Table 2). All mean values were small, which indicated that the patients did not find the treatment troublesome.

Two patients in the FM-SRP group reported use of analgesics on two occasions. In the Q-SRP group, two patients reported use of analgesics on two occasions and two on one occasion.

#### *Treatment discomfort, therapists*

Table 3 reports the therapists' evaluation of the sessions. Mean values for treatment discomfort were higher for FM-SRP than for Q-SRP. This indicates that therapists may experience FM-SRP as more demanding.

#### *Treatment efficiency*

Table 4 lists mean treatment time for FM-SRP and Q-SRP as SRP time and as total treatment time and differences are accounted for.

#### *Initial treatment*

Mean effective SRP time in the FM-SRP group was 165.5 min and in the Q-SRP group, 202.1 min; time saving with FM-SRP was 36.6 min. Total initial treatment time, comprising SRP and patient information and instruction, was 186.7 min for FM-SRP and 235.9 min for Q-SRP – a mean saving of 49.2 min for FM-SRP.

### 3-month visit

At the 3-month visit, mean SRP time was 68.3 min in the FM-SRP group and 63.8 min in the Q-SRP group. Between-group difference in mean SRP time was 4.5 min. The between-group difference in mean total treatment time, however, was 16.7 min (95.0 versus 78.3).

### 6-month visit

Mean SRP time for all visits up to the 6-month visit was 259.5 min in the FM-SRP group and 290.3 min in the Q-SRP group. Thus, mean saving in SRP time was 30.8 min for FM-SRP. Mean total treatment time, comprising SRP and patient information and instruction, was 321.2 min for FM-SRP and 353.0 min for Q-SRP. Thus, mean savings in total treatment time for FM-SRP within 24 hours was 31.8 min.

## Discussion

This study evaluated clinical outcome, treatment efficiency, and treatment discomfort experienced by patients and therapists in a comparison of FM-SRP within 24 hours and traditional Q-SRP within 4–6 weeks. The sample size was small, and this must be born in mind when interpreting the results.

Non-surgical, mechanical periodontal therapy – FM-SRP and Q-SRP – markedly reduced all clinical indices with no differences between the treatment modalities. The range of improvement in clinical measurements is consistent with results from other studies (6,7,19). In studies that reported favourable results for FMD-SRP and FM-SRP (4,14–16,18), participants received no oral hygiene instruction before scaling. Thus, the control groups in these studies (Q-SRP) may have been at risk of reinfection due to scaling performed over a longer time period. This may have adversely affected healing and contributed to the superior effect of FD-SRP and FM-SRP compared to Q-SRP. In our study, the subjects reached a plaque score  $\leq 20\%$  before scaling began. No treatment discomfort such as periodontal abscesses was reported. Also in the *Apatzidou & Kinane* (2), *Koshy et al* (11), and *Jervoe-Storm et al* (10) studies all participants received oral hygiene instruction before scaling, and they reported equally favourable results for the two treatment modalities.

*Quirynen et al* (16) observed a rise in body temperature in the evening after the second scaling session in the FM-SRP and FMD groups, but not in the Q-SRP group. They suggested that this might be a local Schwartzman reaction, which would increase the immunological response and improve clinical results. We observed no rise in body temperature af-

ter scaling, which is in agreement with the findings of *Apatzidou & Kinane* (2) and *Koshy et al* (11).

Participants tolerated both treatment modalities equally well. There were no differences in treatment discomfort such as tiresome treatment, long treatment time, painful treatment, or need of analgesics. The magnitudes of reported discomfort were small. *Wennström et al* (20) compared a single session of full-mouth ultrasonic debridement with four sessions of traditional quadrant-wise scaling at intervals of 1 week. They also reported a minimal degree of patient discomfort. In the *Apatzidou & Kinane* (2) and *Koshy et al* (11) studies, however, patients reported slightly more pain following FM-SRP than after conventional Q-SRP. Their study protocols differed from ours. They performed FM-SRP in one session while we did so in two sessions within 24 hours.

The therapists reported higher mean VAS values for FM-SRP than for Q-SRP treatment. They rated FM-SRP treatment as being more physically demanding and felt the treatment session was too long compared with Q-SRP. Individual ratings varied and reached a maximum of 7.4 for the work being too physically demanding and 9.6 for sessions being too long. This may be an indication of musculoskeletal problems. Lengthy static or repetitive arm work, even at relatively low levels of muscular contraction, may lead to chronic pain symptoms in the neck and shoulders (13,21,22). Thus, regularly performing FM-SRP treatment could imply a higher risk of developing musculoskeletal problems compared with Q-SRP.

Initial time spent on scaling and root planing during the two FM-SRP sessions was 165.5 min. The four Q-SRP sessions took 202.1 min, 36.3 min more than the FM-SRP sessions. Additional scaling and root planing were performed at the 3-month visit. At 6 months therefore, the total time saving for scaling and root planing during FM-SRP treatment was reduced to 30.8 min. Total initial time saving for all treatment, including instruction, after the scaling and root planing sessions, was 49.2 min with FM-SRP. At the 3-month visit more time was spent on re-instruction in the FM-SRP than in the Q-SRP group. In the Q-SRP group there were more initial scaling sessions where oral hygiene habits could be reinforced and therefore the FM-SRP group may have needed more reinstruction time at the 3-month visit. Thus, the mean difference in total treatment time between the two modalities at 6 months diminished to 31.8 min.

The efficiency of these treatment approaches is little studied. *Koshy et al* (11) reported significantly

shorter (51 min) total instrumentation time for FM-SRP compared with Q-SRP. They studied moderate to advanced chronic periodontitis and included single and multi-rooted teeth but did not report number of teeth. Our study participants may have had more severe periodontal disease, more teeth, and more molar teeth, which would have required longer treatment time. The study design of *Wennström et al* (20) differed from those of *Koshy et al* (11) and ours. They set a time restriction for full-mouth ultrasonic debridement. The time spent in traditional Q-SRP (214 min) was comparable to our study.

Thus, FM-SRP may be an option for patients who would benefit from a more concentrated treatment approach, for example due to general state of health or who must travel a long way to receive dental treatment. It is also important to consider that operator experience may influence the effectiveness of subgingival debridement (5,9).

### **Conclusion**

The present study reports equivalent clinical results for (i) full-mouth scaling and root planing in two sessions within 24 hours and (ii) traditional quadrant-wise scaling and root planing in four sessions within 4–6 weeks. The patients tolerated both treatment modalities well, but the therapists felt that full-mouth scaling was more physically and psychologically demanding. Efficiency was higher for full-mouth scaling and may therefore be an advantage for patients in need of a concentrated treatment approach. Working on a regular basis with full-mouth scaling, however, may place greater strain on the therapist than working with traditional quadrant-wise scaling.

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# Symptoms and signs of temporomandibular disorders in patients with sudden sensorineural hearing loss

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## Abstract

© Sudden sensorineural hearing loss (SSH) usually affects one ear and leads to life long deafness in some cases. There are many theories about the origin of the condition but the etiology and pathophysiology are still unknown. However, tinnitus and vertigo frequently occur in patients with SSH, but are also frequent symptoms reported by patients with temporomandibular disorders (TMD). We hypothesized that TMD symptoms and signs are frequent in SSH patients. The objective of this study was therefore to investigate the presence of TMD symptoms and signs in SSH patients compared with healthy individuals.

The groups, matched by gender and age, consisted each of 9 females and 6 males. Both groups answered a questionnaire about TMD symptoms and a clinical examination which included maximum voluntary mouth opening, temporomandibular joint sounds, tenderness to digital palpation of the TMJs and selected masticatory muscles, intermaxillary relations and dental occlusion was performed.

The SSH patients reported significantly higher rates of pain in the head and face region and pain during mandibular movements as well as of aural symptoms compared with the control group. There was also a statistically significant difference between the groups in the number of masticatory muscles tender to digital palpation, as well as in some occlusal variables.

In conclusion, this study shows that self-reported symptoms and clinical signs of TMD are more frequent in patients with SSH than in healthy controls.

## Key words

*Sudden sensorineural hearing loss, temporomandibular disorders, myofascial pain, questionnaire*

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## Temporomandibulär dysfunktion vid plötslig sensorineural hörselnedsättning

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### Sammanfattning

⊙ Plötslig sensorineural hörselnedsättning (PSH) drabbar vanligen ena örat och leder i vissa fall till en livslång dövhet. Det finns många olika teorier om tillståndets ursprung, men etiologin och patofysiologin är fortfarande okända. Emellertid förekommer tinnitus och yrsel ofta samtidigt med PSH och dessa symptom rapporteras också ofta av patienter med temporomandibulär dysfunktion (TMD). Vår hypotes var att symptom och tecken på TMD är ofta förekommande hos patienter med PSH. Syftet med denna studie var därför att undersöka förekomsten av symptom och tecken på TMD hos patienter med PSH jämfört med friska individer.

Grupperna var matchade avseende kön och ålder och bestod vardera av 9 kvinnor och 6 män. Båda grupperna besvarade ett frågeformulär angående symptom på TMD och en klinisk undersökning genomfördes avseende maximal gapförmåga, förekomst av käkledsljud, palpationsömheter i käkleder och utvalda tuggmuskler, käkarnas inbördes relation och ocklusala förhållanden.

Patienterna med PSH rapporterade en statistiskt signifikant högre förekomst av smärta i huvud- och halsregionen, tillika smärta vid käkrörelser och öronsymptom, jämfört med kontrollgruppen. Den kliniska undersökningen visade att patienterna med PSH hade fler palpationsömma tuggmuskler och färre kontakter i sammabitning samt var oftare postnormala än kontrollgruppen.

Slutsatsen är att denna studie visar att egenrapporterade symptom och kliniska tecken på TMD förekommer oftare hos patienter med PSH än hos friska individer.

## Introduction

Sudden sensorineural hearing loss (SSH) is a disease with unknown etiology that affects the inner ear. SSH is often referred to as “sudden deafness” in daily speech and the condition occurs unilaterally in most cases (18, 29). In Sweden the incidence of SSH is 5–20 per 100 000 individuals per year. About one third of them recover spontaneously, about one third improve to a certain extent with professional help, and the final third remain with severely impaired hearing in the affected ear (18). SSH involves a loss of hearing of at least 30 dB (18) and the loss of hearing occurs within hours to three full days (23). SSH is not painful, but some patients experience vertigo and tinnitus in connection with the condition (13, 23). There are no gender differences in the distribution of SSH and it presents itself most commonly in the middle-aged to elderly (18).

The question of the origin of SSH is still unsolved, but various theories have been proposed e.g. the vascular theory, the infectious theory, autoimmunity, baro trauma and acoustic trauma as well as superoxide anion radicals (2, 10, 18, 23). The presence of mental stress has also been presented as a factor that may contribute to the development of both tinnitus and SSH, and to the prevention of healing (22). Temporomandibular disorders (TMD) is a term that collectively embraces various clinical problems that involve the masticatory musculature, the temporomandibular joint (TMJ) with associated structures, or both.

Frequent symptoms are limited or asymmetric mandibular movements, TMJ sounds and pain as well as headaches and facial pain at rest or upon function. Masticatory muscle hypertrophy and abnormal occlusal wear associated with bruxism (jaw clenching and tooth grinding) may be related problems, and TMD often coexists with other craniofacial disorders (19).

It has been found that patients with TMD have a higher incidence of otologic complaints than control subjects without TMD signs (25). Retrospective studies of medical records have shown that, in patients suffering from ear symptoms such as otalgia, tinnitus, vertigo and perceived hearing loss, over 60 percent had TMD (16). These findings indicate that TMD is commonly present in patients with aural problems, although no cause and effect relationship has yet been demonstrated. Other studies indicate in a similar way the co-existence between TMD and ear symptoms (20), but also show the same uncertainty concerning proof of any correlation (15).

It has been recommended that patients with inner ear dysfunctions of unknown etiology, such as SSH, should undergo an examination of the temporomandibular system, since some symptoms that occur in patients with inner ear disorders also occur in patients with TMD (12). If TMD is found it should be treated accordingly. In addition, after studying otalgia in patients with TMJ disorder it could be concluded that TMD patients with otalgia do not form a separate TMD group, and that they responded well to conservative TMD treatment also in respect of otalgia (11). Other findings lead to the conclusion that there is a considerable co-existence between TMD symptoms originating from the TMJ and ear, nose and throat symptoms, especially deafness (4).

We hypothesized that TMD symptoms are frequent in patients with SSH. The aim of this study was therefore to investigate if there are any differences in TMD symptoms and signs between patients with SSH and healthy individuals.

## Material and methods

### Subjects

The study included fifteen Swedish adult patients diagnosed with unilateral sudden sensorineural hearing loss (SSH). They were nine females and six males with a median (range) age of 53 (28–62), years. All patients had received their SSH diagnosis from a specialised audiology clinic within the last two years. The duration of SSH however, ranged from 24 hours to 13 years, with a median (SD) of 1 year. Nine patients had SSH in the left ear and six in the right. SSH patients with other diseases or medication that might influence hearing or the masticatory system, such as, for example, untreated hypertension, local infections and medication with tricyclic antidepressants were not included in the study.

For comparison, 15 age- and gender matched healthy individuals (9 females and 6 males) were selected consecutively from patients attending a private dental clinic to form the control group. They had a median (range) age of 52 (28–62) years. Subjects with ear problems or a history of TMD were excluded.

The study followed the guidelines of the Declaration of Helsinki and was approved by the Regional Ethics Committee in Stockholm, Sweden.

### Questionnaire

All subjects filled out a questionnaire about the duration of SSH, presence of vertigo, tinnitus, hyperacusis, and “ear fullness”. The questionnaire also con-

tained questions about frequency of facial pain, pain at movement, toothache, burning mouth/tongue, headache, jaw fatigue, restrictions in jaw opening, and swallowing difficulties. A 5-graded scale was used where 0 = never, 1 = 1-2 times per month, 2 = 1-2 times per week, 3 = several times every week, and 4 = daily. They were also asked if they were aware of oral parafunctions (tooth grinding and clenching, nail biting, cheek, lip or tongue biting, tongue thrusting), snoring as well as muscle tension.

#### *Clinical examination*

The subjects were examined concerning their temporomandibular status according to a well-established examination scheme at the Department of Clinical Oral Physiology, Karolinska Institutet, Huddinge, Sweden. All subjects were examined by one of two calibrated examiners (RA, BHM). Before the clinical examination the subjects were asked to assess their degree of general and local pain as well as pain upon chewing and mandibular movements on a 0-100 mm visual analogue scale (VAS).

The clinical examination included bilateral digital palpation for presence of tenderness of the following muscles: anterior and posterior portion as well as the insertion of the temporal muscle, superficial and deep portion of the masseter muscle, lateral and medial pterygoid muscles, trapezius muscle, sternocleidomastoid and posterior digastric muscles. The total number of muscle sites presenting tenderness to digital palpation was counted, with a maximum score of 20 tender points.

Presence of tenderness of the TMJ, laterally and posteriorly (via the external auditory meatus), as well as clicking, locking and crepitation of the TMJ during mandibular movement was assessed by digital palpation. The total number of tender sites was counted with a maximum of 4.

Deviation in the intermaxillary occlusal relations in the sagittal (post-/prenormal) and transversal (cross-bite/scissorbite) plane was recorded according to the examination scheme. The horizontal overjet and vertical overbite were measured (mm) with a ruler.

Maximum unassisted mouth opening (mm) calculated as the sum of interincisal distance and the vertical overbite was measured with a ruler. The sum of the horizontal overjet and the maximum movement in protrusion was measured in the same way. The maximum mandibular excursions were recorded (mm) by measuring the distance between a vertical mark on the upper and lower first incisor with the teeth in occlusion and with the mandible at its

farthest position to the right and to the left.

The number of occluding teeth in occlusion and articulation was recorded in the upper jaw with a double-folded eight  $\mu\text{m}$  foil (Hanel-GHM-Dental, Nürtingen, Germany). The intercuspal position (IP) was obtained by asking the subject to bite with the mandible in the position that felt like the natural bite. The retruded contact position (RP) was obtained with the subject in a horizontal position while the examiner gently pushed the mandible posteriorly and upwards until the condyle reached the most retruded position in the temporomandibular fossa and the teeth made contact. It was distinguished whether contacts were uni- or bilateral. Attrition was assessed in incisors, canines, premolars and molars separately. A 4 graded scale was used where 0 = no attrition, 1 = wear within the enamel, 2 = wear within the dentine and 3 = wear within the secondary dentine. Sagittal slide from RP to IP was registered (mm) with a ruler. Tooth contacts at lateral excursions from IP to edge-to-edge contact of the canines were recorded at the same side (laterotrusive contacts, LTR) and contralateral side (mediotrusive contacts, MTR).

#### *Statistical analyses*

Non-parametric statistical methods were used since most of the data were not normally distributed and many variables were dichotomous. Data are presented as median and range. The differences between groups regarding the frequency distributions were tested with the Fisher exact test and differences in variables on a categorical scale were tested with the Mann-Whitney U-test. A p-value less than 0.05 was considered significant.

## **Results**

### *Subjective symptoms*

The frequency of aural symptoms, pain and other self-reported symptoms is shown in Table 1. As could be expected, the presence of hearing loss was statistically significantly higher in the patient group than in the control group ( $p < 0.001$ ). The patients also reported a higher frequency of aural symptoms, such as tinnitus, hyperacusis and ear fullness.

There was a statistically significant difference between groups in the report of facial pain, tooth ache / hypersensitive teeth, and headache at least 1-2 times per week. There was no statistically significant difference between groups concerning pain during mandibular movements or burning mouth/tongue. There was a statistically significant difference bet-

ween groups in the presence of muscle tension and the report of vertigo at least 1-2 times per week with the patients exhibiting a higher prevalence, but no difference concerning restrictions on jaw opening, jaw fatigue, joint sounds or locking of the TMJ or snoring. There was no statistically significant difference between groups concerning parafunctional activities such as clenching of the teeth, tooth grinding or nail biting. However, 8 patients, but only 2 controls reported tongue thrusting ( $p = 0.05$ ) and the patients reported on average 2 parafunctions while the controls reported an average 1 ( $p < 0.01$ ).

Three patients in the SSH group reported resting facial pain at the day of examination with an intensity of 25 (10-30), 10 reported pain during chewing with an intensity of 22.5 (10-70) and 5 reported pain during mandibular movements with an intensity of 30 (10-90). None of the controls had any pain at rest, during chewing or mandibular movements. The difference between groups was statistically significant for pain during chewing and mandibular movements ( $p < 0.001$  and  $p < 0.05$ , respectively).

#### Clinical examination

The findings from the clinical examination are

shown in Table 2. The number of muscles tender to palpation ranged between 1 and 20 in the patients and between 0 and 7 in the control group (Fig. 1). The difference between groups was statistically significant. The muscles most frequently painful to digital palpation among the SSH patients were the lateral pterygoid muscle (27/30 muscles), the posterior digastric muscle (19/30) and the deep part of the masseter muscle (17/30). The patient group also had significantly more tenderness to digital palpation of the TMJ laterally and posteriorly. Significantly more SSH patients than controls had postnormal intermaxillary relation, but there were no statistically significant differences between groups with respect to transversal or vertical intermaxillary relation.

The clinical examination showed no statistically significant difference between the patients and the control group with regard to, jaw mobility, sagittal slide of the mandible from RP to IP, number of unilateral contacts in RP, presence of occluding teeth in LTR and MTR during lateral excursions, or attrition. However, a statistically significant difference was found between the patient group and the control group with regard to number of tooth contacts in IP, with a lower number in the patients.

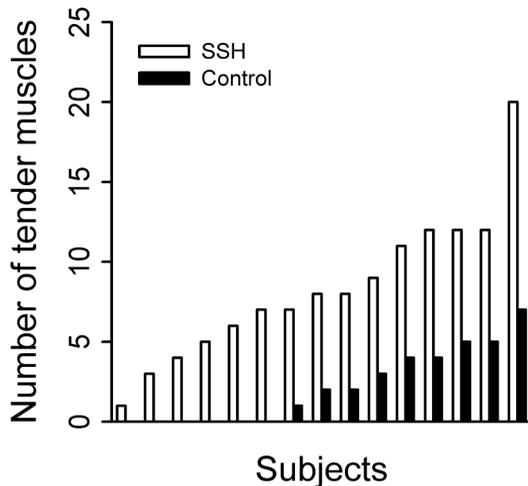
© **Table 1.** Frequency (n of subjects) of ear symptoms, pain and other self-reported symptoms in 15 patients with sudden sensorineural hearing loss (SSH) and 15 age- and gender matched healthy individuals (control).

	SSH	Control	p
Aural symptoms (yes/no)			
Tinnitus	14	0	<0.001
Hyperacusis	8	1	<0.05
Ear fullness	8	1	<0.05
Pain (> 1-2 times/week)			
Facial pain	6	0	<0.05
Pain during mandibular movements	1	0	NS
Toothache / hypersensitive teeth	5	0	< 0.05
Burning mouth / swallowing difficulties	1	0	NS
Headache	6	0	< 0.05
Jaw symptoms (> 1-2 times/week)			
Fatigue	4	0	NS
Restrictions in jaw opening	3	0	NS
Joint sounds	6	1	NS
Locking	0	0	NS
Vertigo (> 1-2 times/week)	8	0	<0.01
Swallowing difficulties	1	0	NS
Snoring (yes/no)	6	6	NS
Oral parafunctions (yes/no)	14	11	NS
Muscle tension (yes/no)	14	6	<0.01

© **Table 2.** Clinical examination of the temporomandibular system in 15 patients with sudden sensorineural hearing loss (SSH) and 15 age- and gender matched healthy subjects (Control). Figures represent median (range) and number of subjects, sites or contacts.

	SSH	Control	p
Jaw mobility (mm) and pain (n subj)			
Maximum unassisted jaw opening	46 (31-61)	50 (33-64)	NS
Pain upon movement	5	2	NS
Latertrusion			
Right	10 (0-14)	8 (3-13)	NS
Pain upon movement	3	0	NS
Left	10 (3-13)	10 (7-15)	NS
Pain upon movement	3	0	NS
Protrusion (mm)	5 (2-14)	6 (3-12)	NS
Pain upon movement	2	1	NS
Jaw sounds (n subj)			
Clicking			
Right	7	6	NS
Left	4	3	NS
Crepitus			
Right	2	0	NS
Left	3	1	NS
Palpatory tenderness (n sites)			
TMJ (0-4)	1 (0-4)	0 (0)	<0.001
Jaw and neck muscles (0-20)	8 (1-20)	3 (0-7)	<0.001
Intermaxillary relation			
Sagittal (n subjects)			
Postnormality	6	1	< 0.05
Prenormality	0	2	NS
Transversal (n subjects)			
Crossbite	4	2	NS
Scissorbite	1	0	NS
Overjet (mm)	4 (1-10)	3 (1-7)	NS
Overbite (mm)	2 (0-10)	3 (0.5-6)	NS
Occlusion and articulation (n contacts)			
IP	8 (5-16)	11 (7-15)	<0.05
RP	1 (1-3)	1 (1-3)	NS
RP-IP (mm)	0 (0-1)	0.5 (0-1)	NS
LTR			
Right	2 (0-3)	2 (0-4)	NS
Left	2 (0-3)	1 (0-3)	NS
MTR			
Right	0 (0-2)	0 (0-1)	NS
Left	0 (0-1)	0 (0-2)	NS

© **Figure 1.** Clinical examination of the temporomandibular system in 15 patients with sudden sensorineural hearing loss (SSH) and 15 age- and gender matched healthy subjects (Control). Figures represent median (range) and number of subjects, sites or contacts.



### Discussion

The main finding from this study is that TMD symptoms and signs are prevalent in patients with SSH. This is interesting and raises the question of the cause and effect of the co-existence between SSH and TMD symptoms. It could also be interesting to evaluate if treating the TMD condition would have any beneficial effect also on the hearing loss in these patients. It must be emphasized though that this is a pilot study and the results should be interpreted with caution due to the limited patient material. Future studies are needed to further evaluate this possible relation. Otologic symptoms, such as tinnitus and vertigo, were more prevalent in the SSH patients compared with the control group. Fourteen of the SSH patients experienced tinnitus but it occurred in none of the control group. This is in accordance with the study by *Koc & Sanisoglu* (13), who found a high prevalence of tinnitus and vertigo in patients with SSH. A study by *Bjorne* has indicated that tinnitus and vertigo could be the result of TMD (3), but this point of view has been debated (28). Since tinnitus and vertigo co-exist with SSH (18) and also commonly co-exist with TMD (16, 25) we wanted to investigate the presence of TMD symptoms and signs in SSH patients.

The SSH patients showed more frequent facial pain as well as tenderness to digital palpation of the masticatory muscles and the TMJ than the control

group. The presence of pain or tenderness in the masticatory muscles, the muscles of the neck and the TMJ, are well-known signs of TMD (19). It should be stated in connection with this that, in spite of calibration, there is always an inter-observer as well as an intra-observer variability in the performance of digital palpation (14), which may influence the result.

Anatomically, the TMJ in particular, but also the masticatory muscles, are situated close to the ear and are, like structures of the ear, innervated by the trigeminal nerve (6, 17). Therefore it has been debated, whether hyperactivity of masticatory muscles also could indicate hyperactivity of the tensor tympani muscle, which could explain the presence of aural symptoms in TMD (1). However, there is no evidence for such a theory (27).

The higher incidence of TMD symptoms and aural symptoms other than SSH in the SSH patients was in accordance with the findings of other studies on TMD and aural conditions. Studies have indicated that TMD may affect the ear (4), and that a wide range of TMD may cause otalgia (11). Studies have also pointed out that TMD patients have more otologic complaints than healthy individuals (25) and that there is a high incidence of TMD in patients with ear problems (16). In other studies it has been demonstrated that mental stress may be an etiological factor in the development of TMD (21). Mental stress has also been presented as a factor that may contribute to the development of SSH and adversely affect recovery from it (22). The SSH patients in this study reported more muscle tension which could be indicative of mental stress than the control group, which is consistent with the fact that they also exhibited more facial pain and pain during mandibular movements than the control group.

In the 1930's studies showed that the position of the mandible might affect the masticatory muscles, the TMJ and the ear (5). Ear problems improved in many patients after receiving dental treatment that restored normal occlusion. Yet, that study consisted of only 11 patients why the relevance may be questioned. In this study, postnormality was more frequent in the SSH patients. The SSH patients also had fewer contacts in IP. The influence of occlusal factors on TMD is a matter of debate. Some studies have reported that patients with class II malocclusion and few occlusal contacts are at a higher risk for symptoms and signs of TMD (8, 24). In contrast, a recent systematic review reported that class II malocclusion was partly protective for TMD (7).

Parafunctions like clenching of teeth, tooth grin-

ding and nail biting are known to cause TMD symptoms (9, 19, 26). However, this study showed no significant difference between the SSH patients and the control group in self-reported parafunctions with the exception of tongue thrusting. These findings were unexpected since mental stress and parafunctional activity are considered by several authors to be connected.

The SSH patients in this study showed more signs and symptoms of TMD than healthy individuals. When there is a co-morbidity between TMD and SSH, one can speculate that treatment of TMD might have a beneficial effect on SSH. Compared to treatment with corticosteroids, TMD treatment involves little or no risk of side effects. TMD treatment could be a complementary treatment of patients with SSH, and early diagnosis and treatment of TMD might perhaps prevent the development of aural symptoms in SSH patients.

### Conclusion

In conclusion, this study showed that self-reported symptoms and clinical signs of TMD are more frequent in patients with SSH than in healthy controls.

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# Oral mucoceles; extravasation cysts and retention cysts

## A study of 298 cases

CARINA GRANHOLM<sup>1</sup>, KAMILLA OLSSON BERGLAND<sup>1</sup>, HANNA WALHJALT<sup>1</sup>, BENGT MAGNUSSON<sup>2</sup>

### Abstract

© Oral mucoceles can be divided in two different forms, extravasation and retention cysts. The aim of this study was to identify the frequency of each form, sex- and age distribution, location, recurrences, referent and the differences between the two forms.

A total of three-hundred-five cases were retrieved from the Department of Oral Pathology at the Institution of Odontology, The Sahlgrenska Academy at Göteborg University between 1993 and 2003. Seven referrals were disregarded because there was insufficient information, leaving 298 cases for this study. In relation to other studies, our study investigated a larger number of cases.

Extravasation cysts were the most common type (258 cases). There was a slight predominance among women (55%) and the most frequent location was the lower lip (71%). 84% occurred between the ages of 0 and 40 years with peak incidence in the second decade (34%). 62% of the referrals came from specialists, 28% from general practitioners, and 10% from the Department of Oral Medicine.

Retention cysts were not found as frequently as extravasation cysts (40 cases) and the occurrence in women was also a bit higher (58%). We found a more even distribution regarding age and location. The most common locations were floor of the mouth (25%), cheek (20%), and lower lip (18%). They occurred more often between the ages of 11 and 30 (31%), and between 50 and 80 (50%). 75% of the referrals came from specialists, 15% from general practitioners, and 10% from the Department of Oral Medicine.

Recurrences were unusual for both cyst types. 17 cases of extravasation cysts were reported as recurrences and one case of retention cyst.

### Key words

*Oral mucoceles, extravasation cysts, retention cysts*

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## Salivcystor; extravasations-och retentionscystor, 298 fall

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### Sammanfattning

© Syftet med denna studie var att studera orala salivcystor och fördelningen mellan extravasations- respektive retentionscystor med avseende på kön, ålder, lokalisering, recidiv, remissinstans samt skillnader mellan de två typerna. Materialet omfattade 305 PAD-remisser till Avdelningen för Oral Patologi, Institutionen för Odontologi, Sahlgrenska Akademien vid Göteborgs Universitet under tidsperioden 1993-2003. Sju remisser uteslöts pga att vissa data saknades och det slutliga antalet blev 298 remisser. Jämfört med de studier vi funnit baseras denna studie på ett av de största underlagen hittills.

Extravasationscystor utgjorde majoriteten av fallen, 258 st. Vi fann en viss överrepresentation bland kvinnor (55 %) och underläppen var den mest frekventa lokaliseringen (71 %). Extravasationscystor var vanligast i ålder 0-40 år, 84%, varav de flesta förekom i åldern 11-20 år (34%). 62% av PAD-remisserna kom från specialister, 28% från allmäntandläkare samt 10% från Oral Medicin.

Retentionscystorna var inte lika vanliga, 40 st, och förekomsten var även här något högre hos kvinnor, 58%. Vi fann en jämnare fördelning med avseende på lokalisering och ålder. Vanligaste lokaliseringen var dock munbotten (25%), kind (20%) och underläpp (18%). Retentionscystorna förekom något oftare i åldrarna 11-30 år (31%) samt 50-80 år (50%).

75% av PAD-remisserna kom från specialist, 15% från allmäntandläkare och 10% från Oral Medicin.

Recidiv var ovanligt för båda typerna. Totalt fann vi 17 recidiv av extravasationscystorna och endast ett recidiv av retentionscystorna.

## Introduction

Mucoceleles are common lesions of the oral mucosa which appear as mucosal swellings of varying size, containing mucus. There are two types, extravasation cysts and retention cysts. Both forms involve the minor salivary glands but differ in their histopathological appearance and pathogenesis (5, 8).

The most common form is the extravasation cyst (3, 4, 5, 7, 9). It is caused by trauma to the minor salivary gland excretory duct resulting in extravasation of mucus into the surrounding connective tissue, which induces a secondary inflammatory reaction. Histologically, the extravasation cyst is characterized by the lack of epithelial lining and the mucus is surrounded by condensed granulation tissue. Clinically, they appear as translucent or bluish diffuse swellings of varying size from 1 to 1.5 cm. The lower lip is the most frequent location and the cyst is more common in younger patients (5, 8).

The retention cyst is characterized by mucus surrounded by an epithelial lining, caused by obstruction of the salivary glandular duct system (resulting in intraglandular development of the cyst). The colour is that of normal mucosa mostly without peripheral inflammatory infiltration. On palpation they are mobile and the size varies from 3 to 10 mm. They appear in all different locations of the oral mucosa, even extra orally, and are more common in older patients (5, 8).

Mucoceleles located in the floor of mouth are usually defined as "ranula" in the literature. They are associated with the duct system of the sublingual glands and they vary in size. Large ranulas can even deviate the tongue (5).

The purpose of this study was to identify the frequency of each form, sex- and age distribution, location, recurrences, referent and the differences between the two forms.

## Material and Method

Three-hundred-five cases of mucoceleles were retrieved from the departmental archives of the Department of Oral Pathology at the Institution of Odontology, The Sahlgrenska Academy at Göteborg University between 1993 and 2003. Sex, age, location, recurrences, referent and differences between the two types were recorded for all cases. The mucosa was divided into the following locations: floor of the mouth, lower lip, upper lip, cheek, palate, tongue, alveolar crest and extra oral. Cysts in the sinus and nasal cavity were categorised as extra oral. Remittents have been divided into specialists, general practitioners, and the Department of Oral Medicine.

## Results

The total number of biopsies during the period studied was 12,857. Of the biopsies diagnosed as mucoceleles, 264 were extravasation cysts and 41 retention cysts. The mucoceleles comprized 2,4% of the total number of biopsies. Of a special subgroup of extravasation cyst, the so called superficial mucocele (9), two cases were included. One in the palate and 1 in the lower lip, both without recurrences. The material included 18 recurrences (17 extravasation cysts, 1 retention cyst). Six cases of extravasation cysts were excluded because locations were not mentioned in the referrals and 1 case of retention cyst because age was missing. This study is based on the remaining 298 mucoceleles, 258 extravasation cysts and 40 mucus retention cysts.

Age, sex distribution and localisation are shown in Diagrams 1-4 and in Table 1. 161 referrals (62%) came from specialists, 72 (28%) from general practitioners, and 25 (10%) from the Department of Oral Medicine. 17 cases (7%) were recurrences. In 13 cases of mucous retention cyst sialolithiasis were found in the biopsies.

## Discussion

Our study investigated one of the largest number of cysts, compared to earlier studies (1, 2, 3, 4, 6, 7, 9, 10), and confirmed that extravasation cysts are the most common form of the two types (2, 7, 9, 10).

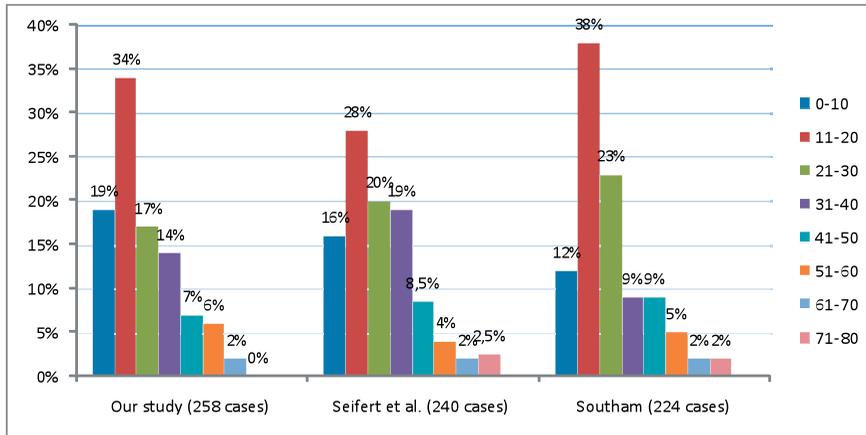
A number of studies have shown that there is an equal distribution of mucoceleles among both sexes (1, 2, 3, 10). In our material we found that both types had a moderate predominance among women, extravasation cysts 55%, retention cysts 58%. Seifert et al (7), on the other hand, found that extravasation cysts were more common among men (60%). This was also found by *Praetorius et Hammarström* (4), although they had a different definition of their cysts, e.g., oral mucoceleles without epithelial lining. Regarding retention cysts, *Seifert et al* (7) also found a slight predominance in women.

The age distribution for extravasation cysts showed that approximately 50% occurred between the

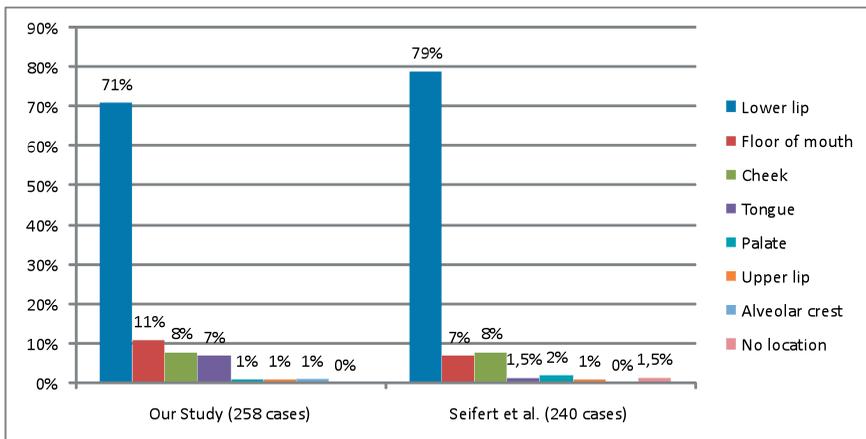
© Table 1. Sex distribution extravasation and retention cysts (%)

	Extravasation cysts		Retention cysts	
Men	116	45%	17	42,5%
Women	142	55%	23	57,5%
Total	258	100%	40	100%

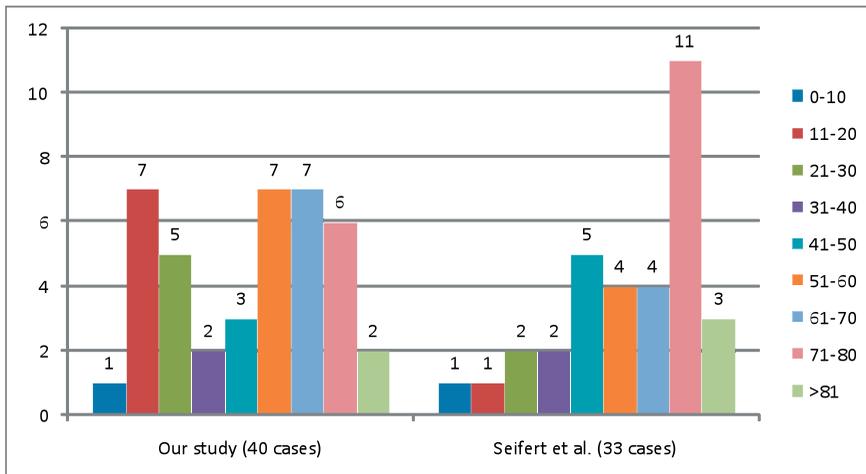
© Diagram 1. Age Distribution Extravasation cysts (%)



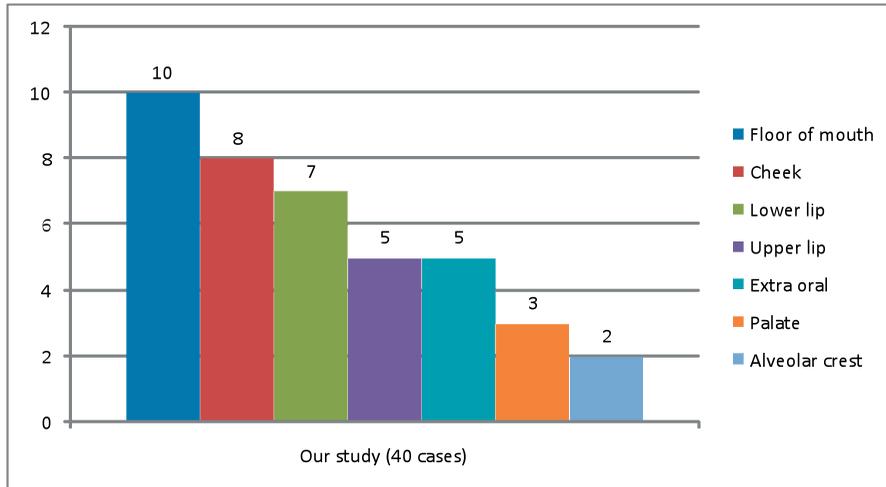
© Diagram 2. Location Extravasation cysts (%).



© Diagram 3. Age Distribution Retention cysts (n)



© Diagram 4. Location Retention cysts (n)



ages of 0 and 20 years and had a peak incidence in the second decade. This is confirmed in studies and literature (5, 8). 84% of the cases were under 40 years of age in our study. Similar results have been shown by *Southam et al* (9), *Seifert et al* (7) and *Praetorius et Hammarström* (4), Diagram 1.

*Seifert et al* (7) have published a comparable study with 33 cases of retention cysts. They found that retention cysts were more common over the age of 70 years (42%). They also had an age peak in the eighth decade with 33%. In our 40 cases only 20% of the retention cysts were found in this age group and no specific age dominated. Retention cysts were most uncommon in the ages between 31 and 50 years, Diagram 2.

The lower lip was by far the most common location for extravasation cysts, 71% in our study. The same findings have been made by *Southam et al* (9) 68%, *Harrison et al* (2) 73%, *Seifert et al* (7) 79%, *Chaudhry et al* (1) 71%, *Oliveria et al* (3) 60%, *Praetorius et Hammarström* (4) 69%, *Robinson et al* (5) 51%.

Retention cysts, on the other hand, were most often found in the floor of the mouth, cheek and lower lip. But there were no significant differences between locations. *Seifert et al* (7) have shown an even more equal distribution between locations. *Harrison et al* (2) found that floor of the mouth and cheek were the most frequent locations (9/10) with a total of 10 retention cysts. *Southam et al* (9), on the other hand, found most retention cysts in the palate (6/12) with a total of 12.

Recurrences are not often reported. In our study

recurrences were found in 17 cases of extravasation cysts (7%) and in only one case of retention cysts (2.5%). *Yamasoba et al* (10) who reviewed 70 patients with lower lip mucoceles only reported 2 cases of recurrences. *Oliveria et al* (3) found 20 recurrences out of 112 cases (18%) where previous trauma was still present in 10 of the cases (9%).

### Conclusion

Extravasation cysts are without doubt the most common form of mucoceles. There is a slight predominance in women and the cysts occur in most cases in the lower lip. There is a peak incidence in the second decade and approximately 80% occur in patients under 40 years of age.

The sex distribution of retention cysts is similar to that of extravasation cysts. It is harder to draw any general conclusions from the findings relative to age and location since they are more evenly distributed.

Recurrences are quite rare in both types of cysts.

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# Periodontal health status in Swedish adolescents: an epidemiological, cross-sectional study

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## Abstract

© The aim of this epidemiological survey was to analyze the periodontal conditions of 19-year old individuals in two rural county areas, i.e. Fyrbodal and Skaraborg, Västra Götaland, Sweden, with special reference to gender and socioeconomic grouping. A randomized sample of 506 individuals (Fyrbodal 250 and Skaraborg 256 individuals, respectively) was clinically examined with regard to oral hygiene, gingivitis, periodontal pockets and gingival recession. Bitewing radiographs were used for assessment of alveolar bone level (ABL) and dental calculus. A questionnaire-based interview regarding oral hygiene habits was included.

A majority of the subjects (76%) claimed to brush their teeth at least twice a day, while interdental hygiene means were used daily by 4%. The subjects showed a mean plaque score of 47% and a gingivitis score of 56%. Forty-six % of the adolescents had a plaque score of  $\geq 50\%$ , whereas the corresponding figure for gingivitis was 62%. The subjects had on average 5.5 teeth with facial gingival recession. The mean prevalence of sites with probing depth (PPD) of  $\geq 4\text{mm}$  was 8, out of which 99% were located at proximal sites. A radiographic bone level of  $>2\text{mm}$  was observed at on average 0.4 teeth per subject. Logistic regression analyses revealed that gender (males) and county area (Fyrbodal) were significant factors for a high plaque and gingivitis score. There was no significant difference in periodontal conditions in relation to socio-economic grouping.

In conclusion, the survey revealed higher prevalence of plaque and gingivitis among male than female adolescents, but no differences between socioeconomic groups.

## Key words

*Gingivitis, periodontal disease, oral epidemiology, gender, socio-economical.*

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## En epidemiologisk tvärsnittstudie avseende parodontalt hälsostatus bland 19-åringar i Västra Götaland

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### Sammanfattning

☉ Syftet med studien var att undersöka parodontalt hälsostatus bland 19-åringar i Västra Götalandsregionen med fokus på eventuella skillnader i relation till kön och socio-ekonomisk gruppering. Ett randomiserat urval om 506 individer (Fyrbodal 250 och Skaraborg 256) deltog i studien. Den kliniska undersökningen omfattade registrering av plack, gingivit, ficksonderingsdjup samt bukkal gingival retraktion. Den röntgenologiska undersökningen omfattade 4 bite-wing som analyserades avseende alveolär benhöjd och förekomst av tandsten. Vidare användes ett strukturerat frågeformulär rörande munhygienvanor. Socio-ekonomisk gruppering av individerna baserades på ett index som ligger till grund för resursfördelning till Folktandvårdens kliniker.

Majoriteten (76%) uppgav att de borstade tänderna  $\geq 2$  gånger per dag, men endast 4% uppgav daglig approximal rengöring. Medelvärde för plackindex var 47% och för gingivalt blödningsindex 56%. Fyrtio-sex procent av ungdomarna hade ett plackindex  $\geq 50\%$  och 62% uppvisade ett gingivalt blödningsindex av motsvarande grad. Gingival retraktion noterades i medeltal vid 6 tänder. I genomsnitt uppmättes 8 ytor med ett sonderingsdjup  $\geq 4$  mm och 99% av dessa fickor var lokaliserade approximalt. Alveolär benförlust  $>2$  mm noterades vid i genomsnitt 0.4 tänder/individ. Logistisk regressionsanalys visade att kön (man) och regiondel (Fyrbodal) var signifikanta faktorer för högt plack- och gingivit index. Inga signifikanta skillnader i parodontalt status noterades med avseende på socio-ekonomisk gruppering.

Sammanfattningsvis påvisade studien högre plack och gingivitförekomst hos män jämfört med kvinnor men att det inte förelåg några skillnader i parodontalt status med avseende på socio-ekonomisk gruppering.

## Introduction

Data reported from epidemiological surveys performed in Sweden during the last decade have revealed comparatively poor oral hygiene conditions and a high prevalence of gingivitis among adolescents (1, 7). From an epidemiological survey of a city population of 19-year old individuals, *Abrahamsson et al.* (1) reported that 70% of the individuals showed a plaque score of  $\geq 50\%$  and that the corresponding figure for gingivitis was 37%. High prevalence figures of plaque and gingivitis, although lower than those in the previous study, were also reported among young adults in epidemiological studies from the county of Jönköping (7). However, the most recent cross-sectional survey performed in 2003 in the county of Jönköping (5) revealed a decrease in plaque- and gingivitis scores compared to 10 years ago. It has been speculated that changes in the society influencing oral health care as well as oral health behavior among young people (1, 10, 12) may account for differences over time as well as between various urban and rural country regions.

A key-factor for the prevention of periodontal diseases is the individual's own efforts with regard to daily oral hygiene. However, individuals' willingness to adhere to different health promotion programs is a complex issue (11) and it is indeed a challenge for dental professionals to motivate young individuals to prevent an oral disease that might be evident merely in a distant future. Interestingly, *Hugoson et al.* (4) concluded based on comparison of cross-sectional data collected in 1973, 1983, 1993 and 2003 that the knowledge among individuals about periodontal diseases has not changed much in Sweden during 30 years, despite extensive information programs provided by schools and dental clinics. Hence, although oral health promotion programs were shown to result in a reduction of plaque and gingivitis scores in a short-term perspective, the long-term benefits of such interventions have been questioned (18). In a 3-year clinical trial (6) on the effects of dental health promotion programs directed to young adult individuals it was reported that simple preventive programs had a positive effect on knowledge regarding oral health issues, but lasting beneficial changes in the individual's oral health behavior were less evident. This finding point to the necessity to focus on analysis of psychosocial-behavioral factors related to periodontal health/disease in order to enhance the cost-effectiveness of prevention programs. However, information in the literature on such aspects is very limited. In a previous study we investigated

the periodontal health conditions in a Swedish city population of 19-year olds (1). The present epidemiological survey was performed to generate information about periodontal conditions and a broad variety of psychosocial-behavioral factors related to periodontal health conditions of adolescents/young adults living in two rural areas in the county council of Västra Götaland, Sweden. The aim of this first report of the study was to describe the periodontal health conditions with special reference to gender and socio-economic grouping.

## Material and methods

### Subjects

The survey was performed during the period August 2005 to September 2006 and comprised a computer-based random selection of 10% of all individuals born in 1987 and living in two different areas (Fyrbodalen and Skaraborg) in the county council of Västra Götaland, characterized as mainly rural areas with small municipalities and a few medium-sized cities. A total of 708 individuals (356 individuals in Fyrbodalen and 352 individuals in Skaraborg) were invited by mail to a clinical examination and a questionnaire based interview. The individuals who were willing to participate in the study were scheduled for an appointment at their regular dental clinic for a structured interview and a clinical and radiographic examination. The adolescents who did not respond to the invitation were contacted a second time. The Ethics Committee of Göteborg University reviewed and approved the study protocol and all participants provided informed consents.

### Questionnaires

The participants were asked to complete a set of questionnaires for self-assessment of perceptions and attitudes towards dental care and oral health issues immediately before the clinical examination. The questionnaire-package took about 25 min to answer. The results of this part of the study will be reported in a separate publication.

### Structured interview

A structured interview was performed to obtain information about general health conditions and oral hygiene habits (tooth brushing frequency and interdental cleaning).

### Clinical assessments

The clinical examinations were performed by four specially trained and calibrated dental hygienists.

The following variables were assessed (3rd molars excluded) in the order listed:

- Number of teeth
- Oral hygiene status (Plaque score) - assessed as presence/absence of visible plaque on 4 surfaces (mesial, buccal, distal, lingual) of the 6 Ramfjord index teeth (15).
- Gingivitis – defined as presence of bleeding following manual, angulated probing of the sulcus area (9) and registered at 6 sites (mesio-buccal, mid-buccal, disto-buccal, disto-lingual, mid-lingual and mesio-lingual) of all teeth.
- Probing pocket depth (PPD) - measured at 6 sites per tooth with a standard periodontal probe (UNC 15 probe) to the closest higher mm.
- Gingival recession - defined as location of the gingival margin apical to the cement-enamel junction (CEJ) and scored in mm for facial tooth sites.

#### *Radiographic assessments*

Four standardized bitewing radiographs of the premolar and molar regions were obtained. In the radiographs, the alveolar bone level (ABL) was assessed by measuring the distance in mm from the CEJ to the alveolar bone crest, i.e. the point at which the periodontal ligament space was considered to have a normal width (2). The measurements were made by the use of a magnifying lens (7x) to the nearest lower 0.5mm at all mesial and distal tooth surfaces reproduced in the bite-wing radiographs. A site was considered “non-readable” if the alveolar bone crest or the CEJ could not be defined. In addition, dental calculus was scored dichotomously as present/absent for each posterior jaw quadrant. A jaw quadrant was scored positive for calculus if at least 2 tooth surfaces demonstrated presence of radiographically detectable calculus. One examiner (JSE) performed all the radiographic assessments. The intra-examiner reproducibility of alveolar bone level measurements was determined by repeated assessments of 62 randomly selected subjects (a total of 1841 sites) with a 1-3 week interval. The standard deviation for the repeated measure was 0.34 with 96.7% of the measurements reproduced within a difference of  $\pm 0.5$  mm.

#### *Socio-economic grouping*

A socio-economic (SE) characterization of the population sample was performed in accordance with an index used by the Community Dental Service by which the SE-index for a specific region in the com-

munity is determined based on the % of individuals in the age of 18-64 years (i) having a native country other than the Scandinavian countries, (ii) receiving social allowance, (iii) being unemployed, and (iv) having a low education level (elementary school only), in relation to corresponding figures for the total population in the community. Based on the calculated SE-index for the various regions of geographic location of dental clinics three SE-groups were defined; SE-1 (SE-index < 8%), SE-2 (SE-index > 8%), SE-3 (SE-index > 19.5%) (1). The adolescents were socio-economically classified according to the SE-index of the community dental clinic at which they were listed as patients.

#### *Data analysis*

The highest value with respect to probing measurements (pocket depth, gingivitis) at mesio-buccal/mesio-lingual and disto-buccal/disto-lingual tooth sites, respectively, was selected to represent the proximal site. The outcome data were expressed as mean values and standard errors (S.E.) and as absolute and % frequencies on the subject level. Differences in proportions of individuals with regard to various characteristics were statistically tested by the use of  $\chi^2$ -analysis. Student's t-test was used for analysis of continuous variables. Finally, multiple logistic regression analysis was used in order to explore associations between various subject and clinical characteristics. The dependent variables evaluated were plaque ( $\geq 50\%$ ), gingivitis ( $\geq 50\%$ ), probing pocket depth  $\geq 4$ mm ( $\geq 10$  sites), and facial gingival recession ( $\geq 1$  site). All data analyses were processed by the use of the Statistical Products Service Solutions - SPSS (17) and with a p-value of 0.05 as the level of statistical significance.

#### *Results*

Out of the 707 randomly selected subjects 506 (72%) attended the examination; 250 (70%) in Fyrbodalen and 256 (73%) in Skaraborg. Fifty-three % of the respondents were females and 10% were born outside the Scandinavian countries. There were no significant differences between the two county areas in these respects (Table 1).

Reasons for not participating in the survey (n=201) were (i) no time/not interested (66%), (ii) moved from the area (3%), (iii) did not show up at the examination (15%), (iv) no contact/unknown reason (16%). The proportion of males was greater among the non-respondent than the respondents (62% vs. 46%;  $p < 0.001$ ). The socio-economic classification of

© **Table 1.** Description of the study group (N=506) in the respective county area (Fyrbodal and Skaraborg) with regard to gender, native country and SE-index.

Variable	Fyrbodal n=250	%	Skaraborg n=256	%	Significance
Males	123	49	111	43	NS
Females	127	51	145	57	
Native country					NS
Scandinavia	233	93	236	92	
Other countries	17	7	20	8	
SE- index					NS
SE-1	125	50	144	56	
SE-2	125	50	112	44	
SE-3	0		0		

$\chi^2$  test; NS= not significant

the subjects revealed no significant difference between the county areas (Table 1). Since initial analysis indicated no correlations between SE-index and clinical variables, the variable SE-index was omitted in further description of the data.

*Oral hygiene habits*

A majority (76%) of the respondents stated that they brushed their teeth at least twice a day while about 4% of the subjects did not perform daily tooth-brushing. Interdental hygiene means (mainly dental floss) were used daily by 4% of the adolescents and 45% reported a sporadic use. A significantly higher proportion of females than males brushed their teeth at least 2 times/day (81% vs. 70%;  $p < 0.05$ ). There were also a significantly higher proportion of females who stated daily use of dental floss compared to males (6% vs. 1%;  $p < 0.001$ ). No difference in reported oral hygiene habits were observed with regard to county area.

*Clinical assessments*

Number of teeth

The mean number of teeth among the adolescents was 27.3. Fifteen % missed 1-2 teeth, 12% 3-4 teeth and about 0.5% (3 individuals) >4-5 teeth. Missing teeth were predominantly premolars (2.5% of the total material). There was no significant difference between gender or between the two county areas regarding missing teeth.

Oral hygiene status

The mean % of tooth surfaces harboring visible plaque was for the entire sample 47%, with a higher score for proximal (51%) than buccal (24%) tooth surfaces. Forty-six % of the examined individuals had a plaque score  $\geq 50\%$  whereas a score of  $< 20\%$  was found in only 13% of the subjects. Males had a significantly higher mean plaque score than females (53% vs. 41%;  $p < 0.001$ ). The oral hygiene standard assessed by plaque scorings was significantly poorer among individuals living in Fyrbodal than in Skaraborg (Tables 2 and 3).

© **Table 2.** Plaque and gingivitis scores. Mean percentage (S.E.) of sites with presence of visible plaque and gingivitis in the respective county area (Fyrbodal and Skaraborg).

Variable	Fyrbodal Mean (S.E.)	Skaraborg Mean (S.E.)	p-value
Plaque score (%)			
All surfaces	55.8 (1.3)	37.6 (1.5)	<0.001
Buccal	25.8 (1.6)	22.1(1.6)	>0.05
Proximal	64.1 (1.5)	38.1 (1.6)	<0.001
Gingivitis score (%)			
All surfaces	64.3 (0.9)	46.9 (1.2)	<0.001
Buccal	31.8 (1.6)	24.7 (1.3)	<0.01
Proximal	90.1 (0.8)	63.4 (1.2)	<0.001

Student's t-test

© **Table 3.** Plaque and gingivitis scores. Percentage (%) of individuals (n) with different levels of plaque and gingivitis in the respective county area (Fyrbodal and Skaraborg).

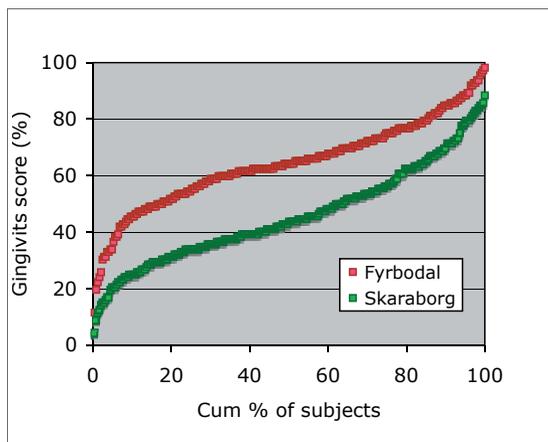
Variable	Fyrbodal % (n)	Skaraborg % (n)	p-value
Plaque			
<20%	3.6 (9)	22.6 (58)	<0.001
$\geq 50\%$	62.4 (156)	29.3 (75)	<0.001
Gingivitis			
<20%	0.8 (2)	4.3 (11)	<0.05
$\geq 50\%$	84.0 (210)	39.8 (102)	<0.001

$\chi^2$  test

### Gingivitis

The overall mean gingivitis score was 56%. Gingivitis was more prevalent for proximal (77%) than buccal (28%) sites. Sixty-two % of the individuals showed a full-mouth gingivitis score of  $\geq 50\%$  and only 3 % had a score of  $< 20\%$ . Males had significantly higher % of sites with gingivitis than females (59% vs. 53%;  $p < 0.001$ ). The adolescents in Fyrbodol showed significantly higher prevalence of gingivitis than those in Skaraborg (Tables 2 and 3, Figure 1).

© **Figure 1.** Cumulative distribution of the subjects according to Gingivitis scores in the respective county area (Fyrbodol and Skaraborg)



### Probing pocket depth

For the entire sample, the mean number of sites with PPD  $\geq 4$  mm was 8, out of which 99% were located at proximal sites. Nine % of the adolescents showed no such sites, while 50% had  $> 5$  sites and 4% had  $> 25$  sites. The highest number recorded was 44 sites (a man born in Sweden). The overall prevalence of sites with PPD  $\geq 6$  mm was low (mean value 0.1 sites/individual). Sites with this magnitude of PPD was only found in 5.5% of the adolescents and predominantly located on the distal aspect of the second molars. One individual (a man born in Somalia) had 8 sites with a PPD  $\geq 6$  mm. Males had significantly higher mean number of sites with PPD  $\geq 4$  mm compared to females, 10 vs. 6 sites ( $p < 0.001$ ), respectively. There was significantly higher prevalence of sites with PPD  $\geq 4$  mm among individuals in Fyrbodol compared to Skaraborg (Table 4).

© **Table 4.** Probing pocket depths (PPD), gingival recession and alveolar bone level (ABL). Mean number of sites (S.E.) in the respective county area (Fyrbodol and Skaraborg).

Variable	Fyrbodol Mean (S.E.)	Skaraborg Mean (S.E.)	p-value
PPD $\geq 4$ mm			
All surfaces	10.2 (0.5)	6.1 (0.4)	$< 0.001$
Proximal	9.9 (0.5)	5.9 (0.4)	$< 0.001$
PPD $\geq 6$ mm			
All surfaces	0.05 (0.03)	0.1 (0.03)	$> 0.05$
Proximal	0.05 (0.03)	0.1 (0.02)	$> 0.05$
Gingival recession (Facial sites)			
ABL $> 2$ mm	9.5 (0.4)	1.7 (0.2)	$< 0.001$
ABL $> 2$ mm	0.3 (0.07)	0.6 (0.05)	$< 0.01$

Student's *t*-test

### Gingival recession

The subjects had on average 5.5 teeth with facial gingival recession. Thirty-two % of the individuals had no recession defects, while 1-5 teeth with gingival recession was observed in 28% and  $\geq 6$  teeth in 40% of the adolescents. More than 17 teeth with facial gingival recession were found in 6% of the subjects and the highest observed number of gingival recessions was 24. Adolescents in Fyrbodol showed significantly higher prevalence of gingival recessions than in Skaraborg (Table 4), while there were no statistically significant difference in this aspect between males and females (5.8 and 5.4 teeth, respectively).

### Radiographic assessments

On the average 31 tooth sites per subject were assessable with regard to alveolar bone level (ABL). The mean number of proximal sites with a distance between the CEJ and the marginal bone crest of  $> 2$ mm was 0.4 (range 0-15). Sixty-eight % of the individuals showed no sites with an ABL  $> 2$ mm. Five individuals had 3 positive sites and the maximal recorded number was 15 (a male born in Somalia). Radiographically detectable calculus in at least one jaw quadrant was observed in 3% of the individuals. No statistically significant differences with regard to radiographic assessments were found between the two county areas (Table 4) or between males and females (mean number of sites with ABL  $> 2$ mm; 0.5 and 0.4, respectively).

### Regression analyses

Multiple logistic regression analyses were performed in order to identify associations between subject

© **Table 5.** Logistic regression models (enter) predicting plaque ( $\geq 50\%$ ), gingivitis ( $\geq 50\%$ ), PPD $\geq 4$  mm ( $\geq 10$  sites) and facial gingival recession ( $\geq 1$  site).

Variable	$\beta$	S.E.	OR	CI	p-value
<i>Model 1 Plaque</i>					
County area (Fyrbodal)	1.4	0.2	4.1	2.8-5.9	<0.001
Gender (males)	0.9	0.2	2.4	1.7-3.6	<0.001
<i>Model 2 Gingivitis</i>					
County area (Fyrbodal)	2.1	0.2	7.9	5.2-12.0	<0.001
Gender (males)	0.4	0.2	1.6	1.0-2.3	<0.05
<i>Model 3 PPD <math>\geq 4</math>mm</i>					
County area (Fyrbodal)	1.1	0.2	3.0	1.3-2.9	<0.001
Gender (males)	0.7	0.2	1.9	1.0-2.3	<0.01
<i>Model 4 Facial gingival recession</i>					
County area (Fyrbodal)	2.7	0.3	14.5	8.6-24.5	<0.001
Gender (males)	-0.2	0.2	0.8	0.5-1.3	>0.05

characteristics (gender and county area) and defined clinical outcome variables. The models formulated for plaque ( $\geq 50\%$ ), gingivitis ( $\geq 50\%$ ) and PPD  $\geq 4$ mm ( $\geq 10$  sites), respectively, revealed that gender (males) and county area (Fyrbodal) were statistically significant factors associated with high plaque and gingivitis scores, as well as PPD  $\geq 4$ mm (Table 5). The level of explained variance ( $R^2$ ) for the three models was 19%, 27% and 11%, respectively. The regression model having gingival recession as dependent variable revealed significant predictive power ( $R^2=0.35$ ) for county area (Fyrbodal) but not for gender (Table 5).

## Discussion

The aim of the present survey was to analyze periodontal conditions of 19-year olds living in two rural county areas (Fyrbodal and Skaraborg) in Västra Götaland, Sweden, with special reference to gender and socioeconomic grouping. The results revealed poor oral hygiene conditions among 19-year olds, with higher prevalence of plaque and gingivitis in Fyrbodal compared to Skaraborg and among male than female adolescents, but no differences between socioeconomic groups.

The study sample was generated by random selection of 10% of 19-year olds living in the two county areas. This age cohort was selected since it represents the final year of organized free-of-charge dental care for Swedish children and adolescents. Out of the randomly selected subjects, 72% attended the clinical

examination; a figure that was somewhat higher than that of other recent epidemiological surveys of young individuals in Sweden (58-65%) (1, 4). Among the non-respondents males were overrepresented, as was also shown in a previous epidemiological study of a similar age-group of a city population (1) and may be related to reported differences with regard to oral health related attitudes and behaviors between male and female adolescents/young adults (3, 13, 14, 16).

The great majority of the adolescents brushed their teeth daily, but approximal cleaning was not frequently practiced. In fact, only 4% reported daily use of dental-floss. It was also evident that females had more favorable oral hygiene habits than males. These observations corroborate findings reported from previous surveys of oral hygiene habits in adolescent and young adult populations (1, 4, 8, 13). With regard to the efficacy of the oral hygiene, the data revealed that 46% of the adolescents showed a plaque score of  $\geq 50\%$  and 62% a gingivitis score of corresponding magnitude. A plaque and gingivitis score  $< 20\%$ , which may be regarded as a high standard of self-performed plaque control, was only found in 13% and 7% of the individuals, respectively. Furthermore, differences in these respects were observed between gender, with higher plaque and gingivitis scores among males than females and between the two county areas (poorer conditions among individuals in Fyrbodal than in Skaraborg), but not with respect to the socio-economic factor. The findings are in line with data from a previously

reported survey of oral hygiene conditions in a Swedish city population of the same age (1). Similarly, Hugoson *et al.* (7) reported a high prevalence of plaque and gingivitis among 20-year old individuals in the county of Jönköping. However, the most recent cross-sectional survey of the same county population (in 2003) (5) revealed improved oral hygiene conditions compared to 10 years ago. Our findings of high plaque and gingivitis scores are not in support of an interpretation of a general improvement in oral hygiene among young individuals, but rather indicate that there may be differences in oral hygiene conditions between individuals living in different geographic regions of Sweden. Further studies are warranted, however, before any conclusions can be drawn about potential geographical differences and/or general trends altered oral hygiene conditions among young individuals.

Poor oral hygiene status in adolescents/young adults may not necessarily lead to the development of a destructive periodontitis later in life. Even so, the most important factor for the prevention of periodontal disease is a high standard of oral hygiene. In this context, the results from the current and previous studies are disappointing bearing in mind that Swedish individuals up to 20-year of age receive regular dental care free of charge and that the Public Dental Service in most counties provide comprehensive preventive programs directed to children and adolescents. The quality and content of such prevention programs, however, may differ. It has also been speculated that the findings may reflect a cut-down in preventive actions as a consequence of restricted financial resources for the community dental service during recent years (1, 10). However, explanations may also be found in social and behavioral factors influencing motivation and willingness for oral health care among young individuals (12). Hence, information- and prevention programs may not be adequately adapted to nowadays adolescents/young people and as a consequence not effective enough in motivating them to take own responsibility for their oral health care. According to Hugoson *et al.* (4) the knowledge about periodontal diseases has not changed much during the last decades, despite the ambitious and extensive information provided by dental professionals at schools and dental clinics. Moreover, the lasting beneficial effect of different oral health promotion interventions has been questioned (6, 18). Taken together, these findings underline the importance to focus on psychosocial/behavioral aspects of oral health. A deeper know-

ledge about such factors might increase the effectiveness of oral health promotion programs directed to young individuals.

To conclude, the results of the current epidemiological survey demonstrated poor oral hygiene conditions among Swedish adolescents and emphasize the need for a psychosocial/behavioral research approach for improvement of the oral health care among young people.

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# Use of radiography in public dental care for children and adolescents in northern Sweden

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## Abstract

© The primary aims were to investigate the total number of radiographs and the reason for dental radiography in children and adolescents in the Public Dental Health Service. Secondary aims were to study the influence of caries experience and orthodontic treatment on the number of radiographs. For this retrospective study, 544 adolescents regularly attending three Public Dental Health clinics in the county of Västerbotten, northern Sweden were selected. The number of radiographs exposed each year from 3 to 19 years of age was registered. Information on reason for the radiographic examination was extracted from dental records as well as the caries experience at 19 years of age. The attrition rate was 7% due to incomplete data. The total mean number of radiographs exposed was  $23 \pm 6$  of which  $1 \pm 2$  were extra-oral radiographs. Bitewing radiographs for caries registration constituted 87% of the intra-oral radiographs with a mean number of  $19 \pm 4$  exposures. There was a statistically significant difference ( $p < 0.01$ ) between subjects with caries experience ( $20 \pm 4$ ) and those with no caries ( $16 \pm 4$ ). No gender-related differences were displayed. During preschool ages, bitewing radiographs were taken in less than 10% of the children. Children treated at specialist clinics in orthodontics displayed higher number of radiographic examinations than non-referred children ( $p < 0.01$ ).

Conclusion: A mean of 23 radiographs were exposed and bitewings for caries detection were the most common radiographic examination. Fewer bitewing radiographs were exposed in caries-free subjects over time but its use during the preschool ages was low. Orthodontics treatment increased the frequency of radiography significantly.

## Key words

*Bitewings, caries, dental care, dental radiography*

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## Utnyttande av röntgen inom barn- och ungdomsvården

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### Sammanfattning

☉ Det främsta syftet med studien var att mäta det totala antalet röntgenbilder exponerade på barn och ungdomar mellan 3 och 19 år i Folk tandvården och skälet till att bilderna togs. Dessutom var syftet att studera hur karieserfarenheten påverkade antalet bitewing röntgenbilder samt hur behandling på specialistklinik i ortodonti påverkade det totala antalet exponerade röntgenbilder. 544 ungdomar, födda 1986, från 3 Folk tandvårdskliniker i Västerbotten, i norra Sverige valdes ut för studien. Hos 7 % fanns inga tillgängliga journaler. Antalet röntgenbilder tagna varje år från 3 till 19 år räknades. Information om anledningen till röntgenundersökningen hämtades ur journalerna, liksom tidigare karieserfarenhet uttryckt som karierade och fyllda ytor (DFS) och karierade och fyllda approximalytor (DFSa), vid 19 års ålder. Det totala antalet röntgenbilder tagna mellan 3 och 19 år var  $23 \pm 6$ , av vilka  $1 \pm 2$  var extraorala bilder. Bitewing bilder utgjorde 87 % av de intraorala bilderna med i medeltal  $19 \pm 5$  exponeringar med  $16 \pm 4$  på individer utan karieserfarenhet jämfört med  $20 \pm 4$  på individer med karieserfarenhet ( $p < 0.01$ ). Inga könsskillnader kunde ses. Under förskoleåldern togs bitewing röntgenbilder hos mindre än 10 %. Individer som behandlats vid specialistkliniker för ortodonti fick i medeltal  $25 \pm 7$  röntgenbilder tagna jämfört med  $22 \pm 6$  hos dem som inte fått ortodontibehandling ( $p < 0.01$ ).

Slutsatser: I medeltal exponeras 23 röntgenbilder och bitewing röntgen för kariesdiagnostik är den vanligaste orsaken till dental röntgen. Färre bitewing röntgenbilder tas på kariesfria individer. Under förskoleåldern tas få bilder. Behandling på specialistklinik i ortodonti medför ett signifikant ökat antal röntgenbilder.

## Introduction

Since 1974 the Public Dental Health Service organised within the County Councils in Sweden has a responsibility to provide full dental service free of charge for all children and adolescents up to the age of 20 years. In the periodic recall oral examinations, dental radiography is a frequent diagnostic tool. Radiographs are used for caries detection but the technique is also utilized for examination of traumatic injuries, disturbances in tooth development and growth as well as for other pathological conditions. Extraoral radiography, such as panoramic methods and lateral cephalometric projection is utilised when a more complete evaluation of the patient's maxillo-facial situation is required.

Only few studies have investigated the number of radiographs taken within the dental care for children and adolescents. A study from Sweden showed that the mean number of intra-oral radiographs exposed between 3 and 19 years was 24 and that 70-80% of the adolescents underwent a bitewing examination every year (6). The same authors demonstrated that experience of previous caries did not seem to be a significant indicator for when next radiographic examination should be performed (10). Other Swedish data showed that 75% of the patients between 9 and 18 years were subjected to at least one bitewing examination every year (9).

Along with the decreasing caries prevalence (11, 12) and a reduced progression rate of proximal lesions (13) it has been advocated that recall intervals should be based on individual risk assessment and individual needs (7). However, it is not clear whether or not this have influenced the radiographic routines. Moreover, approximately one fourth of the Swedish child population is provided with specialist orthodontic care in which radiography is often used for diagnosis, planning and evaluation of treatment (18). About 30% of 16-year-olds have experienced one or more episodes with a dental trauma (3) and use of radiography is common for diagnosis and follow-ups. No study has hitherto investigated the total number of radiographs in child dental care. The aims of the present study were therefore to enumerate the total number of radiographs exposed between the ages of 3 and 19 years in the Public Dental Health Service and to explore the reason for radiography, to study the influence of caries experience on the number of bitewings and orthodontic treatment at specialist clinics on the number of radiographs.

## Material and methods

The study had a retrospective design and was performed during 2006 in the County of Västerbotten in northern Sweden. The initiative to the study was taken by the Public Dental Health Service as a quality assurance of the oral examination process in child dental care. Since all registrations were extracted solely from dental records and stored anonymously, it was stated by the ethical board that an application for permission not was needed for the project.

### *Subjects and clinics*

544 subjects, born in 1986, from three Public Dental Health Service Clinics were selected for the investigation. The clinics represented different socio-demographic characteristics; two were urban clinics with contrasting socio-economic status and one was located in a rural area. Criteria for inclusion were that the subjects should have been listed and dentally examined at the clinics regularly from 3 to 19 years of age. In two of the clinics, all individuals who fulfilled the inclusion criteria were included in the study. In the third clinic, which was a larger clinic, every second individual according to the recall list was included. Subjects listed and examined at another clinic for some years were included if the dental records and the radiographs could be identified. 38 subjects had moved out of the area and their radiographs could not be located. Thus, a total of 506 individuals (93%) were available for the final evaluation. None of the clinics had introduced digital radiography at the time the investigation was performed.

### *Data collection*

The collection was performed by one examiner (CFK), a specialist in paediatric dentistry, and each subject was given a code number. The number of radiographs exposed each year from 3 to 19 years of age were recorded and transferred to a data file. Information on the reason for the radiographic examination was extracted from the dental records and categorized as shown in Table 1. The caries experience at 19 years was collected from the digital record system (T4; PracticeWorks, Sweden AB) which stores caries scored on dentine level in accordance to the WHO criteria (20) and expressed as the total number of decayed and filled surfaces (DFS) and decayed and filled approximal surfaces (DFSa). Additional information on the number of radiographic exposures was also collected from the orthodontic clinics in the region as well as the specialist clinic for oral radiology. Data were collected by checking

© **Table 1.** Distribution of intraoral radiographic examinations between 3 and 19 years of age (n=506). The figures denote percent, mean, standard deviation and range.

Indication/method	No of radiographs								mean sd range	
	0	1-2	3-4	5-6	7-8	9-10	11-20	21-30		>30
Bitewing						2	65	32	1	19.1±4.6
<i>Periapicals</i>										
Trauma	74	17	6	2			1			0.6±1.6
Missing or supernumerary teeth	80	15	3	1	1					0.4 ± 1.0
Position localization	73	10	9	5	1	1	1			1.0±2.3
Endodontics	95	3	1	1						0.2±1.0
Other	71	22	5	1	1					0.6±1.2
Total intraoral radiographs										21.9±5.9 0-43

whether the participants had records at these clinics and the number of radiographs and reasons for exposure were then registered. In order to check the intra-examiner reliability (4) of number of radiographs and reasons for exposure, 50 subjects were re-examined one month after the first registration by checking their records at the Public Dental Health Service clinics, Orthodontic clinics as well as the specialist clinic for Oral Radiology. The kappa-value which provides a measure of concurrence between the two assessments was 0.96.

#### Statistical methods

Data were processed with the SPSS software (version 15.0, Chicago; Ill, USA). For the statistical calculations, caries experience was dichotomized as positive (DFS/DFSa >0) or negative (DFS/DFSa=0). A similar dichotomization was also performed for treatment at a specialist clinic in orthodontics; positive if treated and negative if the subject not had been treated. ANOVA was used to test differences in number of radiographs between gender, caries experience, clinics and treatment at specialist clinics in orthodontics. The statistically significance level was set at  $p < 0.05$ .

#### Results

##### Total number of radiographs

The total number of radiographs exposed up to 19 years of age was  $23 \pm 6$ , of which  $1 \pm 2$  were extra-oral radiographs. Concerning extra-oral imaging, 34%

were examined with 1-2 panorama radiographs while 5% had  $\geq 3$  (Table 2). The distribution and reasons for taking the radiographs is shown in Table 1 and 2. The dominating reason for intraoral radiography was caries detection (87%) followed by localization of tooth germs (5%), trauma (3%) and missing teeth (2%). No significant differences in relation to gender were noted (data not shown). The distribution of total number of radiographs, bitewing radiographs and extraoral radiographs is further detailed in Figure 1.

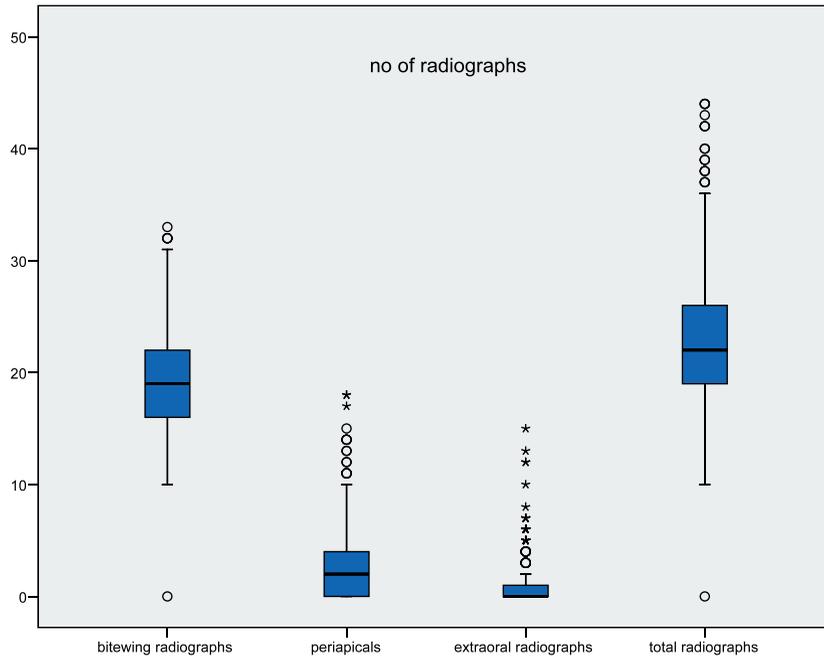
##### Bitewing radiographs

The mean number bitewing radiographs were 19

© **Table 2** Distribution of extraoral radiographic examinations between 3 and 19 years of age (n=506). The figures denote percent, mean, standard deviation and range.

Extraoral radiographs	No of radiographs				mean, sd, range,
	0	1-2	3-4	5-6	
Panorama	61	34	4	1	0.6±0.9
Lateral cephalometric projection	82	15	2	1	0.3±0.8
Other	93	6	1		0.1±0.5
Total no of radiographs					1.0±1.9, 0-15

© **Figure 1.** Number of bitewing radiographs, periapicals, extraoral radiographs and total number of radiographs. Boxes denote 50 per cent of the cases and lines across the boxes the median value. Whiskers show lowest and highest values. Outliers are indicated with a small circle and represent those who extend more than 1.5 lengths from the edge of the box. Extremes are indicated with an asterisk.



±5 and the frequency over the years is presented in Table 3. Bitewings were taken in 3% and 9% of the children at 4 and 5 years of age, respectively, with an increasing prevalence up to 75% at 13 years. Between 14- and 18-years of age, a reduced frequency was displayed while at 19 years, bitewing radiographs were used in 99% of the patients. In 8- to 9-year-old children, two bitewing radiographs were exposed yearly in about 50% of the subjects.

*Bitewing radiographs in relation to caries experience*

Twenty-two percent of the 19-year-olds had no dentine lesions and 60% exhibited no approximal caries experience. The mean DFS-value of the total study group was  $4 \pm 6$  (median 3, range 0-62) and the corresponding DFSa value was  $1 \pm 3$  (median 0, range 0-34). The mean number of exposed bitewing radiographs in subjects with and without caries experience is shown in Table 4. There was a statistically significant difference ( $p < 0.01$ ) between the two groups with fewer exposures among the caries-free. A total of 5,394 bitewing radiographs were exposed among individuals with no approximal caries

© **Table 3.** Distribution of bitewing radiographs for caries detection between 3 and 19 years of age (n=506). The figures denote percent at each age.

Age	No of bitewing radiographs								
	0	1	2	3	4	5	6	7	8
3	100								
4	97	1	2						
5	91	1	8						
6	74	1	24		1				
7	77	1	21		1				
8	53	1	45	1	1				
9	45	1	50	1	2				
10	35	1	61	1	2				
11	38	1	58	1	2				
12	26	1	71	2					
13	22		75	1	2				
14	41		54	2	3				
15	31	1	62	2	3	1			
16	34		59	2	4	1			
17	30		64	2	4				
18	38	1	50	2	8	1			
19	1		57	3	35	1	2		1

compared to 4,241 in individuals with approximal caries experience. The number of bitewing radiographs differed statistically significant between the three clinics, in clinic 1; 20+5, in clinic 2; 18+6 and in clinic 3; 19+5  $p<0.05$ . In clinic 2 which had the lowest number of exposed bitewing radiographs a statistically higher DFSa compared to clinic 3 was displayed ( $p<0.05$ ).

#### *Radiography in relation to treatment at specialist clinics in orthodontics*

One third of the subjects had been referred to orthodontic treatment and they were subjected to more radiographic examinations compared to those who did not attend special clinics ( $p<0.01$ ), (Table 5). The difference in number of radiographs was mainly ascribed to a higher number of extra-oral radiographic examinations.

© **Table 4.** Number of bitewing radiographs used in 3 to 19 years of age in relation to caries experience at 19 years ( $n=506$ ).

	n	Number of bitewing radiographs		
		mean $\pm$ sd	range	median
DFS=0	113	16.4 $\pm$ 4.1,	0-30	16 **
DFS>0	393	19.8 $\pm$ 4.4	10-33	20
DFSa=0	305	17.7 $\pm$ 4	0-32	18 **
DFSa>0	201	21.1 $\pm$ 4.5	10-33	20

ANOVA, \*\*  $p<0.01$

#### **Discussion**

This retrospective study was undertaken to enumerate the total number of radiographic examinations carried out in public dentistry for children and adolescents. The clinics were selected to represent different socioeconomic areas and the attrition rate due to missing data was low. Thus, the study material was considered as representative for the dental

care provided by Public Dental Health Service in the region. The intra-examiner reliability was high but it should be underlined that only the radiographs that were documented and stored in the records were enumerated and possible re-exposures due to projection and dark-room failures were not taken into account. Consequently, no attempt was done to estimate the cumulative radiation dose throughout the first 19 years of life. Furthermore, the quality of the exposed radiographs was not assessed in the present paper but will be subjected to an evaluation in a further report.

The results established clearly that the most common reason for radiography was detection of caries. Although a statistically significant difference in the number of bitewing radiographs taken in subjects with and without a caries experience was noted, it was somewhat surprising that the difference was not larger and that the difference in number of bitewing radiographs between the three clinics not correlated to the approximal caries experience in the clinic. One important reason may be that clinicians strongly adhere to the guidelines that individual selection criteria must be used and that a radiographic examination must be preceded by a clinical examination (16). Another explanation was that only dentine lesions were included in the DFS-values and it is known that many 19-year-olds exhibit slowly progressing approximal enamel lesions (13). It was therefore possible that the bitewing radiographs were used to monitor progression or effects of preventive intervention on established approximal enamel lesions over the years. A striking finding was the high number of bitewing radiographs exposed in 19-year-olds in comparison with the other ages. The reason was unclear but it may reflect the organisation of dental care rather than a specific need for examination in this age. It seems that many patients were offered an extra examination before leaving the organised

© **Table 5.** Number of radiographs in relation to treatment at specialist clinics in orthodontics ( $n=506$ ).

Treated at specialist clinic in orthodontics cephalometric	Total number of radiographs mean, sd, range	Intraoral radiographs mean, sd, range	Extraoral radiographs (panorama, lateral projection, other) mean, sd, range
yes, 30 %	25.2 $\pm$ 6.7, 13-44 **	22.5 $\pm$ 6.2, 12-43 n.s	2.7 $\pm$ 2.6, 0-15 **
no, 70 %	22.0 $\pm$ 5.9, 0-44	21.7 $\pm$ 5.8, 0-43	0.27 $\pm$ 0.7, 0-4
total	22.9 $\pm$ 6.3, 0-44	22.0 $\pm$ 5.9, 0-43	1.0 $\pm$ 1.9, 0-15

ANOVA, \*\*  $p<0.01$ , ns  $p>0.05$

dental care but the high number of bitewing radiographs may also reflect an ambition to investigate the occurrence and localisation of third molars.

The mean number of bitewing radiographs observed here was lower than previously reported by *Edblad et al.* (6) and may reflect the recent shift towards a more individualised dental care based on risk assessment. The ultimate goal is of course to reduce the number of bitewings in those that do not gain from the examination. Although knowledge concerning the effectiveness of methods to identify such individuals is incomplete it is generally accepted that previous caries experience is the best predictor for future caries with a high specificity (5, 19). Thus, in patients with active caries, annual radiographic examinations may be motivated but when the caries risk or activity is low, a prolonged interval should be considered (14).

In a study from Greater Glasgow in Scotland, the routines of bitewing radiography for diagnosis of caries in children were investigated (17). The findings displayed that only 17% of the dental practitioners would consider taking bitewing radiography in children under 6 years. This was in harmony with our findings of a very low use of bitewings in the preschool age group. We did not collect data on caries experience in the primary dentition but there are reasons to suspect that approximal caries is overlooked during preschool ages. Compared to mirror and probe only, the use of bitewing radiography increased the mean-value for proximal dentine caries in 5-year-olds with factor 3 (2). Caries in the primary dentition is closely associated with caries in the permanent dentition (1, 15) and an early diagnosis is a prerequisite for an early intervention. Therefore, it may be argued that bitewings should be considered for preschoolers even in so-called low caries populations.

Orthodontic treatment increased the experience of radiography and imaging in order to localize the pre-eruptive position of tooth germs, extra-oral panorama and lateral cephalometric projections for cephalography were the second most common reason for use of radiography in this study group. Twenty-six percent had one or more radiographic examinations for a dental trauma albeit the additional number of radiographs was relatively small. The proportion was slightly lower compared to the cumulative trauma experience reported for 16-year-olds from the same area (3). In the present study, the examined age interval was larger but the classification was somewhat different. As recently stated by

Glendor (8), epidemiology of traumatic dental injuries may depend on behavioural and cultural diversities but also lack of clinical standardisation.

During 2006 digital radiography was introduced in the public dental service in the County of Västerbotten. It is not known if the technique has changed the frequency or use of bitewing radiographs in caries examination. However, many dentists report problems with the new technique among preschool children and further studies are needed to elucidate this issue.

In conclusion, a mean of 23 radiographs were exposed and bitewings for caries detection were the most common radiographic examination. The number of bitewing radiographs was lower in caries-free individuals than among those with cavitated lesions but bitewings were infrequently utilized during preschool ages. Treatment at specialist clinics in orthodontics increased the use of radiography.

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# Fracture strength of three-unit fixed partial denture cores (Y-TZP) with different connector dimension and design

ZDRAVKO BAHAT, DEYAR J HADI MAHMOOD, PER VULT VON STEYERN

## Abstract

True crystalline ceramic materials presently used in restorative dentistry are Al<sub>2</sub>O<sub>3</sub> (alumina) and yttrium-oxide stabilised tetragonal polycrystalline zirconium-dioxide (Y-TZP). To ensure optimal clinical performance, the dimensions of the Fixed Partial Denture (FPD) framework in general and of the connectors in particular, must be adequate. Considered recommendations for connector dimensions for Y-TZP FPDs vary from 2 to 4 mm in occluso-gingival height and 2 to 4 mm in bucco-lingual width. In order to reduce the fracture probability when designing all-ceramic FPDs, the shape of the connector is an important factor to consider. The radius of curvature at the gingival embrasure plays a significant role in the load-bearing capacity. FPDs with small gingival embrasure radii are subjected to high stress concentrations in the connector area during loading, compared to FPDs with large embrasure radii.

The aim of this in-vitro study was to investigate how different radii of curvature in the embrasure of the connector area and different connector dimensions could affect the fracture resistance of 3-unit all-ceramic FPDs made of Y-TZP. Forty-eight FPDs in 6 groups of 8 FPDs with different connector design were produced in Procera® Zirconia Bridge material. The FPD cores were subjected to heat treatment to simulate veneering. Following cementation, the FPDs were firstly thermocycled for 5,000 cycles, then preloaded for 10,000 cycles and finally loaded to fracture. All the FPDs fractured in the connector area. All the crack propagation which led to fracture started at the gingival embrasure of the connector.

Within the limitations of this in-vitro study, the recommended minimum dimension of an anterior 3-unit all-ceramic FPD of Y-TZP is 3 mm in incisal-cervical direction and 2mm in buccal-lingual direction.

By increasing the radius of the gingival embrasure from 0.6 to 0.9 mm, the fracture strength for a Y-TZP FPD with connector dimension 3 x 3 mm increases by 20%.

## Key words

All-ceramic FPDs, Y-TZP, gingival embrasure, CAD/CAM, connector dimension

## Brotthållfasthet hos helkeramiska (Y-TZP) tre-leds broskelett beroende på connectorns dimension och utformning.

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### Sammanfattning

© Två polykristallina helkeramiska material, aluminiumoxid och yttriumoxidstabiliserad zirkoniumdioxid (Y-TZP), används idag inom den rekonstruktiva tandvården. Helkeramiska broar måste dimensioneras och utformas särskilt avseende connectorn och med hänsyn taget till bromaterialens specifika materialegenskaper för att minimera konstruktionens frakturrisik. Rekommendationer i litteraturen för Y-TZP broars minsta connectordimension varierar från 2 till 4 mm i ocklusal – gingival riktning och från 2 till 4 mm i buccal – lingual riktning. Utöver dimensionering måste även hänsyn tas till connectorns utformning för att minimera frakturrisken eftersom connectorns gingivala radie antas ha en stor betydelse för konstruktionens lastbärande förmåga. Broar med liten gingival radie utsätts för högre spänningskoncentrationer i connectorn jämfört med broar med större gingival radie.

Syftet med föreliggande studie var att undersöka hur connectorns dimension och gingivala radie påverkar brotthållfastheten hos helkeramiska 3-ledsbroar framställda i Y-TZP.

Fyrtioåtta broskelett framställdes i ett Y-TZP material i grupper om 6 makroskopiskt identiska broar. Skillnaderna mellan grupperna bestod i att connectorns dimension (D) och gingivala radie (r) varierats enligt följande: Grupp 1) D = 2 x 2 mm / r = 0,6 mm, Grupp 2) 2 x 2 mm / r = 0,9 mm, Grupp 3) 3 x 2 mm / r = 0,6 mm, Grupp 4) 3 x 2 mm / r = 0,9 mm, Grupp 5) 3 x 3 mm / r = 0,6 mm, Grupp 6) 3 x 3 mm / r = 0,9 mm.

Samtliga broar utsattes för värmebehandling (simulerad porslinsbränning), termocykling (5°C – 55°C / 5000 cykler), cyklisk förbelastning (30 – 300N / 10 000 cykler) och belastades slutligen till brott. Samtliga broar frakturerade i connectorn med sprickstart i connectorns gingivala avsnitt.

Medelvärden för laster vid brott: Grupp 1) 358 N, Grupp 2) 399 N, Grupp 3) 579 N, Grupp 4) 576 N, Grupp 5) 651 N, Grupp 6) 831 N.

Med reservation för de begränsningar en In-vitro studie har dras följande slutsatser: Anteriora treledsbroar utförda i Y-TZP bör dimensioneras med en minsta connectordimension om 3 mm i incisal – cervikal riktning och 2 mm i buccal – lingual riktning. Genom att öka connectorns gingivala radie från 0,6 till 0,9 mm på en Y-TZP bro med 3 x 3 mm:s connectordimension, ökar brotthållfastheten med 20%.

## Introduction

Aluminium oxide (alumina) and yttrium-oxide stabilised tetragonal polycrystalline zirconium-dioxide (Y-TZP) are true crystalline ceramic materials presently used in restorative dentistry. Alumina was introduced in the mid nineteen-sixties as a reinforcing inclusion for dental porcelain. Together with new firing techniques, this introduction made it possible to use porcelain restorations in the anterior region with acceptable durability. The inherently low tensile strength of porcelain, however, still did not allow them to be used in high stress-bearing applications without using some kind of high-strength support (1, 25).

The first promising material for all-ceramic fixed partial dentures (FPDs) was the In-Ceram® Alumina system that was introduced in the early nineteen-nineties. This system consists of partly-sintered alumina cores, reinforced by a glass infiltration technique and subsequently veneered with specially developed porcelain to give the restoration the desired aesthetics. Conclusions made from early clinical studies were that FPDs based on glass-infiltrated alumina showed acceptable clinical performance, but that the majority of failures associated with such reconstructions were fractures in the connector region (11, 15, 43). A few long-term follow-up studies supported those findings (15, 28, 44).

Y-TZP was introduced in dentistry in the nineteen-nineties and when comparing products currently available on the market with sale statistics, it could be deduced that zirconia has replaced alumina as the dominant all-ceramic core material for FPDs. Pure zirconium-dioxide (zirconia) exists in three crystalline phases at different temperatures. Above 2370°C, zirconia forms a cubic solid solution. At intermediate temperatures, 2370 - 1170°C, the material transforms into a solid solution of tetragonal microstructure and below 1170°C it changes to a monoclinic one. During cooling a transformation from tetragonal to monoclinic structure occurs, resulting in a volume increase in the range of 3 - 5%. This volume increase induces stress within the material and can initiate crack formation which makes pure zirconia unsuitable for structural or mechanical applications. These crystal-structure changes can be decreased or eliminated by adding one of several oxides which dissolve within the crystal structure of zirconia. By adding a small portion of Y<sub>2</sub>O<sub>3</sub> to ZrO<sub>2</sub>, it is possible to densify the material in the tetragonal phase range to yield a fine-grained microstructure consisting almost completely of tetragonal grains, metastable at room temperature (Y-TZP) (8, 22, 29).

If a crack is formed in the material, each tetragonal grain has the potential to transform into a monoclinic one near a crack tip and thus to inhibit further propagation of the crack. This mechanism is described as transformation toughening, giving the material great potential for stress-bearing and wear-resistant applications (22, 29). Although Y-TZP has a considerably high flexural strength compared to all other ceramic materials currently used in dentistry (19, 21), it is not evident that the clinical performance is proportional to the above-mentioned properties. Other material properties, such as elastic modulus and hardness, are much lower for Y-TZP compared to densely-sintered alumina. This complexity makes it difficult to base design recommendations on experience derived from other material systems. Consequently, to ensure optimal clinical performance, the dimensions of the FPD framework in general and of the connectors in particular, must be adequate. It is not evident from the literature what constitutes adequate connector dimensions, as large variation is displayed (5, 10, 18, 19, 23, 26, 31, 32, 33, 35, 38, 39, 41, 45, 46).

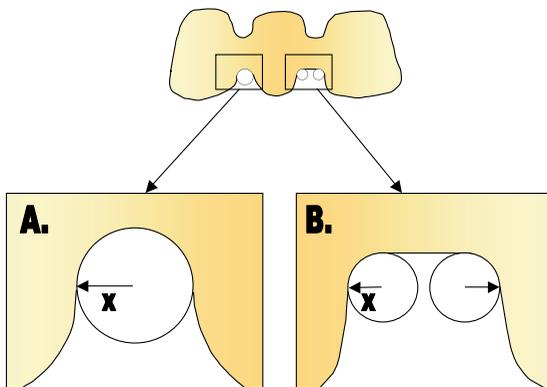
Considered recommendations for connector dimensions for Y-TZP vary from 2 to 4 mm in occluso-gingival height and 2 to 4 mm in bucco-lingual width (5, 19, 23, 32, 39, 40). Furthermore, it has been shown that, in order to reduce the fracture probability when designing all-ceramic FPDs, the shape of the connector is an important factor to consider (3, 7, 10, 26, 27, 30). In particular, the radius of curvature at the gingival embrasure plays a significant role in the load-bearing capacity. FPDs with small gingival embrasure radii are subjected to high stress concentrations in the connector area during loading, compared to FPDs with large embrasure radii. One study shows that a larger radius of the gingival embrasure results in significantly higher fracture resistance compared to FPDs with smaller embrasure radii (26). In that study two types of connector design of the curvature at the gingival embrasure were compared, one with a radius of 0.9 mm and the other with a radius of 0.25 mm respectively.

The advent of CAD/CAM has not only made it possible to produce all-ceramic FPDs in materials with a higher degree of purity, previously inaccessible to conventional techniques, but also to produce them with a high degree of accuracy (2, 5, 24, 34). In all CAD/CAM systems the design is basically dependent on the design limitations of the CAD-software. This has led to one other type of connector design, seen more frequently in recent years, which

represents a design type of its own (Figure 1). It differs from the other designs, having small radii approximately, connected with a straight beam (19, 39, 40).

In a survey of the literature, the authors have found one study, apart from finite element analyses, that evaluated the effects of changing the radius of the gingival embrasure and dimensions of the connector in all-ceramic FPDs (26).

©Figure 1. Different connector designs of the gingival embrasure, where X represents the radius of the curvature. B represents a connector design frequently encountered in recent years in CAD-software.



### Aims

- The first aim was to investigate how the fracture strength of 3-unit all-ceramic FPDs made of Y-TZP is dependent on different connector dimensions.
- The second aim was to evaluate the effect of how different radii of curvature in the embrasure area of the connector could affect the fracture strength of 3-unit all-ceramic FPDs made of Y-TZP.

The null-hypothesis of the study was that a change in the connector dimension equalizes a change in the radii of curvature in the embrasure area concerning fracture strength.

### Materials and Methods

A total of 48 three-unit anterior all-ceramic FPDs supported by end abutments and with one pontic were to be made. Six groups of 8 FPDs with different connector design were produced. The connectors varied in dimension and in radius of curvature in the gingival embrasures as shown in Table 1. The choice of dimensions to be tested were based on a previous study (19) and the two radii of curvature were the default setting of the CAD/CAM system used and a radius-increase according to a suggestion found in the literature (26).

A master model resembling an upper jaw, with teeth 21 and 23 serving as abutments and tooth 22 missing, was made in die stone (Vell-mix, Kerr, Romulus, MI, USA). The distance between the abutments was 6.6 mm, corresponding to the average mesio-distal width of one lateral incisor (48). The abutments 21 and 23 were shaped with a 15° angle of convergence and a cervical preparation design with a 120° chamfer, according to the recommendations of the manufacturer of Procera® Zirconia Bridge (Nobel Biocare, Gothenburg, Sweden). The master model was scanned with a mechanical scanner, Procera® Forte (Nobel Biocare, Gothenburg, Sweden). The connector dimensions and the radii of the gingival embrasure of the different groups were adjusted from the scanned data created in a single scan using CAD software (Procera PCMS, version 1.5, build 75 software).

The CAD-data for the FPDs was then sent to a production centre (Procera Production Centre, Nobel Biocare, Stockholm, Sweden) where it was used to produce 48 FPDs in Procera® Zirconia Bridge material according to the manufacturer's recommendations, following the regular production line. (Figure 2) After manufacturing, all FPDs were sent back to the faculty of Odontology, Malmö University, where they were to be tested.

The FPD cores were subjected to heat treatment in a calibrated porcelain furnace (Multimat Touch & Press, Degudent, Dreieich, Germany) to simulate firing of the recommended veneering porcelain (Nobel Rondo™ Zirconia, Nobel Biocare, Gothenburg, Sweden). Four firing programs were used: Liner (930°C), Dentin 1 (910°C), Dentin 2 (900°C) and finally Glaze (890°C).

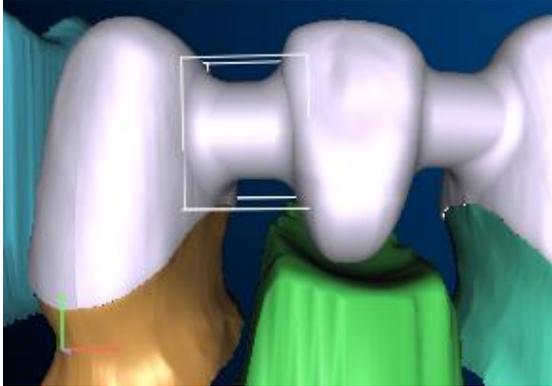
Initially, the abutments of the master cast, 21 and 23, were reproduced using an A-silicone impression (President, Coltene AG, Altstätten, Switzerland),

©Table 1. The connector diameter and radius of the gingival embrasure.

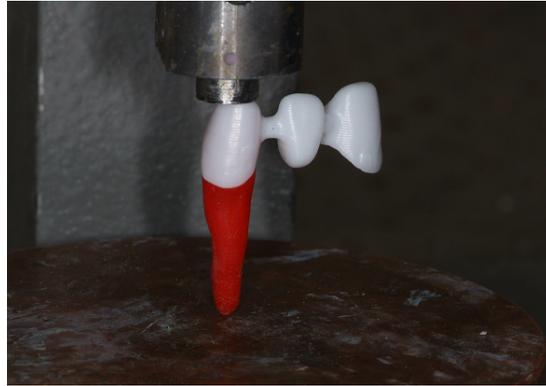
Group	Hight mm	Width mm	*Radius OE	**Radius GE
1	2mm	2mm	0.6mm	0.6mm
2	2mm	2mm	0.9mm	0.9mm
3	3mm	2mm	0.6mm	0.6mm
4	3mm	2mm	0.9mm	0.9mm
5	3mm	3mm	0.6mm	0.6mm
6	3mm	3mm	0.9mm	0.9mm

\*Radius of Occlusal Embrasure \*\*Radius of Gingival Embrasure

©Figure 2. The CAD design.



©Figure 3. One FPD loaded on a tooth analogue during setting of the cement.



to make two tooth-like end-abutments on which the FPDs could be cemented and fixated in acrylic blocks. Subsequently the impressions were poured in die stone (Vell-mix, Kerr, Romulus, MI, USA) with a metal dowel pin centred in each abutment to stabilize the following build-up of a wax-up. Grooves were made on the dowel pins to facilitate retention of the wax.

The above-mentioned reproduction abutments were to be used only to create the shape for the final test model and were not to be used in the test. They were copied in a second step using an A-silicone impression (President, Coltene AG, Altstätten, Switzerland) and subsequently poured with inlay pattern resin (Dura Lay<sup>®</sup>, Reliance Dental MFG Co., Worth, Illinois, USA) thus creating the final model for the test. The pattern resin was mixed according to the manufacturer's recommendations.

A total of 96 copies, 48 incisors and 48 canines, were made. Prior to cementation, the Dura Lay<sup>®</sup> abutments of the FPDs were washed with phosphoric acid (Etching Agent, Kuraray Medical Inc, Sakazu, Kurashiki, Okayama, Japan) for 15 seconds then thoroughly rinsed with water. The FPDs were then luted onto the abutments with Panavia F 2.0 luting cement (Kuraray Medical Inc, Okayama, Japan) according to the manufacturer's recommendations. During setting of the cement, the FPDs were loaded, also according to the manufacturer's recommendations (Figure 3). The load was applied in the direction of insertion with a load of 15 N for a period of 60 seconds to simulate the clinical situation and based on a previous study (19).

In the first stage of testing - thermocycling - all FPDs underwent 5,000 cycles in a specially-constructed thermocycling device. Two water baths - at

temperatures of +5 °C and +55 °C - were used. A basket holding 24 FPDs was used to cycle the FPDs between the two baths. Each cycle lasted 60 seconds: 20 seconds in each bath and 10 seconds to complete the transfer between baths.

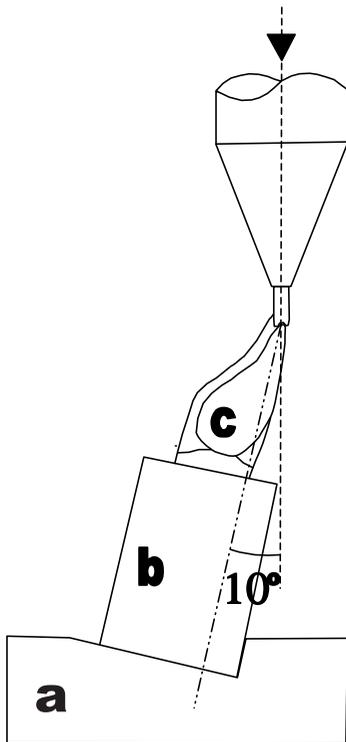
Following thermocycling, the cemented FPDs were fixated in holes in acrylic blocks with die stone (Vell-mix, Kerr, Romulus, MI, USA) as described in previous studies (19, 42, 46).

To simulate the moist environment in the oral cavity, the FPDs were placed in a plastic container, with a sealable lid, and had distilled water (37±1°C) covering their bases before the start of mechanical testing the following day.

In the second stage of testing - preloading - all FPDs underwent cyclic preloading comprising 10,000 cycles at loads between 30 and 300 N and a load profile in the form of a sine wave at 1 Hz. The force was applied with a stainless steel indenter, placed centrally on the incisal edge of the second incisor pontic to avoid sliding during loading. All FPDs were stored in distilled water during preloading and mounted at a 10° inclination relative to the vertical plane (Figure 4). The loads and the 10° inclination were chosen to allow comparisons with earlier studies (19, 42, 46).

In the third stage of testing - load to fracture - the FPDs were mounted in a testing jig at a 10° inclination, from the palatal side, again to allow comparisons with earlier studies (19, 42, 46), and subjected to a load applied by a universal testing machine (Instron 4465, Instron Co. Ltd., Massachusetts, USA). The crosshead speed was 0.255 mm/min, and the load was applied with a stainless steel indenter, again placed as described above. Throughout the test pe-

©Figure 4. A schematic picture of the jig and the application of the load in the preloading and loading tests. a) Brass foundation. b) Acrylic block. c) The pontic.



riod, whenever the FPDs were not being actively tested, they were stored in distilled water at 37°C. In the final step of the procedure, the FPDs were loaded until a fracture occurred, whereupon the loads at fracture were registered. Fracture was defined as a visible fracture through the entire construction. The record was based on acoustic events and by observing changes in the load curve. Any difference between groups was tested by means of the student's t-test with a level of significance of  $p < 0.01$ .

The starting points for the crack formations of all FPDs were detected, and the directions of propagation were interpreted, using a light microscope (Wild M7A, Wild-Verkaufsgesellschaft Mikroskopie GmbH, Heerbrugg, Switzerland).

**Results**

The fracture data and statistics are listed in Table 2.

All the FPDs fractured in the area of the connector and the fracture modes were distributed as follows:

- (A) 62.5% of the fractures started from the corner between the pontic and the connector through the pontic.
- (B) 16.7% of the fractures started in the connector area from the corner between the pontic and the connector through the connector.
- (C) 10.4% of the fractures occurred from the middle of the connector beam through the pontic.
- (D) 8.4% of the fractures occurred from the corner between the pontic and the connector and through the middle of the connector.

©Table 2. Fracture load (N), mean fracture load and standard deviation. The groups represent different connector dimensions (2 x 2, 3 x 2, 3 x 3 mm) and different radii of curvature (0.6 and 0.9 mm). Significant differences between FPDs with same dimension but different radii.

Group	1	2	3	4	5	6
Dimension/radius	2 x 2 / 0.6	2 x 2 / 0.9	3 x 2 / 0.6	3 x 2 / 0.9	3 x 3 / 0.6	3 x 3 / 0.9
Significance	NS		NS		P<0.01	
FPD No						
1	442	300 **	512	580	755	730
2	300 ***	455	673	726	489	800
3	353	300 **	633	581	670	987
4	388	375	615	521	580	873
5	300 **	499	621	554	499	783
6	349 *	498	426	460	803	739
7	300 **	300 **	669	590	659	839
8	434	469	482	599	754	899
Mean	358	399	579	576	651	831
SD	58	91	93	76	119	87

\*FPDs which lost retention at one abutment

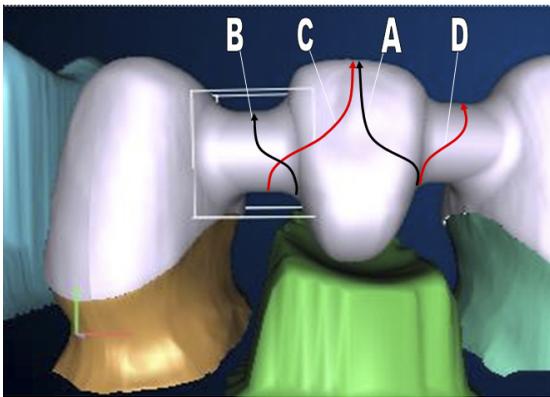
\*\*FPDs fractured at 30-300 N preload

All the crack propagation which led to fracture started at the gingival side of the connector. (Figure 5).

Two of the FPDs with connector dimension 2 x 2 mm,  $r = 0.6\text{mm}$ , lost retention at one abutment during thermocycling (No. 2, 6).

During the cyclic mechanical preload (30-300 N), three FPDs with connector dimension 2 x 2 mm,  $r = 0.6\text{mm}$  (No. 2, 5, 7) and three FPDs with connector dimension 2 x 2 mm,  $r = 0.9\text{mm}$  (No. 1, 3, 7) fractured.

©Figure 5. The four different crack propagation directions.



## Discussion

All-ceramic FPDs are quite complex in shape since they have to fulfil several functional requirements such as strength, aesthetics and hygiene. The highest level of stress concentrations in an FPD occurs in the connector area during loading. As ceramics are highly susceptible to tensile forces, it is important to reduce such stress concentrations, especially in the gingival portion of the connector where tensile forces often occur. By increasing the dimension of the beam, it is possible to increase the load-bearing capacity of the FPD. This is, however, not always possible due to anatomical limitations such as low vertical dimension or voluminous gingivae.

An alternative way to increase the strength of this thin portion of the beam is to design the connectors with a stress-reducing, u-shaped, gingival embrasure (10, 26, 27, 30, 31, 43).

A score of studies discuss the dimensions in the connector area of different all-ceramic FPDs. Although there are many suggestions to be found in the literature, there is no general consensus concerning

what constitutes adequate connector dimension. (Table 3).

Only one study tests the different radii of curvature in the embrasure of the connector area, and this study does not aim at FPDs made of Y-TZP (26). Hence, there are no general design recommendations currently established for anterior all-ceramic FPDs.

The aims of the present study were: 1). To investigate how the fracture strength of 3-unit all-ceramic FPDs made of Y-TZP was dependent on different connector dimensions and 2). To investigate how different radii of curvature in the gingival embrasure of the connector area influence the fracture strength of 3-unit all-ceramic FPDs made of Y-TZP.

To be able to compare the strength of FPDs of different design, it is important to use specimens that are identical, as far as possible, in all aspects except for the one that is to be tested. By using CAD/CAM technology, it has become possible to produce all-ceramic FPDs in shapes equivalent to those used clinically and to reproduce them in a desired quantity. Furthermore, the CAD-software allows small changes to be made, such as connector-diameter and design of the approximal embrasures, while still keeping other measures unchanged.

Presently there are a number of CAD/CAM systems available with different kinds of scanning and grinding methods(2, 12, 24, 34, 37). In the present study the Nobel Biocare CAD/CAM system was used with a mechanical scanning process where the CAD-data was subsequently sent to a production centre, where it was used to produce the FPDs, following the regular production line.

Conversely, the veneer material is more complicated to build-up in a standardized way, as generally veneering requires a high level of skilled workmanship. It was therefore decided to exclude this production step in the present study. Another reason for this decision was based on the assumption that the veneering itself, would not affect the fracture strength in the connector area significantly, since the elastic modulus of the veneering material is much lower than that of the core material (~100 GPa for porcelain compared to ~200 GPa for Y-TZP)(42).

According to some studies, the temperatures that the core is subjected to during porcelain firing may, however, decrease the mechanical properties of Y-TZP. A possible explanation is that the machine grinding initiates the tetragonal to monoclinic transformation, creating a compressive layer and that these residual stresses are relaxed during porcelain firing

©Table 3. CH: Connector height in mm, CW: Connector width in mm, CS: Cross-section of the connector dimension in mm<sup>2</sup>, JP: Jaw Position: A= anterior, P= posterior.

Reference	Core material	CH	CW	CS	JP
Chitmongkolsuk et al, 2002	IPS Empress 2**	4	4	-	P
Esquivel-Upshaw et al, 2001	Lithium-disilicate based ceramic	4	4	-	P
Filser et al, 2001	Vita In-Ceram® Alumina	2.7	2.6	6.9	P
	DCM (Y-TZP)	2.7	2.6	6.9	P
	IPS Empress 2**	2.7	2.6	6.9	P
Fisher et al, 2003	IPS Empress*	4	3.5	14	P
	IPS Empress 2**	4	3.5	14	P
	Zirconia (3Y-PSZ)	4	3.5	14	P
Gerami-Panah et al, 2005	IPS Empress 2**	4	4	-	P
Kamposiora et al, 1996	Vita In-Ceram® Alumina	4	-	-	P
Kern et al, 1994	Vita In-Ceram® Alumina	3	1.5	-	A
Koutayas et al, 2002	Vita In-Ceram® Alumina	3	1.5	-	A
Larsson C et al, 2007	Y-TZP	2-4	2-4	-	P
Lüthy et al, 2005	In-Ceram® Zirconia®+	2.8	2.7	7.3	P
	Y-TZP	2.8	2.7	7.3	P
	IPS Empress 2**	2.8	2.7	7.3	P
Oh et al, 2002	Lithium-disilicate based ceramic	4	5	-	P
Pospiech et al, 1996	Vita In-Ceram® Alumina	4	2	-	A
Raigrodski et al, 2001	Vita In-Ceram® Alumina	4	3	-	P
	IPS Empress 2**	4	4	-	A
	In-Ceram® Zirconia®+	4	3	-	P
	Y-TZP	-	-	6.9	P
Raigrodski et al, 2006	Lava™ (Y-TZP)	-	-	9	P
Sailer et al, 2006	DCM (Y-TZP)	-	-	7	P
		-	-	9	P
		-	-	11	P
Stappert et al, 2004	IPS Empress 2**	4	4	-	P
	EPC#	4	4	-	P
Suarez et al, 2004	In-Ceram® Zirconia®+	4	-	-	P
Sundh et al, 2005	Y-TZP	3	3	-	P
Sundh et al, 2006	Y-TZP	3	3	-	P
	Mg-PSZ	3	3	-	P
Tinschert et al, 2001	IPS Empress*	4	-	-	P
	IPS Empress 2**	4	-	-	P
	Vita In-Ceram® Alumina	4	-	-	P
	In-Ceram® Zirconia®+	4	-	-	P
	DC-Zircon (Y-PSZ)	4	-	-	P
Vult von Steyern et al, 2001	Vita In-Ceram® Alumina	3	3	-	P
Vult von Steyern et al, 2005	DC-Zircon (Y-PSZ)	4	4	-	P
		3	3	-	A
Vult von Steyern et al, 2005	Procera® All-Ceram (Alumina)	3	2	-	P

\* = Leucite-reinforced porcelain

\*\* = Lithium-disilicate glass ceramic

+ = Zirconia-reinforced glass-infiltrated alumina

# = Experimental Press Ceramic

reversing the transformation. The transformation from the monoclinic to the tetragonal metastable phase may occur as soon as a given temperature is reached, regardless of the holding time (8, 17, 39, 40).

Consequently, the FPD-cores used in the present study were subjected to a firing programme to simulate porcelain firing according to the manufacturer's recommendation (Procera® Rondo Zirconia, Nobel Biocare, Gothenburg, Sweden).

The test methodology used was selected to simulate the clinical situation as closely as possible, especially concerning the mechanical properties of the supporting tissues. Reproduction of the abutments made from inlay pattern resin, fixated with dental stone in acrylic blocks, was based on previous studies regarding the choice of materials and methodology (13, 19, 42, 46). Inlay-pattern resin has an *E*-module that is close to that of dentine and was furthermore chosen to allow comparisons with previous studies (19, 42, 46). The handling of the resin during processing the abutments was carefully carried out, especially concerning the mixing-ratio and working/setting-time, in order to standardize the material properties of the abutments.

Cementation of the FPDs was done according to the manufacturer's recommendations. During setting of the cement, the FPDs were loaded in the direction of insertion with 15 N for a period of 60 seconds. The method was based on a previous study to simulate the clinical situation (19).

The FPDs were thermocycled in order to simulate ageing and to expose the materials to fatigue. The change in temperature creates stresses corresponding to mechanical stresses in the mouth. The wet environment could furthermore affect the materials due to stress corrosion by enhancing the micro-crack growth. The strength degradation rate is a slow process and is affecting TZP zirconia differently depending on several micro structural parameters, like yttria distribution and concentration, the distribution of the flaw population and grain size. (29).

Cyclic preloading in an aqueous environment was used to simulate ageing of the material in the oral cavity during function. It has been described that ceramic materials show an abrupt strength degradation and transition in damage mode after multi-cyclic loads compared to static loading tests. Hence, it is essential to consider fatigue and environmental influence, as water in the saliva enhances crack-growth in a ceramic reconstruction when subjected to small alternating forces during mastication in the clinical situation. The number of cycles, the preloading force

and the 10° inclination were chosen to make it possible to make comparisons with earlier studies (19, 42, 46).

The second aim of the present study was to evaluate the effect of how different radii of curvature in the embrasure area of the connector could affect the fracture strength of 3-unit all-ceramic FPDs made of Y-TZP. There are very few reports on this subject in general and these are mostly finite element analyses (10, 27, 30). One report (26) concluded that the radius of connector curvature at the gingival embrasure strongly affected the fracture resistance of all-ceramic FPDs.

All the FPDs in the present study fractured in the area of the connector, which corresponds with previous studies of all-ceramic FPDs (3, 4, 10, 11, 14, 18, 26, 27, 39, 40, 41, 42, 43). When analyzing the results concerning the connector dimensions, it appears that there is a significant difference between the test groups, but that the radius of curvature at the gingival embrasure only affects the fracture strength when the connector dimension is 3 x 3 mm. The fact that there was no difference between the 2 x 2 mm groups could be attributed to the fact that some of the FPDs were already fractured during preloading, at a load of 300 N or below. It could not be established at what preload value below 300 N the fracture occurred. This could imply the possibility of a significant difference but, as the data was inaccessible, this could not be confirmed.

It could be presumed that the size of the radius was not significant with regard to the fracture strength of the FPDs at the smaller connector dimensions. The reason that no significant difference in fracture strength could be observed between beam dimensions 3 x 2 mm and 3 x 3 mm, could probably be attributed to the fact that the angle of the load direction was fairly small. If the angle of the load had been greater, lower values might well have been the result in the 3 x 2 mm group, as the smaller width (2 mm) of the connector beam would have a greater influence on the load-bearing capacity with a more horizontal load direction.

When analysing the results in the present study, it could be concluded that the beam dimensions of the connector have greater significance than the radius of curvature at the embrasure. The only significant differences concerning the importance of the radius of curvature at the embrasure for the fracture strength was seen in the groups with the connector dimensions 3 x 3 mm.

There is one possible source of error in the results,

in the form of the Dura Lay® abutments that came loose during the thermocycling. These abutments were recemented and were then subjected to the same treatment as the other specimens, and showed no deviation in the results. One possible reason for failure of the abutments in the first place during thermocycling could be attributed to some form of contamination of the surface. This would result in an incomplete luting of the surface area. During thermocycling, water absorption could occur in those regions, subsequently decreasing the overall bond strength.

The reported variation of maximal bite forces in the oral cavity has a wide span that ranges from a few hundred N in the anterior region to over a thousand N in the posterior region. Different factors such as gender, age, dysfunctions in the masticatory system and denture wear, lower the values reported (9, 13, 20, 47). It could be assumed that during normal mastication the bite forces are considerably lower than the maximal bite forces registered in the anterior region.

Based on the results from the present study the 2 x 2 mm groups showing mean values of 358 and 399 N respectively, placing themselves in the lower region of the span of the bite forces. When considering a reasonable margin of safety concerning the dimensions, the 2 x 2 mm groups seem to be insufficient. The 3 x 2 mm groups with mean values of 578 N and 576 N respectively, shows a reasonable margin of safety for an anterior FPD, those findings must, however, be confirmed by further studies and clinical trials.

### Conclusions

Within the limitations of this in-vitro study it could be concluded:

The recommended minimum connector dimension of an anterior 3-unit Y-TZP FPD is 3 mm in incisal-cervical direction and 2 mm in buccal-lingual direction.

By increasing the radius of the gingival embrasure from 0.6 to 0.9 mm, the fracture strength of a Y-TZP FPD with connector dimension 3 x 3 mm will increase by 20%. The null-hypothesis is accordingly rejected.

### Acknowledgements

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