

1 Ioanna Dallari Jacobsen¹, Claes-Göran Crossner¹ Harald M Eriksen¹, Ivar Espelid², Christer
2 Ullbro¹

3 **Need of non-operative caries treatment in 16-year-olds from Northern Norway**

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5 ¹Department of Clinical Dentistry, Faculty of Health Sciences, UiT The Arctic University of
6 Norway, Tromsø, Norway

7 ² Institute of Clinical Dentistry, Faculty of Dentistry, University of Oslo, Oslo, Norway

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9 **Corresponding author:**

10 Ioanna Dallari Jacobsen

11 Department of Clinical Dentistry

12 Faculty of Health Sciences

13 UiT The Arctic University of Norway, Tromsø

14 9037 Tromsø

15 Norway

16 Email: ioanna.d.jacobsen@uit.no

1 Abstract

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3 2 *Purpose:* To assess the prevalence of proximal enamel lesions, the need for non-operative
4 3 caries treatment and the quality of dental restorations in 869 16-year-olds from Northern
5 4 Norway.

6 5 *Methods:* All first year upper secondary school students in Tromsø and Balsfjord
7 6 municipalities were invited to participate in an oral- and general health project (Fit Futures).
8 7 The attendance rate was 90%, and all subjects born in 1994 (449 males and 420 females)
9 8 were included in the present study. Dental caries was registered according to a 5-graded
10 9 scale (1-2 = enamel lesions; 3-5 = dentinal lesions). Scores from 1 to 4 were used to register
11 10 the quality of restorations (1 = good; 2 = acceptable; 3 = poor; 4 = unacceptable)

12 11 *Results:* Only 6 % of the 16-year-olds were completely caries-free. Eighty-four per cent of
13 12 the participants presented with proximal enamel lesions. A majority of them had either
14 13 previously restored teeth (35%) or both restored teeth and untreated dentinal caries lesions
15 14 (34%). When using the D-value of the DMFS-index as a diagnostic criterion, 39% of the
16 15 participants were in need of restorative treatment. When proximal enamel lesions were
17 16 included in the diagnosis, the number of participants in need of restorative and/or non-
18 17 operative caries treatment was 85%. Over 1/3 of the participants presented with at least one
19 18 restoration below acceptable quality level.

20 19 *Conclusions:* Dental caries is still a major health problem affecting the total teenage
21 20 population. A non-operative treatment strategy should be considered relevant in order to
22 21 reduce the need for restorative treatment.

23 22
24 23 **Key words:** proximal enamel caries, dental caries, non-operative treatment, adolescents,
25 24 oral health.

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25 Introduction

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2 26 Epidemiological data have shown a considerable reduction in caries prevalence among
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4 27 children and adolescents in Scandinavian and other Western countries over the last decades
5
6 28 (Petersen 2003; Norderyd et al. 2015). A concomitant decrease in the need for operative
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8 29 treatment of caries has also been extensively documented (Mjor et al. 2008). This decrease
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10 30 is, however, in part due to a change in operative, diagnostic and treatment criteria
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12 31 (Gimmestad et al. 2003; Gabre et al. 2006; Vidnes-Kopperud et al. 2011).

13 32 Epidemiological caries data are based on the registration of DMFT/DMFS index values
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15 33 where the D-component represents caries lesions with progression into dentin. However,
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17 34 lesions limited to the enamel constitute a considerable part of all carious lesions (Martignon
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19 35 et al. 2010; Skeie, Klock 2014). As a consequence, valid caries diagnosis in populations with
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21 36 low caries prevalence and slow caries progression may need more sensitive diagnostic
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23 37 criteria including enamel lesions (Nyvad et al. 1999; Pitts 2004). Alm and co-workers (2007)
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25 38 claim that over 80% of proximal caries lesions diagnosed in adolescents are in the enamel
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27 39 only. This indicates that the reduction in caries prevalence is overestimated and that the
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29 40 burden of and the need for treatment of the caries disease is underestimated (Amarante et
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31 41 al. 1998; Nyvad et al. 1999; Alm et al. 2007; Schwendicke et al. 2014).

32 42 Treatment objectives for enamel lesions are to slow down, arrest or reverse the progression
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34 43 of the lesions by non-operative treatment procedures and thereby reduce the need for
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36 44 restorative treatment (Ekstrand, Christiansen 2005; Hausen et al. 2007). In this context, it is
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38 45 important to focus on early detection of caries lesions and include enamel lesions in the
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40 46 clinical diagnosis and epidemiological surveys, in order to adopt a non-operative treatment
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42 47 approach in clinical praxis (Raadal et al. 2011).

43 48 In the Nordic countries, the documented improvement in dental health among children and
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45 49 adolescents is to a large extent maintained into adulthood (Hugoson et al. 2005; Crossner,
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47 50 Unell 2007; Skudutyte-Rysstad, Eriksen 2007; Norderyd et al. 2015). However, a recently
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49 51 performed extensive analysis of age, period and cohort trends of caries in permanent teeth in
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51 52 four developed countries (USA, UK, Sweden and Japan) showed that there is still a gradual
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53 53 increase in DMFT/S-scores in the adult population due to untreated caries and neglect of oral
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55 54 health promotion in adult life (Bernabé, Sheiham 2014).

56 55 Quality and longevity of dental restorations are important issues regarding adult dental
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58 56 health. Secondary caries is reported to be the main reason for restoration failure and
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60 57 replacement (Qvist et al. 1990; Opdam et al. 2010; Pallesen et al. 2014), and preventive and
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62 58 non-operative interventions will thus have an impact on problems related to longevity of
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59 restorations. Newly placed composite Class II restorations might also represent a threat
60 against sound enamel on neighboring tooth surfaces, possibly due to iatrogenic damage of
61 adjacent enamel surface or differences in plaque retention and bacterial colonization on
62 dental restoration surface compared with enamel (Skudutyte-Rysstad et al. 2016).

63 Individually targeted caries preventive and non-operative treatment procedures have many
64 similarities. However, the concept “non-operative treatment” includes a more conscious
65 clinical examination and diagnosis, including evaluation of the activity of the individual lesions
66 as a basis for proper selection of appropriate non-operative treatment modalities. Such
67 modalities may, besides dietary recommendations and individually tailored information and
68 instruction in dental hygiene, include use of flossing, fluoride varnish and fissure sealants
69 (Ekstrand, Christiansen 2005; Hausen et al. 2007).

70 Based on data from a sample of 16-year-olds from Troms County, Northern Norway, the
71 aims of the present investigation were to document the prevalence of proximal enamel
72 lesions, to estimate the need for non-operative caries treatment and to record the quality of
73 dental restorations.

74

75 **Material and Methods**

76 The present paper is based on cross-sectional data from the oral part of the “Fit Futures”
77 project among adolescents in Troms county, Northern Norway (Winther et al. 2014). The
78 study was carried out from September 2010 to May 2011 (Jacobsen et al. 2016) as part of a
79 larger repetitive epidemiological general health project, “The Tromsø Study” (Jacobsen et al.
80 2012). All first year upper secondary school students in Tromsø (urban) and Balsfjord (rural)
81 municipalities, were invited. Out of 1301 eligible students, 1117 were available for invitation.
82 The remaining 184 were, due to illness, relocation and exchange student programs not
83 attending the schools at the time of investigation and were excluded from the study. Out of
84 the invited 1117 students, 1010 (aged 15-19) volunteered to participate in the oral part. The
85 attendance rate among the invited students was 90%, and all subjects born in 1994 (449
86 males and 420 females) were included in the present study. In this material 13 % was of
87 immigrant ethnicity. All participants had received regular dental care free of charge, within
88 the Norwegian Public Dental Health System. The fluoride levels of the drinking water were
89 low in both municipalities.

90 The participants were examined clinically and radiographically. Proximal caries lesions, from
91 the mesial surface of the first premolar to the mesial surface of the second permanent molar,
92 were scored according to a grading system from 1 – 5 based on depth of penetration

93 (Espelid et al. 1990; Amarante et al. 1998). Enamel lesions were graded 1-2 (corresponding
94 to ICDAS level 1-3), and lesions penetrating in to dentin were graded 3-5 (ICDAS level 4-6)
95 and included in the DMF-registrations. Detailed information on material and methods used in
96 the oral part of the “Fit Futures” project are given in a recently published article (Jacobsen et
97 al. 2016). In the present investigation the need for non-operative caries treatment was
98 estimated by using proximal enamel lesions only (score 1- 2, corresponding ICDAS code 1-
99 3) registered on bitewing radiographs from the mesial surface of the first premolar to the
100 mesial surface of the second molar in each quadrant.

101
102 The principal examiner (IDJ) was calibrated with two experienced dentists. For calculation of
103 inter-observer agreement regarding radiographic examination, bitewing radiographs from 88
104 patients (10% of the study sample) were randomly selected. The three dentists
105 independently examined 28 surfaces per patient, making a total of 2464 surfaces, and
106 scored them according to the 5 graded scale. The weighted kappa value between recordings
107 of the three examiners was 0.71.

108 The quality of restorations was registered clinically and, when applicable, radiographically for
109 each participant by the principal examiner (IDJ) according to a modified version of the clinical
110 and radiographic criteria described by Hickel et al. (2010). Scores from 1 to 4 were used, 1 –
111 good, 2 – acceptable (with minor defects), 3 – poor (filling with defects in need for
112 repair/replacement but not immediately), 4 – unacceptable (filling needing immediate
113 repair/replacement). A score was assigned to each participant corresponding to the
114 assessed quality of the poorest filling.

115 Descriptive analyses and cross-tabulations were performed using SPSS 22.0. statistical
116 packet.

117 The project was approved by the Regional Committee for Medical Research Ethics
118 (2012/1197 REK Nord) and the Norwegian Data Protection Authority (07/00886-11).

119 120 **Results**

121 In the present sample of 16-year-olds, the prevalence of dentinal caries has been reported to
122 be 82.7% with a mean DMFS-index of 6.1 ± 6.9 (range 0 – 48) and a mean DMFT-index of
123 4.2 ± 3.8 (range 0-19) (Jacobsen et al. 2016). The present investigation disclosed a
124 prevalence of proximal enamel lesions of 83.9%, with a mean of 5.8 ± 5.0 (range 0 – 24).

125 The distribution of subjects with or without proximal enamel lesions in relation to sound (DFS
126 = 0), decayed (DS > 0) and filled (FS> 0) surfaces is presented in Table 1.

127 In this sample, 16.1% did not have any proximal enamel lesion. However, a majority of these
128 subjects (9.1%) had previously placed restorations and only 50 subjects (5.8%) were totally
129 caries-free. A major part of the participants with proximal enamel lesions had either
130 previously restored teeth (34.6%) or both restored teeth and untreated dentinal caries lesions
131 (34.4%). One hundred and one subjects (11.6%) presented with proximal enamel lesions
132 without any caries experience according to the DMFS-scores (Table 1). The estimated odds
133 not to have any proximal enamel lesions (PEL=0) was 0.16 for a student with previous caries
134 experience (DFS>0), compared to 0.56 for a student without previous experience (DFS=0),
135 (OR = 3.45; 95% CI 2.31 - 5.18).

136 According to the distribution of proximal enamel lesions, a total of 729 subjects (83.9%) were
137 in need of non-operative caries treatment, either as the only treatment modality (46.2%) or in
138 combination with restorative treatment (37.6%) (Table 1). When using the D-value of the
139 DMFS-index as diagnostic criterion, 338 (38.8%) of the participants were in need of operative
140 dental treatment. When proximal enamel lesions were included in the diagnosis, the number
141 of participants in need of individual operative and/or non-operative caries treatment was 740
142 (85.1%) (Table 1). In this material, 706 (81.2%) of the 16-year-olds had experienced
143 restorative care (Table 2). The individual quality distribution according to the poorest
144 restoration is presented in Table 2. More than one-third of the participants with fillings
145 (35.0%) had at least one restoration below acceptable quality levels (poor/unacceptable).

146 **Discussion**

147 The inclusion of enamel caries lesions in epidemiological studies among young people
148 appears to be an important issue, in particular in populations with low caries prevalence as
149 seen in the Nordic countries (Amarante et al. 1998; Mejåre et al. 1999; David et al. 2006; Alm
150 et al. 2007; Poutanen et al. 2007; Norderyd et al. 2015). However, there is no systematic
151 registration of enamel lesions for monitoring oral health at national levels. The present study
152 including all 16-year-olds in one urban and one rural municipality offered a unique
153 opportunity to study the need for non-operative caries treatment in a large and representative
154 sample. When diagnosing caries according to the traditional DMFS-index, 39 % of the
155 participants were in need of treatment. However, by including proximal enamel lesions in the
156 diagnosis, the treatment need more than doubled (85 %).

157 In the present investigation, only enamel lesions limited to the proximal surfaces were
158 registered, as they allow calibration and calculation of inter-observer agreement on bitewing
159 radiographs. The kappa index showed acceptable value. Furthermore, as buccal and lingual
160 decay is a minor problem among Nordic teenagers (Crossner, Unell 2007; Norderyd et al.

161 2015), and in order to eliminate uncertainties in visual discrimination between
162 hypomineralizations and enamel lesions, smooth and occlusal surfaces were not included.

163 Even if a substantial reduction in caries prevalence is reported from many parts of the world
164 (Petersen 2003; Marthaler 2004; Hugoson et al. 2008), a large majority (84%) of the present
165 group of 16-year-olds was diagnosed with enamel proximal lesions. This is in agreement with
166 earlier findings in Swedish 15-year-olds (Alm et al. 2007; Norderyd et al. 2015), indicating
167 that the caries decline might be overestimated and the distribution of the caries disease is
168 still substantial.

169 Caries is a preventable and curable disease. When early signs of disease activity appear, the
170 implementation of non-operative treatment measures is a crucial requirement for successful
171 reduction of restorative need. The generally accepted Nordic philosophy concerning caries
172 treatment for children and adolescents is that the overall progression is rather slow and that
173 a minor part of the population demands the majority of the resources (Crossner, Unell 2007;
174 Schwendicke et al. 2015). This way of thinking leads to an approach trying to identify risk-
175 groups and prolonging the recall interval for the rest of the population (Tan et al. 2006). This
176 is, however, a strategy focusing on the need for operative treatment, and not the cure of the
177 caries disease. In the present study, 94% of these 16-year-olds showed clinical and/or
178 radiographic signs of caries experience. Adolescents from Northern Norway have historically
179 had poorer dental condition than the rest of the country. According to the "Fit Future" study,
180 however, the current caries status seems to approach that of the rest of the country. The
181 participants with immigrant ethnicity did not seem to have influenced the caries prevalence
182 (Jacobsen et al. 2016). The findings of this study indicate that although traditional
183 epidemiological data show a considerable reduction in prevalence, dental caries still is a
184 disease affecting the total teenage population and not a minor risk-group. This is in
185 agreement with previous findings (Hugoson et al. 2008).

186 In this study a large majority of the participants with enamel proximal lesions also presented
187 with either previously restored teeth (FS, 35 %), or both restored teeth and untreated dentinal
188 caries lesions (DFS, 34 %) (Table 1). The odds of having proximal enamel lesions was more
189 than three times higher for subjects with earlier caries experience indicating that non-
190 operative treatment of enamel lesions should have been an integral part of traditional caries
191 treatment earlier in life.

192 Non-operative caries treatment is a modality including clinical examination and early
193 diagnosis of caries lesions, as well as assessment of the activity for the individual lesion,
194 thereby applying the principles of preventive treatment on the individual enamel lesion level
195 (Ekstrand et al. 2003; Selwitz et al. 2007; Raadal et al. 2011; Pretty, Ekstrand 2015). The

196 scientific evidence for the effectiveness and efficiency of non-operative interventions might
197 be considered insufficient (Bader et al. 2001a; Bader et al. 2001b; Källestål et al. 2003;
198 Källestål 2005; Mejare et al. 2015). On the other hand, fluoride-based interventions (varnish,
199 gel and toothpaste) have a beneficial effect in reducing incidence and progression of non-
200 cavitated lesions (Tellez et al. 2013; Mejare et al. 2015; Twetman 2015). A positive outcome
201 of non-operative caries treatment with indications of long lasting effect, and a promising cost-
202 effectiveness of such treatment, are supported by Ekstrand and collaborators (Ekstrand et al.
203 2003; Ekstrand, Christiansen 2005; Ekstrand et al. 2010; Ekstrand, Qvist 2014; Kuzmina,
204 Ekstrand 2015), as well as by other investigators (Hausen et al. 2007; Hietasalo et al. 2009;
205 Fejerskov et al. 2013).

206 A limitation regarding the current cross-sectional design was that it rendered impossible to
207 discriminate between active and arrested lesions, obviously resulting in a certain amount of
208 over-registration. In order to avoid this problem, longitudinal studies are required. However,
209 the results of the present study clearly indicated the magnitude of the clinical problem related
210 to enamel caries lesions. There is an obvious need for further studies regarding the efficiency
211 of non-operative interventions on enamel caries lesions including the utility of auxiliary
212 personnel (Baelum et al. 2012; Fejerskov et al. 2013; Widström et al. 2015).

213 Already at 16 years of age, 81% of the adolescents had experienced restorative care. At this
214 young age, 35% of the participants with restorations had at least one restoration below
215 acceptable quality level. The main reason for replacement of restorations is secondary caries
216 (Mjor, Gordan 2002; Kopperud et al. 2012; Brown et al. 2015) and this is related both to
217 restoration quality and caries activity. It has been shown in a longitudinal study that 90 % of
218 the DMFT-score at the age of 41 is present already at 19 years of age (Crossner, Unell
219 2007) clearly supporting that the main focus of dental treatment after the teens involves
220 repair and re-treatment. Consequently, the benefit of preventing enamel lesions from
221 progressing into dentin and thereby avoiding restorations is obvious, further indicating the
222 importance of early detection and proper handling of such lesions by applying a non-
223 operative approach (Pitts 2004).

224 The present investigation clearly indicates that the caries disease still is widespread within
225 the teenage population. Instead of trying to identify risk-groups and to prolong recall
226 intervals, a relevant and successful treatment strategy for teenagers ought to be general
227 prevention and shorter recall intervals in order to diagnose any active disease in time for
228 non-operative treatment. This imply an individually adjusted treatment cost effectually
229 performed by auxiliary dental personnel during a period when many permanent tooth
230 surfaces are newly erupted. The teen years are a vulnerable time in life needing support

231 passing puberty, leaving parental guidance, family routines and food habits on the way to an
 232 adult life. The DMFS-score and the high number of 16-year-olds with restorations in need of
 233 repair or replacement further indicates the importance of a “non-operative” caries treatment
 234 strategy in order to reduce the need of traditional restorative care aiming at minimizing the
 235 vicious operative re-treatment circle throughout life (Brantley et al. 1995).

236

237 **Compliance with Ethical Standards**

238 There are no conflicts of interest for any of the authors.

239 **Ethical approval**

240 The project was in accordance with the ethical standards of the national research committee
 241 and with the 1964 Helsinki declaration and its later amendments.

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368 **Legends**

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Table 1. The distribution of subjects with or without proximal enamel lesions (PEL), in relation to dentinal caries experience, based on DMFS-values. DS, FS, DFS are correspondingly decayed, filled and decayed-and-filled surfaces.

Table 2. Distribution of subjects according to the quality of the poorest dental restoration.

376 **Tables**

377 **Table 1.**

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Proximal enamel lesions (PEL) = 0		140 (16.1%)
PEL = 0, DFS = 0		50 (5.8%)
PEL = 0, DFS > 0	DS = 0, FS > 0	79 (9.1%)
	DS > 0, FS = 0	3 (0.3%)
	DS > 0, FS > 0	8 (0.9%)
Proximal enamel lesions (PEL) > 0		729 (83.9%)
PEL > 0, DFS = 0		101 (11.6%)
PEL > 0, DFS > 0	DS = 0, FS > 0	301 (34.6%)
	DS > 0, FS = 0	28 (3.2%)
	DS > 0, FS > 0	299 (34.4%)

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380 **Table 2.**

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Individuals with restorations	706 ¹ (81.2%)
Quality of poorest filling	
Good	37 (5.3%)
Acceptable	421 (59.8%)
Poor	159 (22.6%)
Unacceptable	87 (12.4%)

¹The quality of restorations in two subjects was not possible to assess due to orthodontic braces.