

Association of indirect restorations with past caries history and present need for restorative treatment in the Northern Finland Birth Cohort 1966

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Abstract

Objectives: To examine the prevalence of indirect restorations and their association with past caries history and present need for restorative treatment among adults in Northern Finland.

Materials and methods: The study population was a subsample of the Northern Finland Birth Cohort 1966 (n=1,961). The oral examinations were performed in 2012-2013. Indirect restorations (inlays/onlays and single crowns) were recorded tooth wise. Caries history was described with the sum of decayed, missing and filled teeth (DMF). Caries was assessed using the International Caries Detection and Assessment System (ICDAS). The score of 4 was used as the cut-off point for visible decay. Present need for restorative treatment was calculated by summing the decayed (D) and fractured (Fr) teeth. Need for restorative treatment was dichotomized to low $[(D+Fr)\leq 1]$ and high $[(D+Fr)>1]$.

Results: Altogether 7.8% of the study population had indirect restorations. The prevalence of indirect restorations did not differ within DMF ($p=0.925$), but it was higher among the subjects with a low need for restorative treatment ($p<0.001$).

Conclusions: Indirect restorations were rare in the adult population and found mainly among the subjects with a low need for restorative treatment.

Clinical relevance: The results of the study can encourage dentists to consider more often indirect restorations for subjects with a need for restorative treatment.

Key words: Dental restoration, Dental caries, NFBC1966, Restorative treatment, ICDAS, DMF Index

Introduction

Caries is globally one of the most prevalent chronic, non-communicable diseases [1]. It can be arrested and prevented, but if left uncontrolled, it will destroy the affected tooth surface [2]. The burden of caries is lifelong since repeated treatment is needed for the caries affected tooth for the rest of its life span [2,3]. Currently, restorative treatment is mostly performed by direct restorations with, for example, resin composites or amalgam [4,5]. Up to 10% of restorations made with direct technique need repairing within the first 10 years [6]. The patient's caries risk affects the failure rate: the higher the caries risk, the higher the restorations' failure risk [7].

Prevalence of caries has been traditionally determined on the basis of the sum of decayed, missing and filled teeth (DMF) and the International Caries Detection and Assessment System (ICDAS). The current recommendation is to use ICDAS, which is a visual caries detecting system developed by a large group of researchers worldwide to enhance the reliability of clinical examination. ICDAS includes initial stages of caries lesions with activity assessment to count. It classifies caries lesions visually into six categories based on the clinical features and respective histological depth of caries lesions [8,9].

An indirect restoration can be used when the tooth has extensive substance loss and the fracture risk of a conventional restoration would be elevated [10], or if the tooth is endodontically treated [11]. The indications for onlay restorations include cavities with wide isthmuses and endodontically treated posterior teeth with sound facial and lingual tooth structure [12]. Indirect restorations in endodontically treated teeth have been reported to improve the tooth's survival compared to those restored with direct restorations [13]. However, the evidence of the advantages of single crowns compared to inlays/onlays in endodontically treated teeth has been insufficient [14]. In a recent study by Afrashtehfar et al. [15], the key element defining the survival of direct or indirect restorations in posterior teeth was the number of remaining tooth walls. That study showed that direct restoration is the better choice when at least three tooth walls will remain after the preparation of the cavity, whereas an indirect single crown is the better treatment option when only one or no walls remain [15].

The aim of this study was to assess the prevalence of indirect restorations among adults in Northern Finland. Another aim was to investigate the association of indirect restorations with past caries experience and a present need for restorative treatment. The hypothesis was that indirect restorations are found more often in subjects with low caries history and a low need for restorative treatment.

Materials and methods

Study population

The Northern Finland Birth Cohort 1966 (NFBC1966) originally comprised babies in the two northernmost provinces of Finland whose expected date of birth was in the year 1966 (n=12,231) [16]. The members of the NFBC1966 have been regularly evaluated by clinical follow-up examinations and health-related questionnaires. In 2012-2013, the members of the cohort who lived within the range of 100 kilometers of the city of Oulu (n=3,150) were invited to participate in a clinical oral and medical examination. Two thirds (62.3%) of those invited decided to participate and thus formed the study population (n=1,961). (<http://www.oulu.fi/nfbc/>). The cariological status and information about indirect restorations were available for 1,944 and 1,946 subjects, respectively.

Clinical examination

All the oral examinations were carried out in a dental clinic with modern equipment and were performed by using an oral mirror, a WHO ball-pointed gingival probe, and fiber-optic transillumination (FOTI). The examinations were performed by seven calibrated dentists who followed a standardized protocol. The teeth were blow-dried but not professionally cleaned before the clinical examination. A dental nurse recorded the findings in an electronic patient file. The protocol is described in detail by Alaraudanjoki et al. [17]. The clinical examination was carried out by first recording the missing teeth and then assessing the cariological status together with the restorations.

Need for restorative treatment

The cariological status was assessed per tooth surface by using the ICDAS criteria. The highest ICDAS score of the tooth surface was used to define the tooth's ICDAS score. The criteria indicating a need for restorative treatment due to caries were the ICDAS scores 4-6. Tooth fractures were calculated tooth wise, not considering the location or the extent of the fracture. Teeth with both caries and fracture were recorded as decayed. For the analyses, caries lesions were transformed tooth wise into healthy (ICDAS scores 0-3) or visibly decayed (ICDAS scores 4-6), and the decayed (D) and fractured (Fr) teeth were combined to describe the total need for restorative treatment. For statistical analyses, the need for restorative treatment was categorized into two groups, low $[(D+Fr) \leq 1]$ and high $[(D+Fr) > 1]$.

Caries history

The overall caries history was determined with the DMF-index. The ICDAS score was transformed into the DMF-index. In DMF, missing teeth were included regardless of the reason of the extraction and filled teeth despite the material used. For the analyses, participants were dichotomized to those with low (DMF \leq 14) and high caries experience (DMF $>$ 14).

Indirect restorations

Inlays, onlays and single crowns were recorded tooth wise. Inlays and onlays or the material used (gold alloy, all-ceramics) were not recorded separately. A tooth was considered to have an indirect restoration if an indirect inlay/onlay restoration or a single crown was found, not considering its extent. Single crowns as an abutment teeth of a fixed dental prosthesis (FDP) were excluded. The indirect inlays and onlays and single crowns were counted together as indirect restorations and then divided into three groups as 0, 1 and >1 restorations.

Validation

All the examiners were trained and calibrated before the field-phase and every three months during the examinations. To investigate the intra- and inter-examiner agreement, repeated examinations and parallel examinations by a golden standard were carried out. The examiners re-examined one quarter of the dentition of five subjects approximately a month after the previous examination (repeated measures). The golden standard re-examined at least 10 subjects from each examiner (parallel measures) and supervised the entire field phase. The ICDAS criteria were available to the examiners as printed version throughout the field phase.

Ethical issues

The subjects provided their written consent for the study, the participation was voluntary, and the subjects had the right to refuse to give information about themselves at any time. The study was approved by the Ethical Committee of Northern Ostrobothnia Hospital District (74/2011).

Statistical issues

The data were analyzed with SPSS (version 24.0, Illinois, USA). The distributions of D, Fr and DMF, the prevalence of indirect restorations, and the need for restorative treatment were reported as means (SD), frequencies and proportions by gender. The distributions between the categorized DMF, need for restorative treatment and indirect restorations were analyzed with cross tabulation and Pearson's chi-square test. Statistical significance of the differences between the groups was set to $p < 0.05$. The occurrence of D and indirect inlay/onlay restorations and single crowns in dentition were illustrated.

Results

The study population was evenly distributed between the genders (males 46.5%, $n=911$, females 53.5%, $n=1,050$). Almost eight percent (7.8%, $n=151$) of the subjects had indirect restorations; there was no statistically significant difference between the genders. Altogether 4.8% ($n=95$) of the study population had inlays or onlays (range 1-5). The respective proportion for single crowns was 4.0% ($n=77$, range 1-18). Most commonly, the subjects had only one indirect restoration

(n=84). Indirect inlays and onlays were most prevalent on first molars in both jaws, whereas single crowns were most prevalent on maxillary incisors and mandibular molars. (Fig.1)

The mean DMF-score was 14.9 (SD 5.16); the difference between males (mean 15.3, SD 5.44) and females (mean 14.6, SD 4.88) was statistically significant ($p=0.006$). On average, 39.8% (n=773) of the study population had visible decay ($D>0$), males (46.6%) more than females (33.9%) ($p<0.001$). The mean number of D was 0.98 (SD 1.84), males (1.20 SD 1.98) had more visible decay than females (0.79 SD 1.68). Caries was most prevalent in maxillary premolars and mandibular molars (Figure 2.). Fractured teeth were present among 28.5% (n=558) of the study population: males (32.7%) had more fractured teeth than females (24.8%) ($p<0.001$). The mean number of Fr was 0.4 (SD 0.89) (males 0.5, SD 1.01; females 0.4, SD 0.77). Half (51.4%, n=1,009) of the study population were in need for restorative treatment, males (58.6%) more than females (46.1%) ($p<0.001$). The mean number of teeth with a need for restorative treatment was 1.4 (SD 2.31); the number was higher for males (1.7 SD 2.48) than for females (1.2 SD 2.11).

The prevalence of indirect restorations was higher among the subjects with a low need for restorative treatment [$(D+Fr)\leq 1$] compared to the subjects with a high need for treatment [$(D+Fr)>1$] ($p=0.001$). The association was similar between the genders (male $p=0.032$, female $p=0.017$). (Table 1)

Discussion

According to this cohort study of 46-year-old participants, indirect restorative treatment is currently more common among people with a low need for restorative treatment. When the members of the NFBC1966 were young, it was more common to use amalgam than resin composite in restorative dentistry. According to the policy statement of the World Dental Federation (FDI) based on the Minamata Convention on Mercury in 2013, the use of amalgam has decreased worldwide and other restorative materials have been recommended to be used instead [18]. The long-term survival of posterior conventional restorations has been shown to have a relatively short life span due to secondary caries and fractures of the tooth or filling substance [4,7,19,20]. Restorations in general have shown to fail earlier in caries-prone subjects compared to caries-resistant people [21]. Traditional metal alloys (e.g. gold) and ceramic materials (leucite-reinforced glass-ceramics, lithium-disilicate, zirconia) are used in fixed prosthodontics. The long-term durability of different ceramic materials is under research as ceramic materials have been developed and their use has become more frequent. It has been reported that ceramic single crowns have almost the same survival rate as traditional metal-ceramic ones [22-24].

Indirect restorations have advantages compared to direct restorations, such as accurate fit of the restoration (small marginal gap), good proximal contacts with adjacent teeth, improved control of occlusal contour, no polymerization shrinkage, and superior strength and wear resistance [25]. On the other hand, indirect restorations need more removal of

dental tissue (removal of undercuts of the cavity walls), are more expensive, and require more time-consuming chairside procedures [25]. An indirect restoration usually requires several visits to the dentist [26]. However, digital computer-aided design and manufacturing (CAD/CAM) techniques have simplified the impression procedures, in particular. CAD/CAM techniques are getting increasingly frequent, also allowing milling the restoration from a ceramic block during a single appointment. Cast-gold inlays perform better compared to other restorative materials [27], but they are more expensive and less aesthetic. Ceramic materials offer better aesthetics and, when adhesively bound into enamel, also have a smaller risk of microleakage. When bound into dentin, however, the microleakage and secondary caries may still pose a problem [10].

Indirect ceramic materials seem to perform better in inlays compared to direct resin composite [26,28,29]. The more dental tissue is lost and the more time passes by, the better an indirect restoration performs compared to a standard composite resin restoration [26]. With a well-designed and properly prepared cavity, indirect restorations are more durable than traditional direct restorations [10,28]. According to a recent systematic review and meta-analysis, the estimated survival rates of ceramic inlays and onlays were 92-95% at five years and 91% at 10 years [25]. Failures were related to fractures/chipping (4%), endodontic complications (3%), secondary caries (1%), and de-bonding (1%) [25]. Subjects whose oral conditions favor caries could benefit from the features of indirect restorations described above. However, in Finland indirect restorations are remarkably more expensive than direct restorations for the patients. Thus, it can be suspected that one reason for the relatively low number of indirect restorations in the NFBC1966 is the individual's financial status. According to a survey by Heinikainen et al. [30], fixed prosthodontics are chosen more often at private practices compared to public health centers. Their study also stated that although general dentists are aware that indirect restorations should be used for failed large posterior fillings, they still tend to choose a direct composite or amalgam restoration.

The distribution of indirect restorations was almost similar in all mandibular teeth, whereas in maxilla specifically crowns were found on incisors. Most likely the reason for an anterior indirect restoration is either trauma or aesthetics, not caries. The distribution of the need for treatment was highest in maxillary premolars and mandibular molars. In first premolars, an early strong repairing of the tooth is highly recommended due to the complex and narrow two-root anatomy with developmental invaginations and depressions of the tooth material. In premolars, the restoration of a mesial-occlusal-distal cavity with an inlay is questionable [12] because the occlusal force on the inlay produces stress along the sides of the restoration against the surrounding tooth structure, which could fracture the tooth. Covering the occlusal surface with at least an onlay, or a single crown, minimizes the stress on the tooth structure [12]. Previous studies have reported maxillary first premolar to also be the most common tooth to be replaced with FDP [31,32]. A study among young adults

indicated molars to be the most prone to caries [33]. According to our study, indirect restorations could reduce the need for restorative treatment (secondary caries) in upper molars.

The causes for indirect restorations were not available for this study, which can be considered as a limitation. In addition, the DMF-index in an adult population is impossible to interpret since it describes both the past caries history and the present need for restorative treatment at the same time [34]. Past caries history is more accurately described when analyzing decayed, missing and filled teeth separately. ICDAS is an accurate tool to describe present caries stages. Using ICDAS and analyzing restored and missing teeth increases the strength of this study. To evaluate the need for restorative treatment, in addition to caries prevalence, the number of fractured teeth needs to be included in the analyses. However, in this study, the effects of fractures on the results were quite low although nearly one third of the participants had at least one fractured tooth.

The low number of indirect restorations in the cohort can be considered as a limit of this study when evaluating the association between indirect restorations, the present need for restorative treatment, and caries history. Corresponding studies concerning single crowns are also scarce. In the early 20th century, the prevalence of fixed restorations in Europe, including both single crowns and FDPs, was reported to be highest in Sweden (45%) and Switzerland (34%) [35]. In elderly citizens in the southern and northern parts of Finland, the prevalence of single crowns was close to 12% [36]. Compared with these figures, the 7.8 % prevalence of indirect restorations, including inlays, onlays and single crowns, was surprisingly low in this population-based study of 46-year-old subjects in Northern Finland. The follow-up of the NFBC1966 is continuous and although the survival of either indirect or direct restorations could not be studied here, it would be interesting to investigate this topic in the future.

The NFBC1966 represents well the adult population of Northern Finland, and the size of the age cohort enables the adaptation of the results to larger populations. The large size of the NFBC1966 allows the investigation of indirect restorations separated from direct restorations. To our knowledge, no comparable epidemiological study concerning the prevalence of indirect inlays and onlays is found in the literature. These types of studies are needed since it seems that indirect restorative treatment has become more frequent and caries still poses a remarkable burden for the adult population.

Conclusion

Indirect restorations are rare in the adult population and are mainly found in subjects with a low need for restorative treatment. According to our results, indirect restorations should be considered more often, especially when performing restorative treatment on upper premolars and lower molars in cases of large tooth material loss. Indirect restorations could

provide durable solutions to restorative treatment by reducing the prevalence of secondary caries and the risk of tooth fracture.

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Compliance with Ethical Standards

Conflict of interest: All the authors declare that they have no conflict of interest.

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Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent: Informed consent was obtained from all individual participants included in the study.

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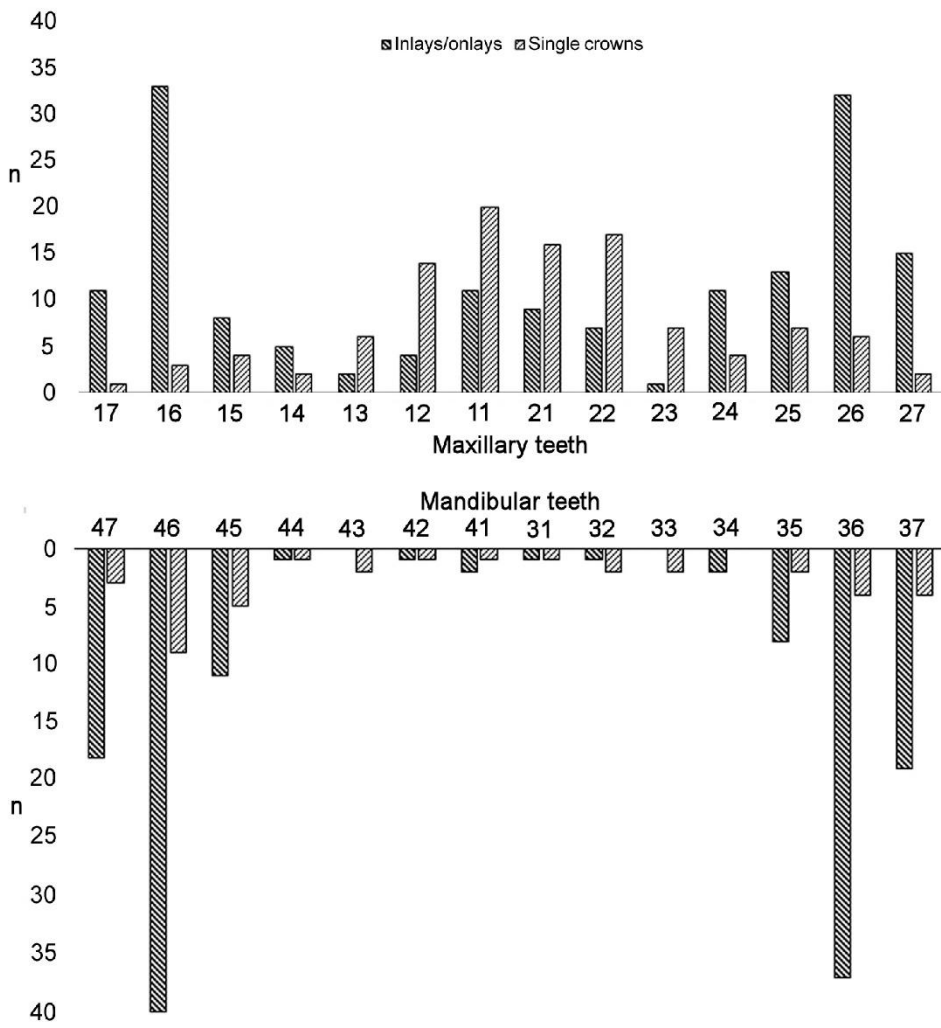
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Figure legends

Figure 1 The observed frequency (n) of inlay/onlay restorations and single crowns on maxillary and mandibular teeth (n=1,944)

Figure 2 The observed frequency (n) of teeth with visible decay (D>0) and fractures (Fr>0) in maxilla and mandible (n=1,944)



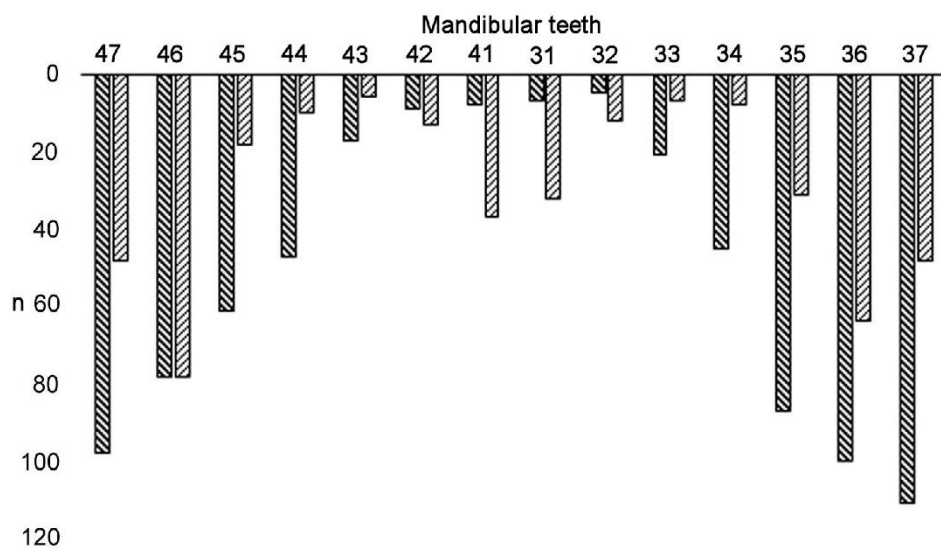
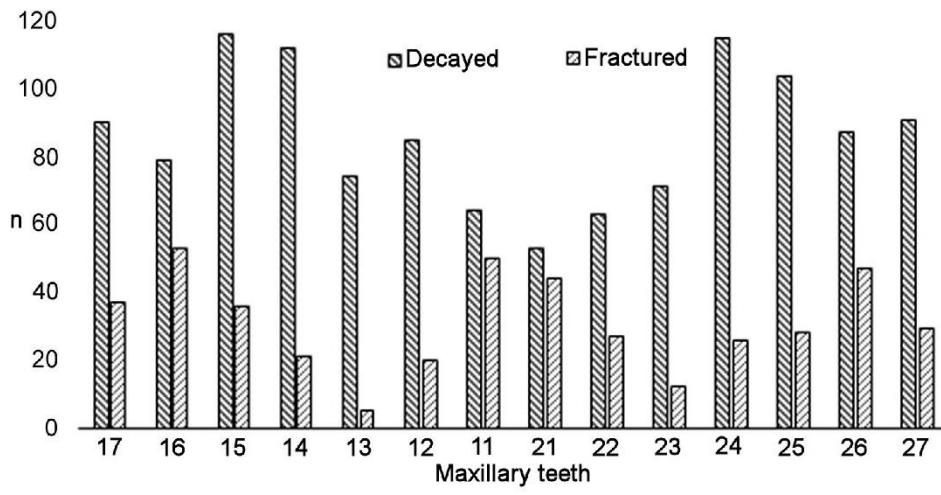


Table 1. The proportions of indirect restorations in association with categorized DMF and need for restorative treatment (Pearson's chi-square test).

		<i>Indirect restorations</i>						<i>total</i>		<i>p-value</i>
		0		1		>1		<i>n</i>	<i>%</i>	
		<i>n</i>	<i>%</i>	<i>n</i>	<i>%</i>	<i>n</i>	<i>%</i>	<i>n</i>	<i>%</i>	
DMF	≤ 14	879	45.2%	35	1.8%	33	1.7%	947	48.7%	0.420
	> 14	915	92.2%	84	4.3%	34	1.7%	998	51.3%	
Need for restorative treatment	$(D+Fr) \leq 1$	1234	63.5%	68	3.5%	59	3.0%	1361	70.0%	0.001
	$(D+Fr) > 1$	559	28.8%	16	0.8%	8	0.4%	583	30.0%	