



Treatment outcome of stepwise caries removal in Sweden – a retrospective registry study

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Abstract

Dental caries is the most prevalent pathologic condition in the world. If left untreated, it can endanger the vitality of the pulp. A treatment method aiming at avoiding endodontic treatment is stepwise caries removal (SCR), however some SCR-treatments will not succeed and these teeth will need endodontic treatment at a later stage.

Aim: To investigate survival of SCR-treatment in public and private dentistry settings by time aspect.

Material and method: This retrospective registry study used longitudinal data from the national quality registry SKaPa (Swedish Quality Registry for Caries and Periodontal Diseases). The sample (n=15 330) consisted of all teeth registered with SCR-treatment during the year 2013 and analysed up to 58 months. Registration of intervention-codes that represented endodontic treatments or extractions were defined as failures. The data was analysed using the Kaplan-Meier statistical test to estimate survival time along with descriptive statistics.

Results: The material consisted of 15 330 treatment cases, with registered subsequent visits to the year 2017. Due to lost cases, 12 444 cases could be analysed. Age ranged between 18–96 years (mean 43 years) and one tooth per individual were included. After a 4-year follow-up period 72% (n=8 957) teeth had no registrations of endodontic treatments or extractions.

Conclusion: This study shows a high success rate for stepwise caries removal registrations in 4-years follow-up in Swedish public and private dentistry settings. The success of this treatment is dependent on the age, which is statistically significant.

Sammanfattning

Dental karies är det mest förekommande patologiska tillståndet i världen. Om kariessjukdomen inte behandlas i tid kan det äventyra pulpans vitalitet. En behandlingsmetod som används i syfte att undvika endodontisk behandling är stegvis kariesexkavering (SCR), men vissa SCR-behandlingar kommer inte lyckas och dessa tänder kommer behöva endodontisk behandling vid ett senare tillfälle.

Syfte: Att undersöka överlevnaden för behandlingen stegvis kariesexkavering utförd inom allmän- och privattandvården, genom att analysera över tid.

Material och metod: Denna retrospektiva studie analyserade longitudinella data från nationella kvalitetsregistret SKaPa (Svenskt Kvalitetsregister för Karies och Parodontit). Datan (n= 15 330) bestod av alla tänder registrerade med SCR-behandling under året 2013 och analyserad upp till 58 månader. Registrering med åtgärds-koder som utgjorde endodontisk behandling eller extraktioner, definierades som misslyckanden. Datamaterialet analyserades med Kaplan-Meiers statistiska test för estimering av överlevnadstiden utefter deskriptiv statistik.

Resultat: Materialet inkluderade 15 330 behandlingsfall, med registrerade efterföljande besök till år 2017. Efter bortfall kunde 12 444 fall analyseras. Åldern varierade mellan 18–96 år (medelvärde 43 år) och en tand per individ inkluderades. Efter en 4 års uppföljningsperiod 72% (n=8 957) tänder hade inga registreringar på endodontisk behandling eller extraktion.

Konklusion: Studien påvisar en hög lyckandefrekvens för registreringar av stegvis kariesexkavering i en 4-års uppföljningsperiod i svensk allmän- och privattandvårdskliniker. Behandlingens lyckande är åldersberoende och statistiskt signifikant.

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Introduction

Dental caries is considered the most prevalent pathologic condition in the world (1). As a consequence of digestion of fermentable carbohydrates by oral microorganisms, acid is produced as a by-product. The acid will eventually demineralize the enamel, until a macroscopic cavity is formed (2). If left untreated, the superficial caries lesion could progress deeper into the dentine and eventually endanger the vitality of the pulp (3).

Deep caries lesions can be a challenge to treat in the clinic, especially as they often threaten the vitality of the pulp. A well-known treatment method aiming at avoiding endodontic complications in cases of deep caries is stepwise caries removal (4), which is a method primarily aimed at lowering the risk of pulp exposure at the time of initial excavation (5).

Despite having been used for over 30 years, interest in this treatment method has rekindled in recent years, as the concept of minimally invasive dentistry has gained momentum. However, studies on the long-term fate of teeth treated with stepwise caries removal is severely lacking in the literature (6).

Development of the caries lesion

Dental caries is an infectious disease that affects the teeth. To develop caries, the presence of a dental biofilm is crucial. Dental biofilm is composed of salivary components, oral microorganisms, and their products. When fermentable carbohydrates are added through the diet, they will be digested by microorganisms present in the dental biofilm, resulting in production of acids which will eventually create an environment with a low local pH. The oral cavity has several defence mechanisms in the saliva, such as oral clearance and salivary buffering capacity, which acts to neutralize the low pH in the biofilm. However, frequent dietary intake of fermentable carbohydrates will lead to extended periods of low pH, which makes the tooth vulnerable by overpowering the oral defence mechanisms, as they are not sufficient to handle such considerable acidic challenges. Moreover, prolonged periods of low pH favours multiplication of microorganisms capable of both producing acids (acidogenic) as well as tolerating the acidic environment (aciduric). This can lead to an ecological shift where especially the genera *Streptococcus*, *Actinomyces* and *Lactobacillus* increase in numbers and become dominant in the biofilm (2).

The changed environmental conditions will affect the balance between re- and demineralization at the affected tooth site. For demineralization to occur, the pH needs to drop below the critical pH for enamel and dentine (pH 5.5 and 6.7 respectively) (2, 7). If the environmental conditions change and the pH increase above the aforementioned critical pH, the process of remineralization will take place instead. In remineralization, the locally dissolved mineral ions, as well as mineral ions from the saliva contribute to the reconstruction of the lost tooth structure. This process can restore lesser carious lesions where a frank cavity has not developed yet. However, if the demineralization process is allowed to progress further into the tooth structure and if it reaches the dentine, it will be harder for the mineral ions to reach the deeper parts of the lesion, thus severely limiting the possibility for remineralization to occur. Also, the remineralization process cannot restore severe loss of tooth structure, such as when a cavity has formed (2).

As long as the carious lesion have not reached the pulp, the pulp will be free of bacterial invasion, but it will react to the secreted bacterial products with an inflammatory response (8). If remineralization would not transpire for some reason, the carious lesion will continue to develop, and a cavity may form, with a need for invasive treatment as a consequence (3).

Deep caries

Deep caries can be defined as carious lesions involving $\geq 75\%$ of the dentine thickness as seen on intraoral radiographs. It has been proposed that, in cases of deep caries, a criterion for the use of stepwise caries removal is that a radiopaque zone between the pulp and the caries lesion can be confirmed radiographically (9). This radiopaque zone indicates that the carious lesion has not penetrated the pulp (9) and therefore the bacteria have not reached to the pulp (3).

Treatments

Non-selective caries removal (formerly described as direct complete excavation) (4) is a well-recognized caries excavation method, which aims at removing all carious dentine tissue until reaching hard and healthy dentine. The procedure is performed in one visit. However, the uses of this method have been proven to be overly invasive and may increase the risk for pulpal exposure (10).

If the pulp would be exposed during the excavation procedure, a conservative procedure in order to preserve the pulp vitality is direct pulp capping (3). However, it has been demonstrated that direct pulp capping of carious teeth has a poor prognosis due to the pulp inflammation that may be irreversible and the high risk of bacterial invasion into the pulp which will cause infection, thereby leading to loss of pulpal vitality (9, 11). A recommended treatment in this stage is pulpectomy (3). This can be unfavourable due to the higher risk of fracture of the dental structure (12).

In cases of pulp necrosis, the only remaining recommended treatment option (other than tooth extraction) is endodontic treatment (3). Such conveys its own disadvantages in form of increased risk of fracture, infectious sequelae and possibility of future endodontic re-treatment (13). However, if the pulp remains unexposed, even in cases of deep carious lesions, there is a good probability that the affected tooth will retain its pulpal vitality (9). Hence, the imperative treatment aims when handling cases of deep caries should be to minimize the risk of pulpal exposure and achieve normal clinical and radiographic conditions, which is precisely what the stepwise caries removal procedure was designed to achieve (10). According to Bjørndal and co-workers and Leksell and co-workers (9, 10) it has been demonstrated that stepwise caries removal result in fewer pulp exposures than non-selective caries removal and might therefore be beneficial for preserving pulp vitality in cases of deep caries.

Stepwise caries removal

Stepwise caries removal is a method to excavate deep caries, at the same time reducing the risk of pulp exposure. The method demands two visits to remove all carious tissue and ensure the recovery of the pulp (14).

First visit

At the first visit, the bulk of the soft cariogenic biomass is removed. In the cavity periphery, the necrotic dentin is fully removed to hard dentine to facilitate optimal bonding between tooth and restoration (15), while the most pulpal parts of the demineralized and infected dentine is left (16). The bonding stage is a prerequisite for the concomitant pulpal defence reactions and healing that will take place after filling and sealing the cavity with a temporary restoration like resin modified glass ionomer (17).

Calcium hydroxide

The stepwise procedure enables remineralization of reversibly damaged dentine, formation of tertiary dentine and other defensive pulpal reactions to take place (9). To enhance these

defensive reactions, a 1 mm thick layer of calcium hydroxide is placed in the cavity over the carious dentine near the pulp (5). In Scandinavia, the use of a calcium hydroxide liner covering the cavity floor when performing stepwise caries removal has been used traditionally, despite the lack of evidence regarding its effectiveness (18).

The postulated rationale for using calcium hydroxide liners is to help in preserving tooth pulp vitality. The attributed mechanisms of calcium hydroxide are (i) by providing a mechanical insulation between the tooth structure and the filling, (ii) by exerting anti-bacterial properties as a result of its high pH, and (iii) by stimulating the formation of tertiary dentine and stimulation of re-mineralization (mainly based on old studies on pulp capping on monkeys) (18).

The high pH of the calcium hydroxide has been shown to be unfavourable for cariogenic bacteria, such as *Lactobacillus* and *Streptococcus mutans*, making their numbers decrease. This could lead to the arrest of the caries lesion left after the first visit in a stepwise caries removal treatment and stimulate the formation of tertiary dentine (19). Another theoretical advantage of calcium hydroxide might be stimulation of tertiary and sclerotic dentine (10).

However, this is controversial, as other researchers have claimed that the anti-bacterial effects are irrelevant, and that the ability to stimulate re-mineralization has not been shown to be an effect of the lining material itself (18). A recent study (20) instead emphasizes the importance of proper sealing of the dental cavity with a biocompatible temporary restoration, thus enclosing the bacteria, thereby inhibiting their growth by changing the micro-ecosystem in the cavity. The same study also claim no difference between adding any covering material in their healing results.

Time interval

To attain formation of tertiary dentine, an expectancy time interval is required after having applied the temporary filling; the most frequently used expectancy time in general dental clinics according to Bjørndal and co-worker is 6 months (21). The expectancy time used varies in different studies and can extend for a period of 8-12 weeks (9), to a longer period extending to 6-9 months (14). The reason to the wide range of the expectancy time is the lack of a general directive and therefore there is a need for studies investigating this issue.

Second visit

Formation of tertiary dentine make it easier to remove the remaining parts of the caries lesion during the second visit, while avoiding pulp exposure (9). During the second visit, the temporary restoration is removed, and a clinical re-assessment of the dentine cavity hardness is made. If the result is satisfying, the residual caries is removed until achieving hardness equal to healthy tooth structure (16).

Previous studies representing survival of stepwise caries removal over time

A randomized clinical trial done by Maltz and co-workers (22) investigated the effectiveness of non-selective caries removal (formerly direct complete excavation) and stepwise caries removal in permanent molars in the age range between 6-53 years. Stepwise caries removal demonstrated a success rate of 69% after a 3-year follow-up period with respect to sustained pulp vitality (total cases, n=101).

In a recent randomized clinical trial done by Bjørndal and co-workers (23) compared stepwise caries removal (n=118) with non-selective caries removal in permanent teeth for the age 18 and above. Stepwise caries removal showed a 60% survival rate after 5-year follow-up, where

these teeth showed signs of pulpal vitality after provocative methods (thermal and electrical) and no radiographic sign of periapical radiolucency.

The present study aims to investigate the outcome of stepwise caries removal registrations, during a 4-year follow-up period. The results will further increase the knowledge of the outcome of this treatment method over time, as current knowledge in the field is lacking.

Specific aim

To investigate the survival of registered stepwise caries removal treatment in Swedish public and private dentistry settings during the year 2013 followed over a 4-year period. Teeth not being registered as endodontically treated or extracted were considered as teeth with a vital pulp and therefore as succeeded treatment.

Main research question

How does the outcome of registered stepwise caries removal treatment appear over a 4-year follow-up period?

Sub-questions

1. Is the outcome dependent on the patient's age?
2. Is the outcome dependent on tooth group?

Hypothesis

Hypothesis to sub-questions

1. Younger patients have higher success rate than older patients after treatment with stepwise caries removal, which has been observed by Bjørndal and co-workers (9).
2. Different tooth groups are not a dependent factor for pulp vitality.

Materials and methods

Materials

Sample

This retrospective study analysed longitudinal data extracted from SKaPa (Swedish Quality Registry for Caries and Periodontal Diseases). SKaPa is a national quality registry commissioned by the government agency “Swedish Board of Health and Welfare”. Medical records consisting of patient data, diagnose codes and intervention codes (TLV code system) are continuously received and accommodated in a database in the council of Värmland. Dental clinics in totally twenty councils and one private corporate group are connected to this system (24).

The extracted data included cases with “stepwise caries removal” (total cases, 15 330) registered during the year of 2013 in Sweden and further included all follow-up data registered for these cases, which included specific treatment code for each tooth, over a period until and included October 2017 (2017-10-03).

Requested variables for this study included gender, age, tooth number, pre-operative tooth status/diagnosis, treatment onset for stepwise caries removal, status/diagnosis at follow-up, treatment at follow-up, and status/diagnosis and treatment for all subsequent visits regarding the specific studied tooth during the analysed period. Only one tooth per patient was included. In cases of patients who got two teeth treated with stepwise caries removal, the chosen tooth was the first one treated in 2013. In cases of several teeth registered with stepwise caries removal at the same day, the most anterior tooth and the one on the right side was chosen by the staff at SKaPa. Intervention codes that were registered and considered as failed treatments were 401-405, 420, 421, 423, 425, 430, 480, 501-504, 521 and 522. The 400-serie for the intervention codes refer to extractions and 500-serie refer to endodontic treatments.

Inclusion and exclusion criteria

The inclusion criteria were permanent teeth registered with stepwise caries removal during the year 2013 in Sweden. Subjects of 18 years of age and above were included. The exclusion criteria were subjects not showing up at all after first stage of stepwise caries removal treatment. These subjects were regarded as missing cases, since no registration was done for the second stage of the treatment and therefore could not be analysed.

Method

Anonymous data was received as a Microsoft Excel-file from the national database SKaPa. The data was imported into SPSS software (Statistical Package for the Social Sciences) and analysed statistically using SPSS 24.0 for Mac (IBM Corporation; Somers, NY, USA), in collaboration with a statistician.

All cases from the baseline that got their registration of stepwise caries removal treatment in 2013 were extracted from SKaPa. Cases with registrations after first stage of stepwise caries removal treatment could be followed-up and analysed.

Ethical considerations

All subject identification data was removed at SKaPa before delivery of the database-file. The research data was only handled by the researchers involved in the project. The project was also reviewed by the local Ethics Committee at the Faculty of Odontology at Malmö University (Dnr: STUD 3.5.3-2017/383) before application to SKaPa for data extraction.

Statistical analysis

Samples of such large numbers of cases did not require a power analysis.

The statistical method used was the Kaplan-Meier survival analysis, in conjunction with various measures of descriptive statistics. A p-value of less than 0.05 was regarded as statistically significant. Log-Rank was used as the main significance test along the Kaplan-Meier survival analyses.

Results

Descriptive analysis

The data analysed in this study were collected between January 2013 and October 2017, consisting of 15 330 registrations of stepwise caries removal (baseline) in 7 581 men and 7 749 women. For men the age range was 18-96 and for women 18-94 years. The cases were composed of 283 incisors, 403 canines, 3 799 premolars and 10 845 molars. A total of 2 886 (18.8%) cases had no further registration after the first stage of stepwise caries removal treatment performed at baseline. The remaining registrations could be analysed up to 58 months. The time interval from first stage of the treatment (baseline) to second stage was up to 45 months. The analysed cases had between 2-12 registrations at the dental clinic.

The means and medians of the age distribution of the analysed cases registered at baseline and missing cases were around 40 years of age and are described in Table 1.

Table 1. Description of the age distribution for missing cases and analysed cases registered at baseline.

	Mean	Standard deviation	Minimum	Maximum	Median
Missing cases	41.04	16.56	18	93	38.00
Analysed cases at baseline	42.76	14.75	18	96	42.00

Table 2 shows the distribution of preoperative status in the extracted data and the survival of stepwise caries removal treatment of the analysed cases for each status.

Table 2. Description of preoperative status and the survival of the treatment of the analysed cases registered at baseline in year 2013.

	Preoperative status*	Total	Missing cases	Survival of analysed cases		
				Yes	No	Survival in percent
Valid status	Krona	114	31	48	35	57.8%
	D3	3 252	687	2 072	493	80.8%
	D2	249	49	133	67	66.5%
	D1	88	25	48	15	76.2%
	D0	470	135	245	90	73.1%
	SEK	3 900	611	2 290	999	69.6%
	REST	6 333	1 028	3 764	1 541	71.0%
	704	6	2	3	1	75.0%
	705	10	6	2	2	50.0%
	706	6	2	2	2	50.0%
	Total	14 428	2 576	8607	3 245	72.6%
Missing status	System	902	310	350	242	59.1%
Total		15 330	2886	8 957	3 487	72.0%

*Krona = crown; D3, D2, D1 and D0 = caries x-ray; SEK = secondary caries;

REST = "restoration" (definition unknown); 704 = filling on one site on molar or premolar; 705 = filling on two sites on molar or premolar; 706 = filling on three or more sites on molar or premolar.

Survival of analysed registrations

The survival of the analysed cases is illustrated in Diagram 1. The function is included with censored data, which illustrates cases that are similar in value at the end of the analysed period but that are unknown in survival outcome after the 58-month study period. The number of registrations considered as succeeded treatment was 8957, which corresponds to 72.0%.

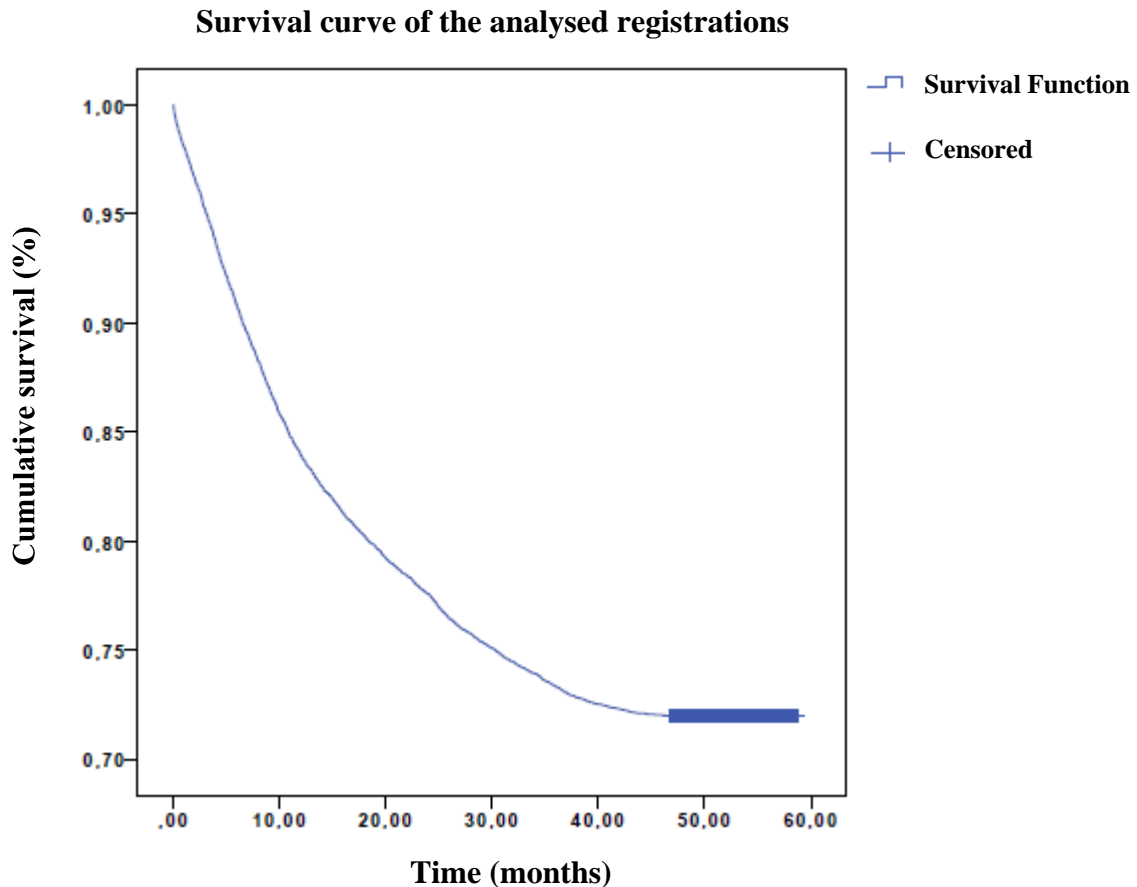


Diagram 1. Cumulative survival of the analysed stepwise caries removal registrations in relation to time in months plotted as a function with the aid of Kaplan-Meier and including censored data.

Survival for age groups of analysed registrations

The survival curves for the age groups of analysed registrations are illustrated in Diagram 2. There is a statistical significant difference in the survival curves between the different age groups ($p < 0.00$). The result was dependent of the age, where 78.1% (2 140) in the age group 18-29, 75.0% (2 132) in the age group 30-39, 69.2% (3 519) in the age group 40-59 and 65.7% (1 166) in the age group 60-96 had no registrations for endodontic treatments or extractions.

Survival curves for age groups of the analysed registrations

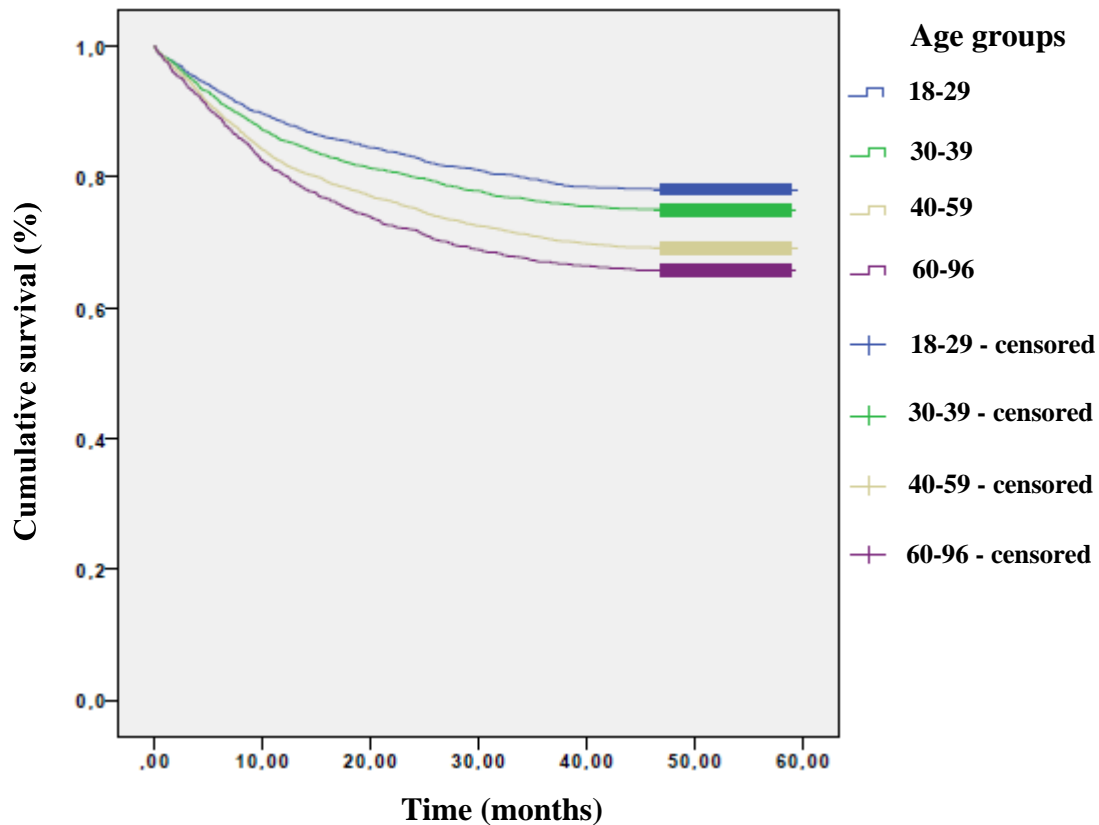


Diagram 2. Cumulative survival of the analysed stepwise caries removal registrations in relation to time in months for age groups plotted as a function with the aid of Kaplan-Meier and including censored data.

Survival for tooth groups of analysed registrations

The survival curves for tooth groups of analysed registrations are illustrated in Diagram 3. There is no statistical significant difference in survival and failure between the different tooth groups ($p < 0.66$).

Survival curves for tooth groups of the analysed registrations

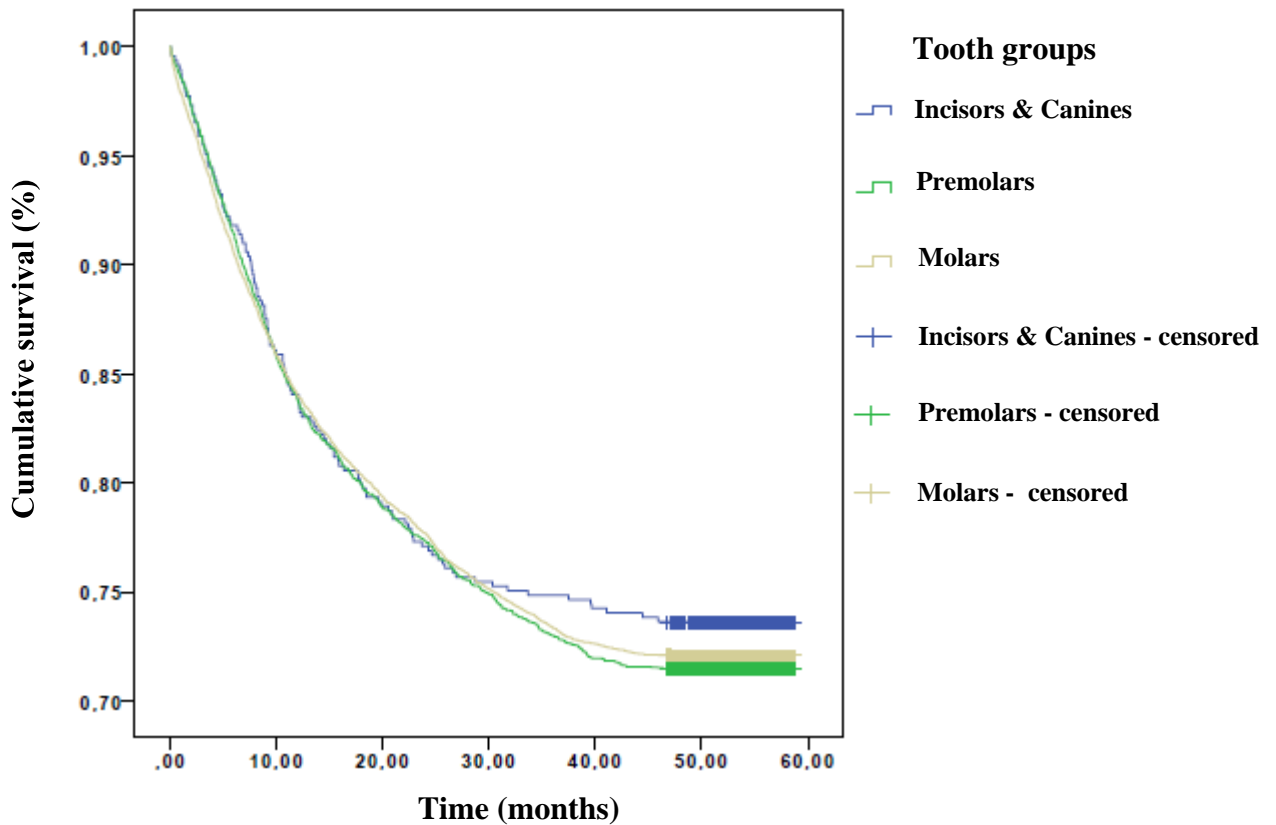


Diagram 3. Cumulative survival of the analysed stepwise caries removal registrations in relation to time in months for tooth groups plotted as a function with the aid of Kaplan-Meier and including censored data.

Failed treatment

The registrations that represented failed treatment were composed of endodontics and extractions. Diagram 4 illustrates the proportions of the different treatment interventions.

Distribution of endodontics and extractions

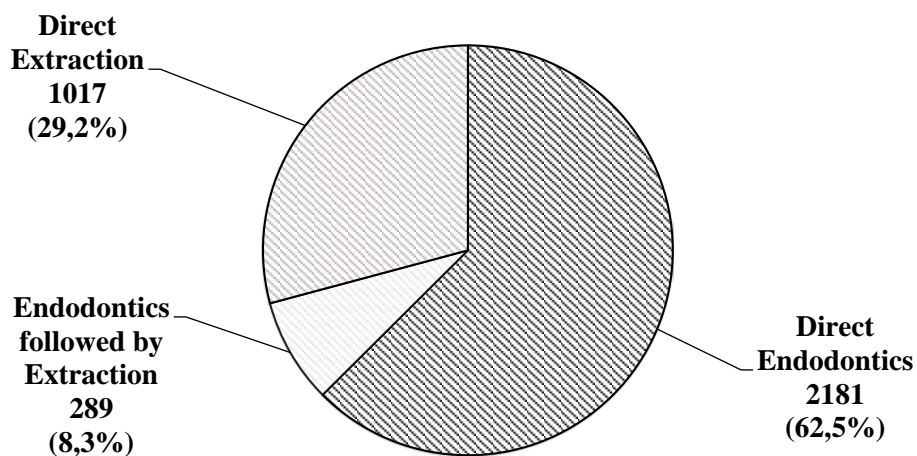


Diagram 4. Distribution of registered endodontics and extractions.

Incidental finding

An incidental finding from the analysed registrations showed that 790 registrations ended up with acute endodontic treatment at the registration following first stage of stepwise caries removal registration (Table 3).

Table 3. Frequency of registrations for acute endodontic intervention distributed in time interval counted from first stage of stepwise caries removal treatment (baseline) to the second registration after baseline.

Time interval (months)	Number of registrations for acute endodontic intervention
< 1	126
1 – 6	359
7 – 44	305
Total	790

Discussion

Outcome of stepwise caries removal in relation to time

All of the survival functions illustrated in the results (Diagrams 1, 2 and 3) show a steep declining curve in the survival of the stepwise caries removal cases in the months 0–12. In the months 13–30 there is a less steep curve, almost one third of the inclination. The curve in the above-mentioned diagrams declines further after 30 months and flatten out after 40 months. This indicates that most failures in relation to stepwise caries removal occur early in time with an obvious decline after 30 months. The survival after 40 months is almost constant until the end of the observed period. These results also indicate that if a failure has not occurred within 30 months, then the future expectancy of failure is low.

This study showed 72.0% preserved tooth vitality of total valid cases after 4 years, after stepwise caries removal. Bjørndal and co-workers (23), reported a 60% success in tooth vitality for stepwise caries removal after 5 years in a recent randomized clinical trial comparing stepwise caries removal (n=118) with non-selective caries removal. A reason for the lower success could be that cases with preoperative pain were included in the study. In a previous study, subjects with preoperative pain were less likely to preserve tooth vitality in teeth treated with stepwise caries removal (9). However, it was not possible to analyse preoperative pain in the current study. Same study (23) was prospective and strictly controlled with criteria on what shall be considered as deep caries. These criteria were caries lesion involving 75% or more of the dentine determined on radiographic picture, visible radiopaque zone between caries lesion and pulp, and no apical destruction. In this current study, it was not possible to identify whether the registrations for stepwise caries removal were based on concurrent criteria for deep caries. Registered stepwise caries removal treatments could have been performed in less deep caries lesions and possibly explain the higher success rate in this study compared to the study mentioned above.

Outcome for different age groups

The results show a statistically significant higher success rate for stepwise caries removal treatment in the age groups 18-29 and 30-39 compared to age groups 40-59 and 60-96 (Diagram 2). This means that age is a dependent factor for the success of the treatment.

In diagram 2, it is apparent that between the age groups 30-39 and 40-59 there is a distinct gap compared to the gaps between the two younger age groups and between the two older age groups. This means that in patients over 39 years, the success of the treatment with stepwise caries removal was lower than in the younger patients. A study done by Bjørndal and co-workers (9) show similar results regarding patient age, where patient group over 50 years had a lower success of stepwise caries removal compared to the younger group.

The age factor in the success of the tooth treated with stepwise caries removal might be explained by the physiological changes that occur in the pulp with age. With increased age, the pulp tissue decreases in size as a result of physiological secondary dentine formation. Additionally, tertiary dentine is formed as a direct response to external stimuli. As a result, in older subjects, the blood supply to the pulp can become insufficient for a regenerative response to occur when performing stepwise caries removal (25). Thus, a consequence of the shortage of blood supply to the pulp could be a higher risk of developing irreversible pulpitis or necrosis (20). Ageing can even contribute to impaired innate immune system with a delayed inflammatory cell response at sites of infection (26), this could make the pulp more vulnerable to bacterial products and could lead to necrosis in the long-term.

Outcome for different tooth groups

Incisors and canines showed a higher success rate compared to premolars and molars. Premolars had lowest survival compared to the other tooth groups observed. The results for the tooth groups showed no statistically significant differences, which means that tooth group is not a dependent factor for the survival of stepwise caries removal treatment.

Incidental finding

At the first follow-up after baseline, 209 cases got registration for acute endodontic treatment. The time span extended up to 44 months. In this study, a total of 126 cases showed up for an acute treatment during the first month after the stepwise caries removal treatment. It can be speculated that the reason for this was dental pain. Possible reasons for dental pain could be unobserved pulp exposure during first stage of treatment or difficulties to preoperatively differentiate between reversible and irreversible pulpitis. In 664 cases the acute endodontic treatment was performed 1–44 months after stepwise caries removal. An explanation could be occurrence of secondary caries, since the most frequent waiting time was 6 months. This might depend on failure of the temporary fillings, as such materials are not designed to withstand over longer periods. Another reason could be pulp exposure during the second stage of stepwise caries removal. A study done by Bjørndal et al. (9) observed 25 pulp exposures after stepwise caries removal from a total of 143 cases. Four of these pulp exposures occurred during first stage of stepwise caries removal treatment.

Is stepwise caries removal always the right choice of treatment?

In this study, 28% of the analysed cases visited the dental clinic between 2–12 times after baseline, eventually ending up in endodontic treatment or extraction. This could question the economical effectiveness of stepwise caries removal. In the mentioned cases, it would be more comfortable, time-saving and more economically beneficent if they had received endodontic treatment at the first visit. However, it is not possible to beforehand determine whether the pulpitis (associated with pulpal symptoms or not) is irreversible or not, which makes it difficult to know if stepwise caries removal treatment is worth the effort. However, if an intact dentine layer can be discerned after caries removal, and the tooth is asymptomatic, it is more likely to be a reversible pulpitis (27).

Patients lacking in compliance might not complete the full treatment procedure and therefore would not be optimal candidates for stepwise caries removal. In these cases, it might be more beneficial to employ partial caries removal (PCR) and a direct permanent restoration (22, 28). However, PCR is currently not recommended by the Swedish authorities due to weak scientific evidence (11).

Missing cases

In 2886 cases (19%), the registration of second stage of stepwise caries removal treatment did not occur, with several possible explanations. The number of missing cases is regarded as low in comparison with other studies. The study done by Maltz (29) showed a 30% loss of the included cases (n=146) at the second stage of stepwise caries removal. Another study (18), had a 17% loss at the second stage of total 1326 included cases.

An asymptomatic tooth with a well-fitting temporary restoration can make some patients ignore the importance of continued treatment, thus they do not return for the second dental visit. Other possible explanations are that patients went to another dental clinic that was not part of the SKaPa project, having financial problems or even that they went to a dental clinic abroad. Some patients might also have passed away.

Time aspects

Regarding the patients showing up a long period after base-line (1-4 years), it could be attributed to the same reasons as the lost cases. Since temporary restorations are not optimal for long term use, this could lead to loss of the restoration and/or secondary caries or pulpal symptoms, prompting the patients to return to the dental clinic after a long period of time. If the carious lesions are allowed to progress, the outcome could be irreversible pulpitis or a necrotic pulp with apical destruction, leaving endodontic treatment or dental extraction as the only remaining treatment options.

Liner (Calcium hydroxide)

The present study does not present any data on the use of cavity liners or calcium hydroxide, as this data were not included in the data received from the SKaPa database. However, it can be suspected that calcium hydroxide liners were used in many of the included cases due to the strong tradition of using liners when performing stepwise caries removal in Sweden. A recent randomized clinical trial investigated the effect of calcium hydroxide as a covering material over the most pulpal spot in the cavity, by using a control group not using any covering material beneath temporary fillings. No difference was observed between the groups (20).

Strengths and weaknesses

One strength of this study is the large number of cases observed over a long period. Thereby it is more likely to resemble the stepwise caries removal treated population in reality.

Additionally, the sample is composed of treatments performed by general dentists in both general and private dental practice, thereby giving a realistic scenario of the success of stepwise caries removal. The age distribution is evenly distributed, and a large number of each tooth group was represented. One tooth per patient was included to exclude possible personal factors.

A weakness of this study is that some of the preoperative diagnoses were unknown or unaccounted for, which makes it impossible to discern the operator's reason for performing stepwise caries removal. Preoperative diagnoses like "D1" and D2", with no indication for any operative treatment, was registered as preoperative diagnoses before stepwise caries removal registration in some cases. It is not possible to find a concrete explanation for this, although a plausible reason for this could be that the diagnose code was not updated before registration of the treatment code.

The expectancy time interval is a vital moment in stepwise caries removal and could be determinant for the outcome. The duration of this interval in the analysed cases had a large span extending up to 45 months, since consensus and national guidelines are lacking, which might be considered as a weakness. It is not known if the expectancy time for each registration was planned. Factors such as post-operative symptoms which make the patient seek the dentistry clinic sooner could make this time interval shorter, while factors such as patients not showing up at the planned time could extend the expectancy time interval.

It was not possible to control whether the treatments were performed on correct indications, since the extracted data did not include clinical or radiographical data of the included tooth. Nor was it possible to verify whether the registration was performed correctly.

With available data, it was possible to analyse diagnose codes, and intervention codes for registered endodontic and extraction treatments in order to investigate the causes for these registrations such as pulpal complications, pulpal necrosis, crown-root fracture, periodontitis or trauma. However, this has not been analysed in this study and therefore all endodontic and extraction registrations were considered as a failure for the registration of stepwise caries

removal. An investigation could contribute to a higher success rate for the registration stepwise caries removal in case diagnose codes such as fracture, periodontitis and trauma were frequently registered before endodontic and extraction registrations.

No control group

This study is analyzing the success of stepwise caries removal treatment and did not aim to be compared with another treatment such as non-selective caries removal. In addition, it was not possible to extract matching control groups for the stepwise caries removal cases from SKaPa.

Ethical considerations

No personal information was included in the data received from SKaPa. The data was handled only by the authors of this study and the statistician. However, this study got approved by the local Ethics Committee at the Faculty of Odontology at Malmö University before extracting the data from SKaPa.

Society and dentistry

Success in stepwise caries removal treatment gives the patient and society an economical advantage compared to treatments as endodontics or prosthetics after extraction. An optimal stepwise caries removal requires two visits and if completed it increases the availability in dentistry.

Future aspects

The registrations considered as succeeded stepwise caries removal treatment could be further analysed in the future for a longer follow-up period. This makes it possible to follow the success of the treatment whether the success rate remains stable or not. Also, more cases could be extracted from SKaPa with different baseline years and the results could later on be compared to this study and each other. This could further strengthen the conclusion about success rate.

Future questions

1. Could the success rate further decrease during a follow-up period longer than 4-year?
2. Will the success rate for this study be similar to future studies with several baseline years?
3. How would analysis on diagnose and intervention codes for the registrations considered as failures change the success rate?

Conclusion

This study shows a high success rate for registered stepwise caries removal treatments, which the dentist considered would result in pulp perforation if complete excavation in a single visit was performed, in a 4-year follow-up in Swedish public and private dentistry settings. The success of the treatment is dependent on the age, which is statistically significant.

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