Tunnel restorations in general practice. Influence of some clinical variables on the success rate

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Using bitewing radiographs and clinical inspection, the success rate for tunnel restorations was assessed in a population with low caries activity. The material consisted of 242 tunnel restorations in permanent premolars and molars in 142 individuals (mean age = 18.8 years). The median DFSappr value (decayed and filled approximal surfaces) at the time of restoration was 4.0. The mean follow-up time was 25 months. Bivariate associations between the outcome variable (success/failure of the tunnel restoration) and conceivable explanatory variables were investigated. In a multivariate logistic regression analysis, the independent variables tooth type (premolars vs molars), surface site (mesial vs distal), radiographic stage of approximal carious progression and age of patient at the time of restoration (9–15 years vs >15 years) were used to estimate the effect on the dependant variable success/failure. Using the life table method, the estimated cumulative proportion of successful restorations was 81% after 2 years and 64% after 3.5 years. The success rate was not related to caries activity and did not differ between the two types of tunnel preparation techniques nor between different follow-up periods. In the multivariate regression analysis, tooth type (molars vs premolars) was the only factor significantly associated with failure. Thus, a failure occurred about 5 times as often in molars as in premolars. Of the failures, half were due to caries; either radiographically observed adjacent to the restoration or progressing enamel caries on the outer proximal surface. Marginal ridge fractures constituted 26% of the failures. From the present results it can be concluded that in a population with low caries activity, the tunnel restoration technique can be recommended for premolars. □ *Permanent dentition; preparation technique*

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The development of restorative materials in recent years has permitted a breakthrough in dentistry. Adhesive properties are such that tooth substance can be spared and retention can be achieved without brutal procedures. Moreover, a conceivable caries-inhibiting property of restorative materials may allow departures from Black's principle of 'extension for prevention' (1). These two advantages are most evident in the combination of tunnel preparation and a glass cermet cement filling. This method of preparing and filling a cavity has been described by several authors (2–10), with varying results, based on a range of observation periods (see Table 1).

The principle behind the tunnel preparation is that decayed tissue emanating from the approximal surface is exposed and removed without this surface being touched externally. In most cases this is achieved by trepanning the occlusal enamel in the fossa inside the marginal ridge. As a result, the amount of sound and valuable tooth substance that is lost is less than with the standard Class II preparation (2).

Depending on how far the carious lesion has progressed, the tunnel preparation may either end in front of a demineralized but nevertheless fairly well-preserved enamel wall, or the enamel may be so affected that a passage has occurred. Various terms have been used to distinguish these two stages of the tunnel preparation; in this report 'partial tunnel preparation' denotes cases with spared approximal enamel and 'total tunnel preparation' cases where the approximal enamel has been perforated.

The comparative therapeutic value of these two types of tunnel preparation—partial and total—has been judged in different ways. Hasselrot (8) suggests that the partial tunnel is an advantage in that the approximal enamel lesion is left undisturbed and may gather fluoride from the glass cermet cement, thus arresting the carious process. A similar notion was suggested in 1962 by Jinks (11), who proposed the inoculation of a cement that would slowly emit fluoride over a long period of time, the main objective being to prevent caries on the adjacent proximal surface. Hunt (2) recommended sparing the approximal enamel in cases where there was a possibility of reducing the diet's cariogenicity and instituting fluoride therapy. In mouths with a high decay rate, however, the more radical total preparation or the minibox procedure may be preferable. In a recent study, Holst & Brännström (9) also found partial tunnel restorations to be superior to the total preparation technique for minor lesions.

Strand (12), on the other hand, regarded the partial tunnel as a hazardous solution: the glass cermet cement may not release a sufficient amount of fluoride to arrest or remineralize the enamel lesion; when an internal restoration is chosen, the approximal enamel lesion should be

Table 1. Studies on the success rates for tunnel restorations in permanent teeth

Author(s)	Location	Follow-up time	No. of restorations	Age (years) (mean)	Success rate, %
Hunt 1984 (2)	USA	19–29 months	20	Not given	100
Svanberg 1992 (3)	Sweden	3 years	18	13–16	96
Knight 1992 (4)	USA	5.25 years (mean)	51	Not given	100
Lumley & Fisher 1995 (5)	England	5 years	33	19–45 (29)	79
Lunder 1997 (6)	Norway	4 years	235	12–27 (20.6)	60
Strand et al. 1997 (7)	Norway	3 years	161	10– > 30	46
Hasselrot 1998 (8)	Sweden	1–7 years	267	11–35	73
Holst & Brännström 1998 (9)	Sweden	3 years	270	9–66 (22.2)	84
Pilebro et al. 1999 (10)	Sweden	3 years	305	10–74 (19.1)	59

treated as an ordinary demineralized lesion, using topical fluoride applications and increased plaque control.

In view of the uncertainty about the clinical usefulness of the tunnel restoration, this study aimed to assess the success rate of tunnel preparations in young permanent teeth. The success rate was related to the following clinical variables: caries activity, tooth type, and surface site, stage of caries progression at the time of restoration, type of preparation (partial or total), age of patient at the time of restoration, and follow-up time.

Materials and methods

The study was carried out at the Ektorp Public Dental Health Clinic in the County of Stockholm. For several years, tunnel preparations had been chosen frequently as a therapeutic alternative for approximal caries in the premolar/molar regions. All tunnel restorations with a minimum follow-up period of 12 months (mean = 25 months; range 12–82 months), performed from 1987 to 1993 in the current clientele of children and adults were included; 242 restorations in 142 individuals. More than one restoration was performed in 52 individuals. The restorations were evenly distributed among all 5 dentists at the clinic (with a minimum of 2 years of clinical experience).

The mean age of the individuals at the time of restoration was 18.8 years (SD = 5.66). The mean and median values of DFSappr (decayed and filled approximal surfaces) of the individuals at the time of restoration according to four age groups are given in Table 2. Lesions that radiographically at least had reached and broken the enamel dentin border were included in the D-component. In 1990 the DFSappr in the Ektorp area of 15-year-olds was 1.6 and in the 19-year-olds it was 2.6. The distribution of the follow-up times is shown in Table 3.

Table 2. Mean and median DFS values of approximal surfaces of the individuals at the time of restoration by age group

Age group (years)	DFS values of approximal surfaces: Mean	Median	SD	Total no. of individuals
9–15	2.5	2	1.61	30
16–19	3.4	3	2.23	56
20–29	5.0	4	3.58	41
>29	10.3	10	6.14	9
Total				136*

* Calculations could not be performed for 6 individuals.

Clinical procedures

Of the restorations, 87% were made with Ketac-Silver (ESPE GmbH, Seefeld, Germany), a glass cermet cement and 13% with Baseline (DeTrey/Dentsply, Konstanz, Germany), a glass ionomer cement. A radiographic scoring system modified after Mejàre & Malmgren (13) was used to classify the depth of the lesions, and in teeth with an intact marginal ridge the indication for performing a tunnel preparation was an approximal carious lesion corresponding to at least a radiographic score of 2 (Fig. 1). The distribution of radiographic scores is given in Table 4.

The clinical procedure was as follows: After trepanation of the enamel inside the marginal ridge, in most cases the carious tissue was excavated with slowly rotating round burs; for advanced carious attacks a sharp-edged spoon excavator was also used. In most cases the occlusal opening was located at least 1 mm from the marginal ridge. The approximal wall was carefully examined for a perforation of the enamel; if this was found, a wedged metal matrix was applied. No attempt was made to excavate the initial enamel caries. After thorough cleaning with a water spray and gentle drying with a jet of air, the cavity was conditioned with 10% polyacrylic acid (Dentin Conditioner, GC, Japan) and filled with a glass cermet cement, using an injection syringe (Centric TM, C-R Syringe System) in accordance with the manufacturer's instructions. In order to avoid trapping air bubbles, the tip of the syringe was inserted to the very end of the tunnel and slowly withdrawn during the injection of the cement mixture. During the curing and maturing phases, the external surfaces of the restoration were coated with varnish (Fuji Varnish, GC, Japan) to protect the material against moisture as well as desiccation. In most cases the cavity was left completely filled with the glass cermet cement; if the occlusal entrance had a diameter of $\geq$2 mm,

Table 3. Number and percent of successful/failed restorations with respect to type of preparation and follow-up time; *P*-values from the bivariate analyses.

	Type of preparation					
	Partial		Total			
Follow-up time (months)	Successful *n* [%]	Failed *N* [%]	Successful *n* [%]	Failed *N* [%]	Total *n*	*P*-value (Fisher's exact test)
12–23	68 [82.9]	14 [17.1]	23 [74.2]	8 [25.8]	113	0.425
24–35	57 [86.4]	9 [13.6]	16 [88.9]	2 [11.1]	84	0.567
>35	24 [85.7]	4 [14.3]	16 [94.1]	1 [5.9]	45	0.635
total	149 [84.7]	27 [15.3]	55 [83.3]	11 [16.7]	242	

however, the occlusal portion of the cement was replaced with a bonded composite resin (about half of the restorations).

Radiographic procedures

At baseline before placement of the restoration and at yearly recalls bitewing radiographs were taken (Philips Oralix 65 kV) with the aid of a film-holder (Kwik-Bite, Hawe-Neos Dental, Bióggio, Switzerland). Kodak Ultra Speed film (Eastman Kodak Company, Rochester, NY, USA) was used and processed in a developing machine (Periomat, Dürr Dental KG). The restorations were defined as total if the restorative material reached the outer proximal surfaces and otherwise as partial.

Procedures and criteria for assessing success or failure

The visual/tactile clinical evaluation of the restorations was made by each dentist at regular follow-ups (in most cases by the dentist who had made the restoration). The presence of one or more of the following conditions was propounded as criteria of a failed tunnel restoration:

- marginal ridge fracture
- progressing enamel caries with cavitation on the outer proximal surface
- radiographic signs of caries adjacent to the restoration
- radiographic appearance of voids of >1 mm^2
- postoperative sensitivity/pain that resulted in replacement of the restoration

Calibration on these criteria took place in terms of continuous joint discussions at the clinic.

At the end of the study, the radiographs were examined simultaneously by all five dentists, who, with the exception of a few cases, reached a consensus. For these cases the majority view prevailed. The clinical data were retrieved from the clinical records and were available at the joint radiographic assessment of results.

Assessment of caries activity

Indicators of caries activity were assessed radiographically in two ways. The first was by counting the individual DFSappr values at the time of restoration (from 4d to 7m). A caries active individual was defined as one with more than the median number of the total DFSappr values according to age group (Table 2). Secondly, the number of new approximal dentin lesions from the time of restoration and 2–3 years ahead was counted and divided by the number of approximal surfaces at risk (unrestored). The value was multiplied by 100, giving each individual a score used as an indicator of caries activity.

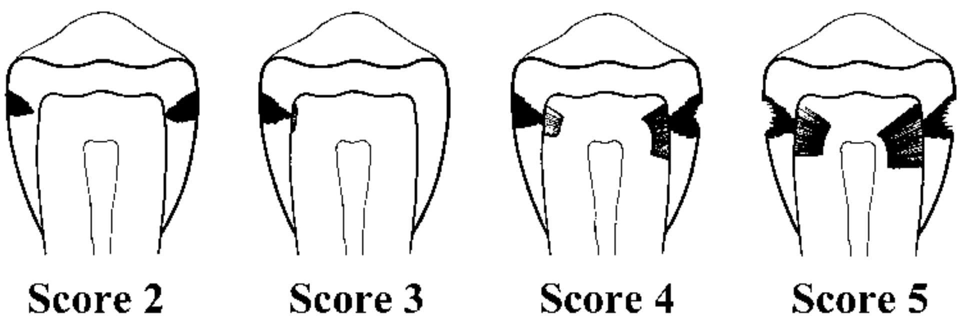

Fig. 1. Radiographic scores used to classify the depth of approximal carious lesions.

Table 4. Distribution of successful/failed restorations with respect to radiographic scores at the time of restoration.

	Successful	Failed	
Radiographic score	*n* %	*n* %	Total *n*
2	13 [92.9]	1 [7.1]	14
3	107 [84.3]	20 [15.7]	127
4	74 [83.1]	15 [16.9]	89
5	10 [83.3]	2 [16.7]	12
Total	204 [84.3]	38 [15.7]	242

Statistical analysis

Since no differences in success rate were observed between the two restorative materials, they were pooled in the statistical analysis. Two-way contingency tables and the χ^2-test were used to test bivariate associations between the dependent variable success/failure and the possible explanatory variables. For cell counts <5, Fisher's exact test was used. The level of significance was set at 5%.

The life table was used to estimate the cumulative survival of the restorations and a multivariate logistic regression model to analyse the effect on the dependent variable success/failure of the independent variables tooth type (molar or premolar), surface site, radiographic carious stage and age of patient at the time of restoration. All the variables except the radiographic carious scores were coded as indicator variables (coded 0 or 1). In the model, each radiographic score (2 to 4) was compared with the average effect of all the score categories. All calculations were made under the assumption that the restorations were independent. The data were processed in SPSS (Statistical Package for Social Sciences), Windows version 8.0.

Results

Patient age, stage of carious progression at the time of restoration and type of restoration were evenly distributed with respect to follow-up times. The number and type of failures are given in Table 5, which shows that caries in connection with the restoration constituted half of all failures. Of these failures, about half constituted progressing enamel caries with cavitation on the outer proximal surface.

Overall, 204 (84.3%) of the 242 tunnel restorations were judged successful after a mean follow-up time of 25 months. Using the life table method, the estimated proportion surviving after 2 years was 81% and after 3.5 years 64% (Table 6). Tunnel restorations in premolars showed a higher success rate than those in molars and the estimated proportion of successful restorations after 3.5 years was 93% for premolars and 44% for molars (Fig 2). From the odds ratios in Table 7 it can be seen that the only factor significantly associated with failure was tooth type. Thus, a failure was about 5 times more likely to be a molar than a premolar.

No differences in success rate were found between the caries activity scores based on the number of new approximal dentin lesions from the time of restoration and 2–3 years ahead (median value = 1) or between high or low DFSappr values at the time of restoration. The number and percentage of the successful/failed restorations in relation to the type of preparation and follow-up time are given in Table 3. No differences in success rate were found either between the two types of tunnel preparation technique or between the different follow-up periods.

Discussion

The life table method was chosen to estimate the survival time of the tunnel restorations because the number of restorations with follow-up times less than 24 months was relatively high. The estimated survival time of 64% after 3.5 years is higher than reported by Strand et al. (7), but

Table 5. Number and percent of failed restorations according to type and time of diagnosis after placement

	Time (months) after placement				
Type of failure	<12	12–23	24–35	>35	Total *n* [%]
Radiographically and/or clinically observed caries adjacent to restoration	5	5	8	1	19 [50.0]
Clinically observed progressing enamel caries with cavitation on outer proximal surface		**5**	**5**		
Marginal ridge fracture		5	3	2	10 [26.3]
Void adjacent to restoration (observed radiographically)	4			1	5 [13.2]
Postoperative symptoms	2				2 [5.3]
Proximal overhang	1				1 [2.6]
Dissolution of restorative material on outer proximal surface				1	1 [2.6]
Total	12	10	11	5	38 [100]

Table 6. The cumulative proportion of successful tunnel restorations estimated from a life table method

Start time months	Entering the interval	Drop-outs	Exposed to risk	Failed	Proportion successful	Cumulative proportion successful at the end	se (of cumulative proportion successful)
0	242	0	242	4	0.98	0.98	0.01
6	238	0	238	8	0.97	0.95	0.01
12	230	54	203	5	0.98	0.93	0.02
18	171	37	152	5	0.97	0.90	0.02
24	129	55	101	10	0.90	0.81	0.03
30	64	18	55	1	0.98	0.79	0.04
36	45	20	35	4	0.89	0.70	0.05
42	21	20	11	1	0.91	0.64	0.08

close to recent results reported by Pilebro et al. (10) and Lunder (6) (see Table 1).

Several factors may influence the outcome of a tunnel restoration, such as caries activity, age of the patient at the time of restoration, tooth type, surface site, visibility, preparation technique and operator skill. The only factor that significantly predicted a failure was whether the restoration was performed in a premolar or a molar. However, operator skill was not analysed and the multivariate model should therefore be interpreted with caution (Table 7).

In contrast to the results of Lunder (6) and Strand et al. (7), the indicators of caries activity were not associated with the success rate in the present study. One possible reason could be that their studies were based on populations characterized by higher caries activity than in the present study. Another reason for the lack of association between caries activity and success rate in the present study could be too short follow-up times.

The most frequent cause of failure was radiographically and/or clinically observed caries adjacent to the restoration. The five restorations with radiographically observed dentin caries within a year after placement (Table 5) indicate that caries had been left at the bottom of the cavity. This reflects the difficulties in creating a cavity that is free from decay. The apparently simple cavity preparation probably fails on account of poor visibility and limited accessibility to probing, also indicated by the fact that tunnel restorations were more successful in easily accessible sites. The second largest group of failures was marginal ridge fracture, probably a result of extensive decay and/or the preparation technique. Fasbinder (14) and Strand et al. (15) have shown that both the diameter of the cavity opening and its distance from the marginal ridge are significant for its strength. Of these two parameters, the distance from the marginal ridge is considered more important and should preferably not be less than 2 mm (16, 17). Thus, a larger cavity opening located centrally is preferable to a narrower opening close to the marginal ridge. In most cases, however, this was difficult to achieve; in general, the preparations were made at a distance of about 1 mm from the marginal ridge. Whether the voids should be regarded as true failures or not might be debated. Since they resulted in replacement, they were considered to be failures.

The difference between the total and the partial preparation technique is of particular interest for long-term success. In accordance with the results of Hasselrot (8), neither was superior to the other in the present study. Thus, our results do not confirm that the partial preparation technique is more advantageous, as proposed by Holst & Brännström (9), or disadvantageous, as proposed by Strand (12).

The present as well as other studies show that tunnel restorations have obvious drawbacks. But so, unfortunately, do the alternatives. The conventional Class II preparation design and its modifications, the minibox and the saucer-shaped cavity design, carried out in a composite resin, have their shortcomings, such as shrinkage of the resin matrix, which generates stresses at the tooth–resin interface that may cause cusp infractions (16). Furthermore, despite considerable improvements in the physical properties of the composites in recent years, microleakage

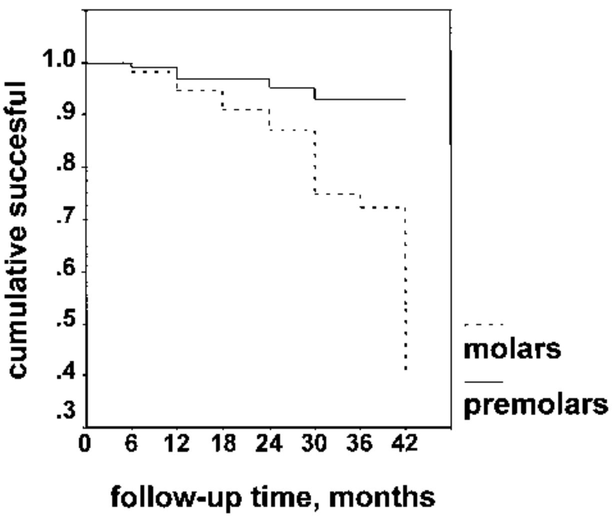

Fig. 2. The cumulative successful functions of premolars ($n = 87$) and molars ($n = 155$).

Table 7. A multiple logistic regression model with successful/failed tunnel restorations as the dependent variable and tooth type, surface site, radiographic stage of caries progression, and age of patient at the time of restoration as independent variables

Independent variable	Regression coefficient	Odds ratio	95% CI
Tooth type premolars (reference) molars	1.63	5.09	1.81–14.31
Surface site mesial (reference) distal	0.41	1.51	0.71–3.25
Radiographic carious stage			
Score 2	−0.84	0.43	0.03–5.67
Score 3	0.14	1.15	0.23–5.87
Score 4	0.22	1.24	0.24–6.41
Age at restoration 9–15 years (reference)			
>15 years	−0.26	0.76	0.33–1.78
Intercept	−3.03 (se = 1.04)		

Statistical analysis: model $\chi^2$14.29, 6 d.f., $P = 0.027$.

and subsequent secondary caries are still a problem (18). The Class II preparation design, which mostly spares the tunnel restoration, also has the disadvantage of inadvertent damage to the approximal surface of the neighboring tooth during preparation (19). Therefore, in a population with low caries activity, the tunnel restoration is a reasonable alternative for premolars.

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References

1. Black GOV. A work on operative dentistry. Chicago: Medico Dental Publishing, 1908. p. 158–7.
2. Hunt PR. A modified class II cavity preparation for glass ionomer restorative materials. Quintessence Int 1984;15:1011–8.
3. Svanberg M. Class II amalgam restorations, and caries development on adjacent tooth surfaces: a 3-year clinical study. Caries Res 1992;26:315–8.
4. Knight GM. The tunnel restoration—nine years of clinical experience using capsulated glass ionomer cements. Case report. Austr Dent J 1992;37:245–51.
5. Lumley PJ, Fisher FJ. Tunnel restorations: a long-term pilot study over a minimum of five years. J Dent 1995;23:213–5.
6. Lunder N. Tunnelrestaureringer etter fire år. Norske Tannl Tidende 1997;107:508–11.
7. Strand GV, Nordbø H, Tveit AB, Espelid I, Wikstrand K, Eide GE. A 3-year clinical study of tunnel restorations. Eur J Oral Sci 1996;104:384–9.
8. Hasselrot L. Tunnel restorations in permanent teeth. A 7-year follow up study. Swed Dent J 1998;22:1–7.
9. Holst AL, Brännström M. Restoration of small proximal dentin lesions with the tunnel technique. Swed Dent J 1998;22:143–8.
10. Pilebro CE, van Dijken JWV, Stenberg R. Durability of tunnel restorations in general practice: a three-year multicenter study. Acta Odontol Scand 1999;57:35–9.
11. Jinks GM. Fluoride-impregnated cements and their effect on the activity of interproximal caries. J Dent Child 1963;30:87–92.
12. Strand G. Therapeutic and functional aspects of tunnel preparations in permanent teeth. Dissertation Bergen: University of Bergen; 1997.
13. Mejàre I, Malmgren B. Clinical and radiographic appearance of proximal carious lesions at the time of operative treatment in young permanent teeth. Scand J Dent Res 1986;94:19–26.
14. Fasbinder DJ, Davis RD, Burgess JO. Marginal ridge strength in class II tunnel restorations. Am J Dent 1991;4:77–82.
15. Strand GV, Tveit AB, Gjerdet NR, Eide GE. Marginal ridge strength of teeth with tunnel preparations. Int Dent J 1995; 45:117–23.
16. McLean JW. Limitations of posterior composite resins and extending their use with glass ionomer cements. Quintessence Int 1987;18:517–29.
17. Leidal TI, Mjör IA. Principles of cavity preparation. In: Hörsted-Bindslev P, Mjör IA, editors. Modern concepts in operative dentistry. Copenhagen: Munksgaard, 1988. p. 108–10.
18. Nordbø H, Leirskar J, von der Fehr FR. Saucer-shaped cavity preparations for posterior approximal composite resin restorations: observations up to 10 years. Quintessence Int 1998;29:5–11.
19. Qvist V, Johannessen L, Bruun M. Progression of approximal caries in relation to iatrogenic preparation damage. J Dent Res 1992;71:1370–3.

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