Durability of tunnel restorations in general practice: a three-year multicenter study

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Twelve dentists, clinically experienced and familiar with the tunnel technique, placed 374 tunnel restorations in permanent teeth. Mean age of the patients was 19.1 years (range 10–74). The filling material used was a glass cermet cement, Ketac Silver. After 1, 2 and 3 years the teeth were controlled by the dentists. The bitewing radiographs from baseline, 1, 2 and 3 years were also analyzed by 2 of the authors, independently. The baseline radiographs showed technical defects in 6% and indicated remaining dentin caries in 8% of the restorations. After 3 years, 305 restorations were accessible for examination. The cumulative replacement rate was 20%. The main reasons for replacement were marginal ridge fracture (14%) and dentin caries (3%). The number of restorations showing untreated progressive caries increased during the study. After 3 years, untreated dentin caries was seen in 28 cases (11%) and almost half of the left enamel lesions showed progression. □ *Clinical; glass ionomer; proximal caries; operative dentistry; tunnel*

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During recent decades, the incidence and prevalence of caries have decreased in Western countries, and at the same time adhesive techniques and new materials have provided the opportunity for the use of other, more conservative, preparation models. As an alternative for treating class II lesions the tunnel preparation has been introduced. The suggested advantage of this technique is the removal of proximal carious tissue through an occlusal opening, thus preserving the marginal ridge and the proximal surface of the tooth.

The clinical application of the tunnel preparation was mentioned by Jinks (1) as early as 1962. He described its use in the distal surface of the second primary molar, his only aim being to prevent caries on the adjacent proximal tooth surface, the mesial surface of the first permanent molar, by using a putative anti-cariogenic filling material. The patients were approximately 5.5 years of age and the restored surfaces of the primary molars were free of carious lesions. Jinks added sodiumsilicofluoride powder and silver alloy to silicate cement and used this as a filling material. He thus optimized the anti-cariogenic property and radioopacity of the cement. In 1984, Hunt (2) and Knight (3) re-introduced the tunnel preparation as a biologically acceptable treatment of proximal caries lesions in permanent teeth. Wilson & McLean (4) suggested that excavation of the enamel part of the lesion was only necessary when a proximal cavitation was located. Glass ionomer cement (GIC) was recommended, due to its possible cariostatic influence on the treated tooth as well as on the adjacent proximal surface. The use of a silver-glass cermet cement facilitated radiographic evaluation of the restoration and was thought to be less liable to wear.

In Scandinavia, the tunnel preparation became popular at the end of the 1980s, partly due to the amalgam debate, the cariostatic effect of the GIC and the tooth substance preserving preparation. The so-called closed, partial or class I tunnel, in which the proximal carious enamel was not excavated, was preferred, relying on the caries-inhibiting effect of the GIC.

At the start of our investigation, only a few studies had been published describing the clinical behavior of tunnel restorations. Hunt (2) reported after 23 months no clinical defects on 20 restorations. Knight (5) followed 51 tunnel restorations during 3–9 years by clinically observing and probing but without radiographic evaluation. He reported 2 marginal ridge fractures and no restorations with caries. In 1993, Nordbø (6) reported preliminary results from 3 different clinical studies in Norway. Clinical experiences after 1 year were very positive, with few cases of marginal ridge fractures or recurrent caries lesions reported. In a study published in 1991, Svärdström (7) described his experiences of partial tunnel restorations. After 4 years, two failures were diagnosed in 80 restorations. Svärdström regarded the method as being easy and less time-consuming than traditional therapy. Lumley & Fisher (8) evaluated 33 tunnel restorations and found a failure rate of 25% after 5 years. Recently, Strand (9) reported 30% replacements in a 3-year follow-up of 161 partial and total tunnel restorations performed by 4 dentists.

The aim of this multicenter study was to evaluate, during a 3-year period, clinically and radiographically, the durability of tunnel restorations performed by a group of general practitioners. An analysis of factors influencing the durability of the restorations will be given in a second report.

Material and methods

Twelve experienced dentists within the vicinity of the city

Table 1. Distribution of treated surfaces

	1st premolar		2nd premolar		1st molar		2nd molar		3rd molar	
	Mes	Dist	Mes	Dist	Mes	Dist	Mes	Dist	Mes	Dist
Upper jaw	1	34	29	58	61	18	0	15	0	1
Lower jaw	0	6	1	33	35	53	28	0	1	0

of Umeå, Sweden participated in the study. Ten of them were from the Public Dental Health Service, 1 from a Private Practice and 1 from the University of Umeå. They were familiar with the tunnel technique and included in the study all the tunnel restorations performed during the period January 1992 to January 1993. Methods and indications for performing and criteria for the yearly evaluation of the restorations were discussed and decided jointly. The dentists diagnosed the dentin lesion as "D2 or D3" on bitewing radiographs, following the directions and official recommendations of the National Board of Health and Welfare (SOSFS 1988:30). A D2 lesion shows a U- or V-shaped radiolucency which reaches or penetrates the enamel/dentin border, but is not obviously spread in the dentin. The D3 lesion is an obvious radiolucency in the dentin. Indications for performing a tunnel restoration were decided by each dentist. Access to the proximal dentin caries was made through the occlusal fossa just inside the marginal ridge using a small diamond burr in a high-speed handpiece. The carious dentin was removed with a slow speed handpiece and/or a sharp-edged excavator. No attempt was made to excavate the initial enamel caries. The extension of the occlusal opening in buccal and palatinal direction was measured in millimeters, as well as the width of the marginal ridge (this will be discussed in a second report). A metal matrix was placed around the tooth and tightened. After cleaning the cavity with 10% polyacrylic acid (Dentin Conditioner, GC, Japan) it was filled with a glass cermet cement (Ketac Silver, Espe, Seefeld, Germany) using an applicator with a metallic tip (Centric TM, C-R Syringe System). The matrix was removed after a setting time of 4–5 min. In every second restoration the occlusal part of the cavity was filled with hybrid resin composite (Fulfil, Dentsply/DeTrey, Konstanz, Germany), after etching the cavity margins with 37% phosphoric acid. The restorations were defined as partial tunnels if the restorative material did not reach the outer proximal surfaces; in other cases they were defined as total tunnel restorations.

In 272 patients (137 female and 135 male), 374 tunnel restorations were performed. The mean age of the patients was 19.1 years (range 10–74), 51% were 16–20 years old. The 12 dentists made 12–50 restorations each. Two-hundred-and-twelve restorations were placed in molars (57%) and 162 in premolars (43%). Table 1 gives the distribution of the tooth surfaces. The surfaces most frequently treated were 16 mesial (36) and 25 distal (32). Baseline bitewing radiographs with good quality were taken in 228 cases. The other restorations could not be evaluated optimally at baseline because of less than good quality or the absence of the radiographs. Table 2 gives the relation between the number of D2/D3 lesions and partial/total tunnel restorations.

Table 2. Distribution of D2 and D3 lesions in relation to number of partial and total tunnel restorations

	Partial tunnel restoration	Total tunnel restoration	Total
D2	51 (81%)	12 (19%)	63 (18%)
D3	167 (58%)	119 (42%)	286 (82%)

Evaluation

The baseline radiographs were analyzed for filling defects such as air bubbles or proximal overhangs. At baseline and after 1, 2 and 3 years the quality of the restorations was evaluated. The dentists carried out the clinical and radiographic evaluations. Clinical evaluation included the presence of marginal ridge fracture, dissolution of the filling material, postoperative sensitivity and new caries lesions. All the radiographs were read by two of the authors (CP and RS) independently and after calibration. Cases of disagreement were solved by discussion. After analyzing the radiographs, new or progressive proximal caries was noted. All the results were compiled by one of the authors (CP).

Statistical analysis

Replacement frequencies and reasons for replacement are reported using descriptive statistics.

Results

Sixty-five patients, with 69 of the 374 fillings, could not be followed during the whole study period (Table 3). Of the 228 restorations analyzed on bitewing radiographs at baseline, 31 (14%) showed defects or failures (Table 4). Nineteen restorations (8%) showed radiographic signs of non-excavated dentin caries contiguous to the newly made fillings.

The frequency and reasons for replacement during the 3 years are given in Table 5. After 1 year, 342 restorations were available for examination. Twelve (3.5%) were judged as requiring replacement. The most common

Table 3. Number and reasons for not evaluated fillings

Patients reasons for dropping out	No. of fillings
Moved from the area	44
Didn't show up	6
Died	1
Called another dentist	5
No reason given	13
Total	69

Table 4. Restoration defects and failures observed on radiographs of 228 restorations at baseline

Defect/failure	No.
Air bubble	4
Proximal overhang	8
Remaining dentin caries near the enamel/dentin border	17
Dentin caries left at the bottom of the cavity	2
Total	31

reason was marginal ridge fracture. No restoration was replaced because of caries during the first year. When a restoration was performed on the mesial surface of the first molar a cavity could sometimes be seen when the neighboring primary molar exfoliated. This was the cause of repair of the tunnel restoration in 1 case. At the 2-year recalls another 31 restorations were replaced. Between 2 and 3 years of service, or at the 3 years' recall, 18 restorations were replaced. Two of the teeth with marginal ridge fractures also showed dentin caries. The cumulative replacement rate after 3 years was 20%, 61 of the 305 restorations.

Restorations showing caries at baseline and/or at the different recalls are given in Table 6. The figures in this table cannot be read as absolute values. This is due to the fact that the number of fillings possible to evaluate is not the same at all the recalls, partly because of the individual recall system used by the dentists and partly because of differences in quality or absence of radiographs. The number of restorations showing untreated progressive dentin caries increased during the study. After 3 years, almost half (83 out of 175) of the enamel lesions showed progression since baseline and/or since the previous evaluation. In total, 41% of the restorations showed either untreated dentin caries or enamel caries with progression.

Discussion

The first reports of the durability of tunnel restorations revealed low failure rates (2, 5), indicating that the technique could be regarded as being generally applicable. Recently published studies reported, on the other hand, higher failure rates. Table 7 summarizes tunnel studies published between 1984 and 1998. Hasselrot (11) reported a yearly failure rate of 7%, which confirms the result in this study. Our failure rate differs between the participating dentists. This will be discussed in a second report. Strand et al. (9) found a 30% replacement rate after 3 years. Reasons for replacement were marginal ridge fracture in 14% and dentin caries in 16%. The number of fractures was similar to that found in our material, but the replacement rate due to remaining and/or secondary caries was higher. The higher caries activity in northern Norway, the differences in indications for replacement (all restorations with dentinal radiolucencies were replaced) and dentists not experienced with the tunnel technique could explain the non-equal results. Strand et al. reported also a second failure group of 24% with proximal cavities and/or increased radiolucencies in the enamel adjacent to restorations. Those restorations were still regarded as being clinically acceptable.

In the present study, 32% of the teeth showed progressive enamel caries on the radiographs after 3 years, and 35% showed non-progressive enamel caries. The other teeth did not show enamel caries on the bitewing radiographs, or it was not possible to evaluate the radiographs properly because of less than good quality. The restorations with adjacent progressive dentin and/or enamel lesions could be regarded as having a doubtful prognosis. Lunder (12) reported from a multicenter study with 11 participating dentists that 60% of the fillings were clinically and radiographically acceptable after a mean period of service of 46 months. The replacement rate was 36%, mainly because of progressive caries.

In the closed tunnel technique, proximal enamel caries is left untreated, as it is assumed to undergo remineralization. The fluoride release of the glass cermet cement did

Table 5. Numbers and cumulative frequencies (percentage) of replaced restorations and reasons for replacement

Recall	1 year	2 years	3 years
No. of evaluated restorations	342	312	262
Marginal ridge fracture	8	20	16
Enamel caries	0	3	0
Dentin caries	0	4	1
Cavity visible when neighboring tooth exfoliated	1	3	0
Postoperative symptoms	2	1	0
Reason unknown	1	0	1
Total	12 (3.5%)	31 (13%)	18 (20%)

Table 6. Restorations with enamel and/or dentin caries observed on the radiographs at baseline, 1, 2 and 3 years. The number of progressive and not progressive lesions since the earlier recall are given. e = enamel caries, d = dentin caries

	Baseline		1 year		2 years		3 years	
			342		312		262	
No. of evaluated restorations	e	d	e	d	e	d	e	d
New lesions	*	19†		10		16		2
Without progression			145	13	132	12	92	13
With progression			3	2	27	9	83	13
Replaced because of caries			0	0	3	4	0	1

* All the partial tunnels as well as the total with initial caries.
† Restorations with remaining caries at baseline.

not prevent caries progression totally in most of the mentioned studies. The material used in our study, Ketac Silver, has shown lower fluoride release compared with some other restorative glass ionomers (13). The internal location of the restorative material in the tunnel restoration may probably also restrict fluoride release and uptake. When a tunnel restoration is performed, it should probably be accompanied by topical fluoride treatment.

The technique sensitivity of the tunnel restoration has been expressed in a study by Hasselrot (10) in a lower failure rate of restorations performed during the second year of his study (18%) compared to the first year (38%). Strand (14) sectioned extracted teeth with artificial caries treated with tunnel restorations and found residual dentin caries in 26% of the teeth. The most frequent sites were close to the proximal enamel, due to inadequately extended preparations. This is also confirmed in our study, where 19 out of 228 restorations (8%) showed remnant dentin caries at baseline.

The bitewing radiograph is the most valued method in diagnosing proximal dentin caries. In this study, no recommendations for the exposure and developing of the radiographs were given. Wenzel (15) investigated in vitro the reliability of the radiographs in detecting residual dentin caries after tunnel preparations. She found that about 25% of the truly carious surfaces adjacent to tunnel restorations were detected on the radiograph pictures, while on average 20% false-positive diagnoses were made

Table 7. Studies of tunnel restorations published 1984–1998

Author	Period	No.	Drop outs (%)	No. of dentists	Failures, not replaced* (%)	Replacements (%)	Reasons for replacement† % of controlled
Hunt 1984 (2)	19–29 mo Mean 23 mo	20	0	1	0	0	
Knight 1984 (5)	3–9 y Mean 63 mo	51		1	n r	4	mrf 4
Svärdström 1991 (7)	4 y	80		1	n r	2,5	mrf 0 dc 1
Hasselrot 1993 (10)	31–56 mo Mean 42 mo	282	25	1	n r	27	mrf 10 dc 10 cav 7
Lumley 1995 (8)	3 y	33	0	1	0	0	mrf 7
	5 y	33	0	1	0	21	dc 15
Lunder 1997 (12)	Mean 46 mo	235	12	11	11	36 27‡	mrf 5 dc 11 cav 18
Bergmann 1997 (21)	7–65 mo Mean 24 mo	82	18	5	n r	13	n r
Strand 1997 (9)	3 y Mean 35 mo	230	30	4	24	30	mrf 14 dc 16
Hasselrot 1998 (11)	7 y	267	57	1	n r	60	mrf 24 dc 24 cav 12
Pilebro 1998	3 y	374	18	12	41	20	mrf 14 dc 3 other 3

* Restorations with dentin caries or progressive enamel caries. Not reported (n r) by all authors.
† mrf = marginal ridge fracture, dc = dentin caries, cav = proximal cavity.
‡ This figure excludes 20 (9%) restorations replaced before the final evaluation. Reasons for replacement are given for 27%.

in sound surfaces. Strand (16) also examined tunnel restorations filled with Ketac Silver in order to detect caries remnants. Six percent false-positive diagnoses (sound teeth diagnosed as carious) were scored on the radiographs. True-positive findings were reported in 13% of the small lesions, 29% of the medium-sized and 82% of the big lesions. It can be concluded that diagnostic quality is high with respect to the largest lesions, while the detection of small lesions is doubtful.

Other restorative techniques for the primary proximal carious lesion generally show lower failure rates compared to the tunnel cavity restored with glass cermet cement. Today, the most commonly used alternative technique is the saucer-shaped or box-only cavity filled with composite resin. Some longitudinal studies have been reported. Nordbø (17) showed a replacement rate of 17% after 3 years and 30% after a mean of 7.2 ± 1.3 years (18). Kreulen et al. (19) reported no failures after 5 years in 68 box-only composites, performed on selectively beveled cavities in premolars. Posterior composite fillings in conventional cavities showed replacement rates between 6% and 12% after 4 years (20). Amalgam restorations in conventional class II cavities serving as control material in the mentioned studies failed in 5–7%. However, in many Western countries amalgam is not a realistic alternative today.

The result of this and other studies showed that the tunnel method should not be regarded as being a general solution for the operative treatment of proximal caries. The high rate of marginal ridge fracture indicates that when the technique became popular too many not suitable caries lesions were treated with tunnel restorations. The use of a restorative material that can strengthen the marginal ridge more and/or prevent caries progression could improve the durability of the tunnel technique. However, with the knowledge we have today we should restrict the indications for tunnel restorations to small dentin lesions and exclude patients with high caries activity.

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References

1. Jinks GM. Fluoride–impregnated cements and their effect on the activity of interproximal caries. J Dent Child 1963;30:87–92.
2. Hunt PR. A modified class II cavity preparation for glass ionomer restorative materials. Quintessence Int 1984;10:1011–8.
3. Knight GM. Tunnel restorations. Dent Outlook 1984;10:53–7.
4. Wilson AD, McLean JW. Glass-ionomer cement. Chicago: Quintessence Publishing Co, Inc; 1988. p. 206–8.
5. Knight GM. The tunnel restorations—nine years of clinical experience using capsulated glass ionomer cement. Case report. Austr Dent J 1992;37:245–51.
6. Nordbø H. Erfaringer med skålform og tunnelpreparasjoner i det permanente tannsett. Norske Tannl Tids 1993;103:132–4.
7. Svärdström G. Minipreparationer för dagens kariessituation och materialutbud. Odontologi 91. Copenhagen: Munksgaard; 1991. p. 67–79.
8. Lumley PJ, Fisher FJ. Tunnel restorations: a long-term pilot study over a minimum of five years. J Dent 1995;23:213–5.
9. Strand GV, Nordbö 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.
10. Hasselrot L. Tunnel restorations. Swed Dent J 1993;17:173–82.
11. Hasselrot L. Tunnel restorations in permanent teeth. A 7-year follow-up study. Swed Dent J 1998;22:1–7.
12. Lunder N. Tunnelrestaureringer etter fire år. Norske Tannl Tids 1997;107:508–11.
13. Wandera A, Spencer P, Bohaty B. In vitro comparative fluoride release and weight and volume change in light-curing and self-curing glass ionomer materials. Pediatr Dent 1996;18:210–4.
14. Strand GV, Tveit AB, Espelid I. Variations among operators in the performance of tunnel preparations in vitro. Scand J Dent Res 1994;102:151–5.
15. Wenzel A, Hintze H, Hörsted-Bindslev P. Accuracy of radiographic detection of residual caries in connection with tunnel restorations. Caries Res 1998;32:17–22.
16. Strand GV, Espelid I, Tveit AB. Radiographic diagnosis of residual caries in connection with tunnel preparations [abstract]. J Dent Res 1992;7:545, Abstract no. 242.
17. Nordbø H, Leirskar J, von der Fehr FR. Saucer-shaped cavity preparation for composite resin restorations in class II carious lesions: three-year results. J Prosthet Dent 1993;69:155–9.
18. Nordbø H, Leirskar J, von der Fehr FR. Saucer-shaped cavity preparations for posterior approximal resin composite restorations: observations up to 10 years. Quintessence Int 1998;29:5–11.
19. Kreulen C, Tobi H, van Amerongen E, Akerboom H, Borgmeijer P. Five-year failure and cost-effectiveness of box-only composite restorations [abstract]. J Dent Res 1998;77:787, Abstract no. 1244.
20. Dijken van JWV, Quist V. Klinisk utvärdering av ersättningsmaterial. Tandläkartidningen 1997;6:49–59.
21. Bergmann J. Tunnelpræparationer og tunnelfyldninger—en holdbarhedsvurdering. Odont Pract 1997;3:81–3.