Clin Oral Invest (2005) 9: 25–30
DOI 10.1007/s00784-005-0011-6

ORIGINAL ARTICLE

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Tunnel or saucer-shaped restorations: a survival analysis

Received: 12 April 2005 / Accepted: 19 July 2005 / Published online: 23 August 2005

Abstract The aim of the present effectiveness trial was to compare the survival of restorations placed in saucer-shaped cavities to that of restorations placed in tunnel preparations. Ten operators placed a total of 85 tunnel and 97 saucer-shaped restorations. The dentinal part of the tunnel was restored by resin-modified glass ionomer cement. The remaining part of the tunnel was restored by composite resin using an adhesive technique. Composite resin was used to restore the saucer-shaped cavities. The restorations were assessed clinically and radiographically for up to 79 months, with a mean observation time of 28.8 months for tunnel, and 30.3 months for saucer-shaped restorations. The survival proportion of the tunnel restorations was 46%, and the survival proportion for the saucer-shaped restorations was 76%. A main reason for failure of the tunnel restorations was fracture of the marginal ridge (24% after 24 months). Caries development in relation to the restoration was significantly higher for tunnel restorations compared with saucer-shaped restorations (41 and 19%, respectively, after 24 months). There was no difference between the two types of restoration in marginal deterioration and caries progression in the neighboring tooth (40% after 24 months). Based on findings from the present study, it is suggested that saucer-shaped restorations should be preferred for tunnel restorations in small- and mid-sized cavities.

Keywords Composite resin · Glass ionomer cement · Cox regression · Randomized trial · Effectiveness trial

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Introduction

The adhesive techniques have changed the principles for cavity preparation. Tooth substance, which previously was removed for retentive purposes, can be preserved, and retentive measures reduced to a minimum. The saucer-shaped cavity design (Fig. 1) represents a contemporary approach that makes the best use of the adhesive technique to preserve noncarious tooth substance. A long-term study of saucer-shaped cavity preparations has demonstrated that 70% of the restorations remain clinically acceptable after a mean of 7 years of follow-up, and the authors suggested that this operative method be considered routine treatment for small approximal lesions in posterior teeth [15]. An alternative tooth substance preserving cavity design is the tunnel preparation, which leaves the marginal ridge unaffected during preparation (Fig. 2). This cavity design has been quite popular in some Scandinavian countries for the restoration of primary approximal lesions. Among 640 Norwegian dentists, about 47% preferred tunnel preparation, 28% preferred a traditional class II preparation, and 24% preferred a saucer-shaped preparation [29]. In Sweden, where 651 dentists were asked, the figures were 48, 20, and 32%, respectively [27].

The results pertaining to the survival of restorations based on tunnel preparations vary considerably. Some reports indicate that 74–90% of the restorations remain acceptable after 3–4 years [4, 6, 14, 18], whereas other reports indicate a lower success rate of 57–68% [11, 19, 22]. However, when the observation period was extended to 5–7 years, the originally high success rate dropped to 35–40% [5, 14]. The reasons quoted for failures of the restorations based on tunnel preparations include marginal

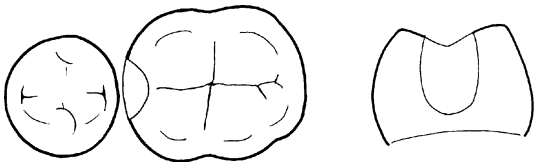

Fig. 1 Saucer-shaped preparation. *Occlusal* and *proximal* aspect

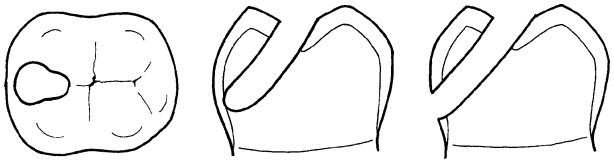

Fig. 2 Tunnel preparation. *Occlusal* aspect and *proximal* aspect class I and class II

ridge fracture and recurrent or progressing caries [5, 14, 18, 22, 23], just as the operator has been shown to significantly influence survival [5, 14, 17].

To the best of our knowledge, no data have been published that compare the survival of restorations based on tunnel preparations with that of restorations based on saucer-shaped cavity preparations. It is therefore the purpose of the present study to compare the survival of restorations placed in saucer-shaped cavities to that of restorations placed in tunnel preparations using a randomized trial study design.

Material and methods

This clinical trial was carried out as an effectiveness trial. Ten dentists serving in eight school dental clinics in the municipality of Odense, Denmark, agreed to participate in the study. Approval from the Ethical Committee of Vejle and Funen counties was obtained. A list was prepared in which the numbers from 1 to 500 were randomly permuted in blocks of ten to one of the two experimental procedures, tunnel preparation or saucer-shaped preparation. Each participating dentist was allocated a block of permuted numbers to cover the anticipated number of lesions that would be appropriate for tunnel or saucer-shaped preparation. The dentists were instructed to use the list of permuted numbers in such a way that whenever a child presented with an eligible approximal caries lesion in a molar or premolar for which a composite restoration was indicated, the dentist would use the permuted list to decide whether a tunnel or a saucer-shaped preparation was going to be made. Thereby, all children who presented with a lesion during the study period, or until the dentist in question decided to terminate participation, were evaluated for eligibility to the study. A lesion was eligible for inclusion if there was a clinically visible cavity or if bitewing radiographs indicated the presence of caries extending at least halfway through the dentine. Lesions were not eligible if the lesion was deemed to involve the pulp when excavated or if the marginal ridge was considered to not sustain a tunnel preparation. Table 1 shows the resulting distribution of the two experimental procedures across the participating dentists. Between 1996 and 2000, a total of 197 restorations were attempted in 142 children. Most children (58) were 11- to 12-year-olds, whereas 34 were 8- to 10-year-olds, and 50 were between 13 and 16 years of age. Most children (102) had only one restoration, 29 had two restorations placed, 7 had three restorations, and 4 children had four restorations each. Most of the restorations were located in the maxillary premolars (50) and first molars (75), while 25 and 45 restorations were located in the mandibular premolars and first molars, respectively. Among these 197 restorations, 99 were indicated to become tunnel preparations, and 98 were indicated to become saucer-shaped preparations (Table 1).

Table 1 The distribution of dentists according to number and type of restorations attempted inserted

Dentist	Numbers allocated	Total no. of restorations	No. of tunnels	No. of saucer-shaped
A	30	8	4	4
B	50	45	25	20
C	50	39	20	19
D	30	7	4	3
E	50	18	7	11
F	30	11	5	6
G	30	18	10	8
H	20	12	5	7
I	20	24	12	12
J	30	15	7	8
Total	340	197	99	98

The preparations were carried out as follows:

Saucer shaped preparation An “Inter Guard” band was placed to protect the neighboring tooth during preparation. Preparation and excavation was made using high-speed diamonds and round burs with air–water spray. If the distance from the cavity bottom to the pulp was estimated to be less than 0.5 mm, a base of calcium hydroxide cement (Alkaliner, 3M-Espe, Seefeld, Germany) was placed and covered with a glass ionomer cement (Vitrebond, 3M-Espe). A transparent or steel band matrix and wedges were applied. The enamel and dentin were conditioned with acid gel (Scotchbond MP Etchant, 3M-Espe) for 15 s followed by water spray and air-drying. The cavity was primed (Scotchbond MP Primer, 3M-Espe), and adhesive was applied (Scotchbond MP Adhesive, 3M-Espe) and light-cured for 10 s. A layering technique by syringing was used to fill the cavity with a hybrid composite (Z100, 3M-Espe). Each layer was cured for 40 s. The restoration was finished and polished 5 min after application of the last layer.

Tunnel preparation The occlusal cavity was prepared with round diamonds aiming at a width of the marginal ridge of 1.5–2 mm. Round burs No. 012 or 014 or a small excavator (Ash 246) were used for excavation. In situations without perforation to the interproximal space, a class I tunnel was attempted (n=28). In situations with

perforations, a class II tunnel was attempted (n=71). In case the width of the marginal ridge after preparation was less than 1.5 mm, and the distance from the proximal perforation of a class II tunnel to the marginal ridge was less than 2.0 mm, the cavity was transformed to a saucer-shaped cavity and excluded from the study. Lining of the tunnel preparations was made according to principles described for saucer-shaped cavities. The dentinal part of the tunnel was restored by a resin-modified glass ionomer cement (Vitremer, 3M-Espe) after priming (Vitremer Primer, 3M-Espe). A layering technique was used, and each layer was light polymerized for 40 s. If contamination of the occlusal part of the tunnel cavity took place, the occlusal enamel and the most occlusal part of the dentin were slightly ground with a diamond to remove any contaminants prior to acid etching. Restoration with composite resin of the remaining part of the cavity and polishing was made using the same procedures as for the saucer-shaped cavities [8].

Recordings The baseline recordings consisted of the following information: tooth condition of neighboring tooth surface, type of restoration, and margin adaptation of restoration. Information on the duration of postsurgical pain was recorded as less than 8, 8–14, 15–28, or more than 28 days. Children were recalled after 1 week, and in case of pain/sensitivity, they were recalled on a weekly basis. At each ensuing recall visit, which was typically scheduled to take place every 12 months, recordings were made of marginal adaptation (acceptable alpha: no ditching or marginal discoloration; bravo: ditching and marginal discoloration; unacceptable charlie: ditching, exposing dentin, or deep marginal discoloration; failure delta: mobile, lost, or fractured) [21, 30], presence of marginal ridge fracture or infraction (yes/no), clinical and radiographic assessment of the presence of caries in the tooth (no, questionable, or yes), and a clinical and radiographic assessment of the presence of caries in the neighboring tooth (no, questionable, or yes).

Statistical analysis The data were analyzed using standard methods for the analysis of time-to-event (survival) studies. Six different events were considered: (1) replacement of restoration due to caries, restoration defects, or fractures; (2) deterioration of the marginal adaptation rating, defined as a transition from the alpha rating to inferior ratings; or (3) from alpha or bravo ratings to inferior ratings; (4) marginal ridge fracture or infraction; (5) caries adjacent to restoration; and (6) caries in neighboring tooth. The time-at-risk for an event was calculated as the time elapsed since insertion of the restoration until the date of detection of the event. Kaplan–Meier estimates of the survival functions were calculated according to type of restoration using the procedure of STATA 8 [26]. No distinction was made in the analysis between class I and class II tunnel preparations due to a limited number of the former. The equality of the survival functions for the two types of restorations (tunnel or saucer-shaped) was tested using the log-rank test. For all outcomes, the 1-, 2-, 3-, and 4-year survival proportions were calculated along with a 95% confidence interval (CI) for the estimates [1]. As 40 of the 142 children involved contributed more than one restoration, calculation of standard errors for the survival proportions using standard methods is likely to provide estimates that are too small. However, Cox proportional hazard regression, carried out using STATA 8 [26], which allows for the calculation of robust standard errors (i.e., standard errors adjusted for the interdependence of restorations within the same child), indicated that the standard errors calculated using the assumption of independence were underestimated by less than 5%.

Results

A total of 14 of the tunnel preparations (14%) failed or were excluded at the stage of preparation, mainly due to fracture of the marginal ridge. One saucer-shaped cavity preparation failed because the size of the caries lesion prompted stepwise excavation. The 95% confidence interval for the estimated 13% difference between the two procedures with respect to the proportion of failed preparations was 6–21%.

The number of tunnel and saucer-shaped preparations actually restored was 85 (27 class I and 58 class II) and 97, respectively. Nine (5%) of the 182 teeth concerned showed postoperative sensitivity, in most cases (six) lasting no more than a week. Immediately following insertion, 18 restorations (eight tunnel and ten saucer-shaped) had a nonalpha score for marginal adaptation.

Before the first follow-up visit, 14 children, carrying 3 tunnel- and 13 saucer-shaped restorations, moved away from the schools involved in the study, and the number of restorations for which follow-up information was available was therefore 82 and 84 for the tunnel and saucer-shaped restorations, respectively. The mean observation time for the 82 tunnel and 84 saucer-shaped restorations was 28.8 (95% CI 25.6–32.1) and 30.3 (95% CI 27.3–33.3) months, respectively, ranging from 1 to 79 months. The percentages of restorations available for observation after 1, 2, 3, and 4 years were 94, 71, 38, and 14%, respectively, for the saucer-shaped, and 88, 63, 38, and 10%, respectively, for the tunnel restorations.

During the entire observation period, 31 tunnel and 13 saucer-shaped restorations were replaced. The saucer-

Table 2 The proportion of restorations surviving with respect to the event replacement

No. of years	Survival proportion event = replacement of restoration	
	Tunnel	Saucer-shaped
1	92.5 (84.0–96.6)	95.2 (87.8–98.2)
2	77.0 (65.5–85.0)	91.0 (82.0–95.6)
3	62.8 (49.6–73.4)	83.9 (72.5–90.9)
4	46.2 (29.5–61.3)	76.2 (59.9–86.6)

log-rank test p<0.003

Table 3 The proportion of restorations surviving with respect to the event deteriorating marginal adaptation (defined as a transition from alpha or bravo to charlie or delta)

No. of years	Survival proportion: event = deteriorating marginal adaptation	
	Tunnel	Saucer-shaped
1	98.3 (88.6–99.8)	96.9 (89.4–99.8)
2	86.4 (74.7–93.0)	89.1 (78.4–94.6)
3	78.3 (64.7–87.1)	83.4 (71.1–90.8)
4	57.3 (36.9–73.2)	74.6 (56.5–86.0)

log-rank test $p>0.30$

shaped restorations performed statistically significantly better than the tunnel restorations ($p<0.003$), and the difference manifested already after 1 year. After 4 years, 76% of the saucer-shaped restorations had survived compared with 46% of the tunnel restorations (Table 2).

Over time, both types of restorations showed a gradual, and similar, deterioration of the marginal adaptation. A substantial number of changes from alpha ratings to lower ratings occurred within the first year after insertion, while the transitions from alpha or bravo ratings to inferior ratings were more evenly dispersed with time. At 24 months, about 50% of the restorations still had an alpha rating for marginal adaptation, while more than 85% of the restorations still received an alpha or a bravo rating (Table 3).

The tunnel restorations showed a gradual increase with time the occurrence of marginal ridge fractures or infractions (Fig. 3). At 24 months, 76% had not experienced such fractures, but after 4 years, less than 50% of the marginal ridges remained intact. The tendency for caries development in the tooth around the restoration was statistically significantly higher for tunnel restorations compared with the saucer-shaped restorations ($p<0.05$). At 24 months, more than 80% of the teeth with saucer-shaped restorations remained caries-free compared with 59% of the teeth with tunnel restorations (Table 4).

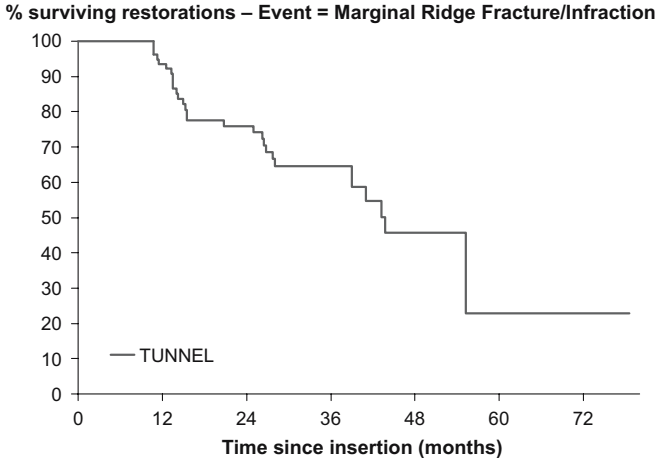

Fig. 3 The Kaplan–Meier estimate of the proportion of restorations that have not experienced a marginal ridge fracture or infraction as a function of time since insertion. Given for tunnel restorations only, as saucer-shaped restorations are not at risk to such fractures

Table 4 The proportion of restorations surviving with respect to the event caries adjacent to restoration

No. of years	Survival proportion: event = caries adjacent to restoration	
	Tunnel	Saucer-shaped
1	92.2 (83.5;96.4)	96.3 (89.0;98.8)
2	59.0 (46.0;69.8)	81.1 (70.1;88.4)
3	53.2 (40.1;64.7)	72.4 (59.9;81.6)
4	47.9 (32.5;61.8)	55.6 (37.5;70.4)

log-rank test $p>0.05$

The tendency for caries development in the neighboring tooth appeared to be fairly similar for the two types of restorations ($p>0.30$). About 60% of the teeth neighboring the restorations remained caries-free at 24 months.

Discussion

The present study has shown that saucer-shaped restorations performed significantly better than tunnel restorations throughout a 4-year period, as 76% of the saucer-shaped restorations survived compared to 46% of the tunnel restorations. The number of restorations assigned to the ten dentists who participated in the study were based on an estimation of the restorative needs at the different school dental clinics (Table 1). A few of the dentists attempted only about 25% of their originally estimated number of restorations, possibly because they never crossed the point of feeling comfortable with the tunnel preparation. Due to a compromised overview, the preparation of a tunnel cavity may be considered more difficult than the preparation of a saucer-shaped cavity. It is also evident from the present study that a number of tunnel preparations failed at the stage of preparation due to marginal ridge fracture, and this may have caused some dentists to discontinue their participation in the experimental procedures. Previous studies have stressed that the quality of tunnel restorations improves with increasing routine [5, 14, 17]. However, within the limits of the present study, it was our impression that the failures did not differ pronouncedly among the dentists who made several restorations whether these dentists were experienced or inexperienced in tunnel preparations.

One of the main reasons why tunnel restorations may be preferred over classical class II restorations is the possibility of maintaining an intact marginal ridge, leading to preservation of much sound tooth substance, particularly in the contact area. However, during cavity preparation, 14 cavities originally scheduled to become tunnel restorations had to be excluded primarily because the marginal ridge became too shallow and fractured. During the observation period, marginal ridge fractures continued to occur, and 24% of the tunnel restorations had experienced marginal ridge fractures after 24 months (Fig. 3). Ridge fracture as a main cause of failure is in agreement with findings from several clinical studies [5, 17, 18, 23]. Apparently, this finding is more pronounced in studies with several oper-

ators [17, 19, 23], whereas efficacy trials, where the restorations are made by one operator, often demonstrate fewer fractures [7, 10, 28]. This, again, may indicate that the clinical procedure is difficult to learn. In the present study, replacement of the restoration was performed when the ridge fractured. Although repair may be possible, both options imply a visit to the dentist and a further expense for the patient and/or the social security system.

A gradual deterioration of the marginal adaptation was seen in both groups (Table 3). Apart from caries, marginal deterioration has been described as one of the main reasons for replacement of composite resinous restorations [3, 12, 13]. In the present study, a substantial number of restorations changed from alpha to bravo, but only a few restorations developed unacceptable margins. No difference was found between the two groups after 24 months (Table 3).

From the present results, it might be inferred that the caries rates observed either in relation to the restoration placed (41 and 19% after 2 years for tunnel and saucer-shaped restorations, respectively) or in relation to the neighboring tooth surface (40% carious after 2 years) are quite high. However, the caries rates for the neighboring teeth should be seen in light of the high risk (>60%) of iatrogenic damage associated with approximal preparations [20]. Iatrogenic damage may promote caries development or may be diagnostically mistaken for caries. Moreover, it must also be borne in mind that the children included in the present study, by virtue of the fact that they needed approximal restorations, belong to a high-caries risk population. Even so, it is noteworthy that the tunnel restorations, with their approximal glass ionomer cement, had a considerably poorer survival rate with respect to caries development than the saucer-shaped restorations consisting entirely of composite resin did (Table 4). In vitro studies have documented a continuous release of fluoride from glass ionomer materials [2, 9], but some in vivo studies have failed to show a clinical effect [18, 23, 30]. As there was no significant difference between the two types of restorations in the rate of caries development in the neighboring teeth, the explanation should probably be sought in the different excavation and filling techniques. Hence, tunnel restorations are technically more demanding and associated with less visibility during excavation, preparation, and filling, and this may have resulted in incomplete excavation and obturation of the most proximal part of the tunnel [16, 24, 25, 31]. This may, in the course of time, predispose to further caries development in relation to the restoration. Unfortunately, our material is too limited to provide valid conclusions to the question of whether factors such as differences in caries progression between individuals or the type of tunnel preparation had any bearing on the results.

In the present study, caries, in relation to saucer-shaped restorations, was seen along the gingival cavo-surface margins. It cannot be totally ruled out that some restorative defects such as marginal gaps were occasionally misdiagnosed as caries in both groups.

The present study has shown that the sacrifice of the marginal ridge and the placement of a saucer-shaped restoration results in a higher survival rate than the placement of a tunnel restoration. It was additionally shown that the release of fluoride from the glass ionomer cement did not, in the present study group, have a discernible clinical caries-reducing effect. Because of the apparent difficulties in making the tunnel restoration, a saucer-shaped restoration should be preferred for the operative treatment of medium-sized caries lesions.

Acknowledgements We wish to thank the following dentists from the Municipal Dental Service in Odense for their participation and commitment to the present study: Anette Christensen, Lise Tofte Hansen, Sanni Jacobsen, Trine Jensen, Birgit Klausen, Marianne Gjerløv Lauritzen, Bente Oddershede, Johnna Rasmussen, and Susanne Buus Thomsen.

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