The quality of routine class II cavity preparations for amalgam

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In spite of many improvements in operative dentistry, the incidence of replacements of amalgam restorations remains high. It is possible that specific cavity features are important for the longevity of the restorations. Six hundred and ten epoxy plastic models, made from impressions of permanent teeth in which class II cavities had been prepared by eight Scandinavian dentists, were examined. The examination showed prevalent imperfect external and internal cavity features. These may reflect the operators' opinion of adequate operative dentistry, neglect to control design features, or lack of training in examining a cavity critically. □ *Internal and external features; operative dentistry; techniques*

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The physical properties and the chemical stability of dental amalgam indicate that it may be used as a permanent type of restorative material in the oral environment. However, clinical surveys show that restorations are replaced after a relatively short time. Healey & Phillips (1) reported an association between the material and operator performances and the deterioration of amalgam restorations. They concluded that inferior cavity preparation was the major cause of the clinical failures.

In spite of a general progress in operative dentistry and many improvements of amalgam, observations reveal mediocre clinical qualities of amalgam restorations (2–6). Some reports of frequent replacements of amalgam restorations have been published (7–9), and the type of clinical failures of amalgam restorations has not changed significantly over time (10–13). Moreover, the longevity of amalgam restorations remains approximately the same (14–20). It is possible that the operator performances, which include cavity preparation, influence the prognosis of dental restorative work more today than some decades ago (21).

Results of short-term studies indicate that certain details in the cavity design increase the number of defects of the restorations (22–24). However, the effects of cavity deficiencies on the long-term prognosis of the amalgam restoration have not been clarified. There are no data in the dental literature on the correlation between preparation features and the site of failure of amalgam restorations. A detailed examination of class II cavities prepared by dentists in general practice was therefore initiated. The cavities are part of a longitudinal study of the clinical performance of amalgam restorations.

Materials and methods

Epoxy plastic models, made from impressions of permanent teeth in which class II cavities for amalgam restorations had been prepared by eight Scandinavian dentists, were examined. The material included cavities prepared because of primary caries and failed restorations. The clinical experience of the operators varied from 15 to 30 years.

The operators were instructed to make an impression (Optosil/Xantopren, Bayer) of the tooth before the insertion of the amalgam. No instructions on preparation

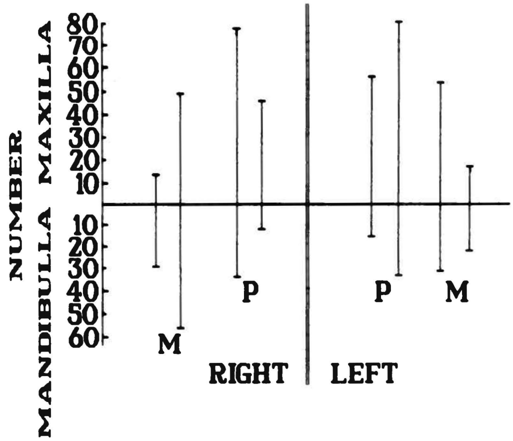

Fig. 1. The distribution of the examined cavities in premolars (P) and molars (M). The two vertical lines represent the number of mesial and distal cavities in each tooth category on the right and the left side in the maxilla and mandibula.

techniques were issued in advance; that is, no information on the ideal, adequate, or minimum quality of the cavities was presented to the operators. Furthermore, whereas it was clear to the clinicians that the cavities were to be examined, they were not aware of what was to be measured and how. The cavities are therefore considered to reflect the clinical situation in everyday dental practice.

The models were examined in a stereomicroscope (Spencer American Optical) at ×10 and ×20. One evaluator examined the models at random, with no knowledge of the operator. A classification system applicable to models was used to categorize the cavities (25). The proximal cavosurface margins were also classified by means of a cavity margin index (CMI) (26).

The intrareliability was 85% agreement on separate scores. The chi-square test for independence was used to assess any potential association between various cavity features and the surfaces or the operators.

Results

A total of 610 cavities were examined (Fig. 1). The distribution of the cavities is presented in Table 1. The number of impressions returned by each operator varied from 19 to 108. The location of the cavities also varied (Table 1).

Finish

The evaluation of the proximal cavosurface margins, rated by the CMI, is summarized in Table 2. Most margins scored 3 (rough), and extremely few margins scored 0 (smooth) or 1 (light roughness).

External features

Distinct and smooth angles throughout the full length of the cavosurface margins were seen in only 6% of the models. The cavity

Table 1. The distribution of cavities prepared by eight different operators

Operator no.	Upper				Lower				Total
	Premolar		Molar		Premolar		Molar		
	Mesial	Distal	Mesial	Distal	Mesial	Distal	Mesial	Distal	
1	30	33	6	1	6	11	3	2	92
2	7	8	24	—	—	2	19	2	62
3	20	31	8	11	8	18	6	5	107
4	12	22	14	6	3	11	19	16	103
5	8	31	38	2	1	4	19	5	108
6	18	22	10	6	4	12	15	13	100
7	—	5	1	—	—	2	5	6	19
8	4	5	—	—	4	6	—	—	19
Total	99	157	101	26	26	66	86	49	610

Table 2. Cavity margin ratings of the proximal surfaces using the CMI index

	Margin					
	Buccal/ lingual		Line angle		Gingival	
CMI	*n*	%	*n*	%	*n*	%
0	0		0		0	
1	25	4.3	4	1.1	1	0.3
2	120	20.6	41	11.0	33	9.3
3	438	75.1	329	88.0	320	90.4
Total	583		374		354	

was without form in 2% of the models (Fig. 2). Margins that were considered to be indistinct or to have an irregular continuity were observed in 67% of the models (Fig. 3). The cavities with external discrepancies were distributed equally on all tooth surfaces (Fig. 4).

Margins with carvosurface angles <90°—that is, unsupported enamel—were seen in 54% of the models, mainly in the distal surfaces of the lower molars and the upper premolars (Fig. 4). Unsupported enamel

Fig. 2. Example of a cavity preparation in a lower first premolar without external and internal defined form proximally.

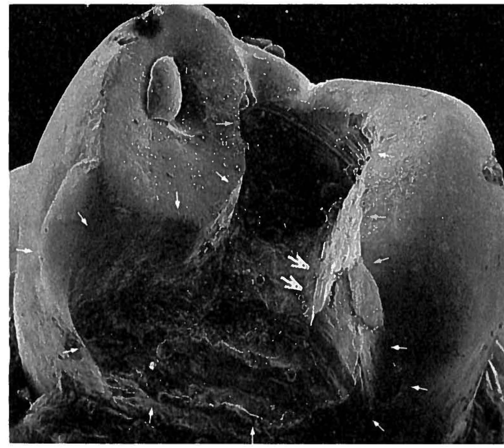

Fig. 3. Example of a cavity preparation with poor external definition, at the distal surface in an upper second premolar. Note also an acute occlusal internal line angle lingually (double arrow).

prevailed along the gingival cavosurface margin (Fig. 5). Fig. 6 illustrates the prevalent intrasurface location of the unsupported enamel.

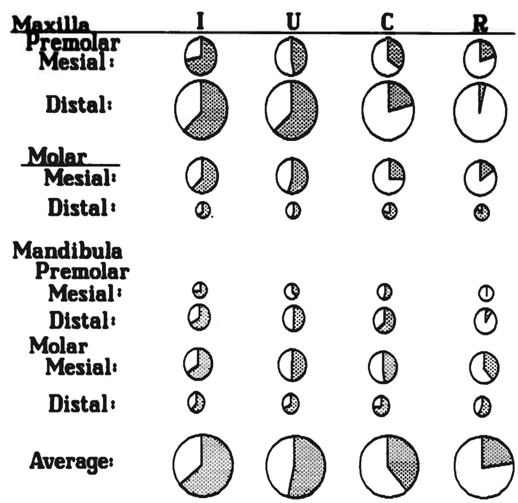

Fig. 4. Sector diagrams of the prevalence of external discrepancies tabulated by tooth surfaces. The size of the circles represents the number of surfaces in each tooth category. The extent of the shade in each circle indicates the percentage of discrepancies. I = indistinct cavity definition; U = unsupported enamel; C = cusp reduction > 2/3; R = remaining parts of enamel < 1 mm.

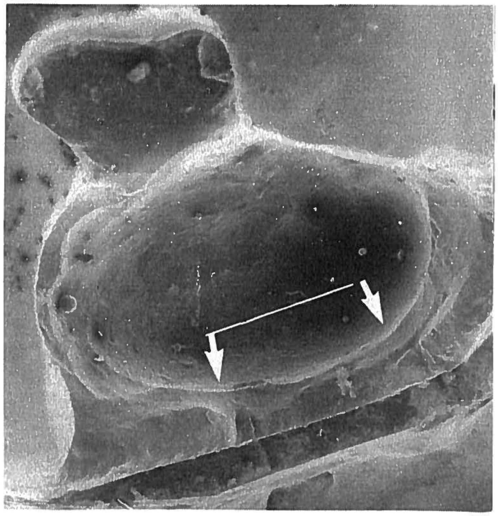

Fig. 5. Example of a cavity preparation with unsupported enamel along the gingival margin (arrows), at the mesial surface in an upper first premolar.

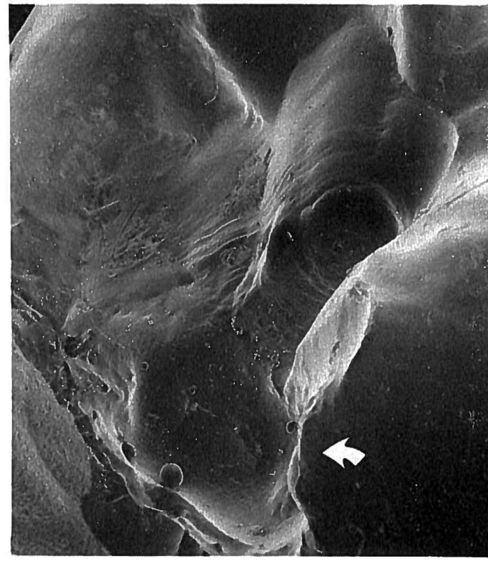

Fig. 7. Example of a cavity preparation with irregular margin on the lingual wall (arrow), at the distal surface in an upper second premolar.

Discontinuations of the cavosurface margin were noticed in 12% of the models (Fig. 7), mainly on the distal surface of the upper molars.

Cavities that involved >2/3 of a cuspal incline were observed in 40% of the models (Fig. 8). The feature was observed distally in 3/4 of the molars (Fig. 4).

Deep fissures that extended from the cavity margins were seen in 5% of the models (Fig. 9). Remaining fissures prevailed on the buccal part of the lower molars.

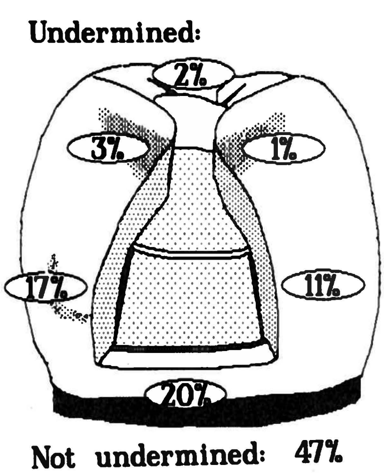

Fig. 6. The prevalent locations of unsupported enamel.

Fig. 8. Example of a cavity preparation with margin extended > 2/3 of a cuspal incline (arrow) at the mesiolingual cusp in a lower first molar.

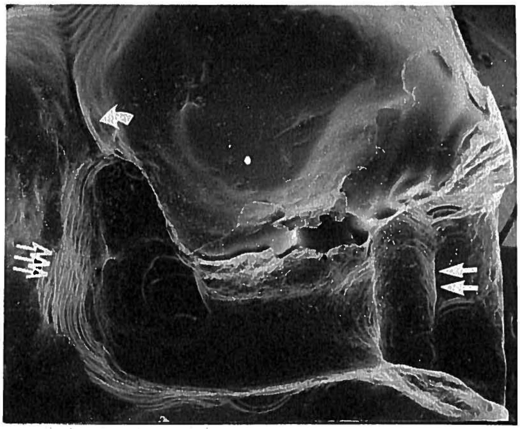

Fig. 9. Example of a cavity preparation with a margin extending into a deep buccal fissure (arrow), in an upper first molar. Note also extensive proximal locking (double arrow) and an undulating pattern lingually produced by the diamond particles on the bur (triple arrow).

Segments of enamel <1 mm between the cavity and previous restorations or fissures were registered in 20% of the models (Fig. 4). The enamel slices were usually fragments of the mesiolingual–distobuccal triangular ridge in the upper molars (Fig. 10) or central parts of the occlusal surface in the lower molars.

Fig. 10. Example of a cavity preparation with a thin enamel segment (arrows), between the margin and a remaining amalgam restoration (a), at the oblique ridge in the upper first molar. Note also the sharp axiopulpal line angle (double arrows).

Internal features

A flat pulpal floor was observed in 66% of the models. A pulpal floor with variable levels prevailed in the upper molars (Fig. 11).

An acute axiopulpal line angle (isthmus) was observed in 27% of the models (Figs. 10 and 11). An acute isthmus was most prevalent in the mesial parts of the upper and lower molars (Fig. 12).

Acute occlusal internal line angles were seen in 14% of the models, mainly in the distal part of the upper molars (Figs. 3 and 12).

Locks in at least one proximal internal line angle were included in 48% of the models (Fig. 9). Gingivoaxial line angles with no lock were found in 30% of the models. An inclined gingival floor or a gingival lock resulting in unsupported enamel (Fig. 13) was observed in 21% of the models. This feature prevailed on the distal surface of the upper premolars (Fig. 12).

Retention

Lack of retention in the occlusal part was seen in 35% of the models. The incidence of

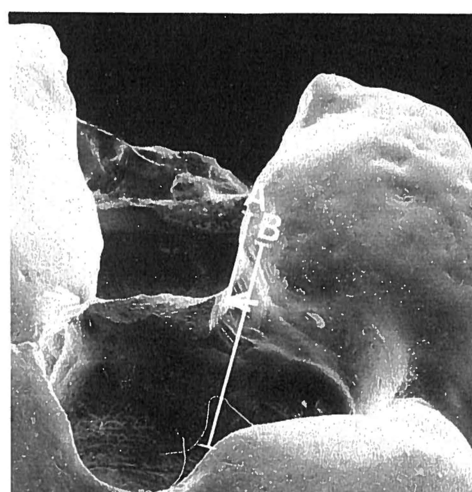

Fig. 11. Example of a cavity preparation with a variable occlusal level of the pulpal floor. The average occlusal depth (B) is 5 mm, while the depth at the ridge at the axiopulpal line angle, the isthmus, is 2 mm (A). This results in a sharp ridge at the isthmus (arrows).

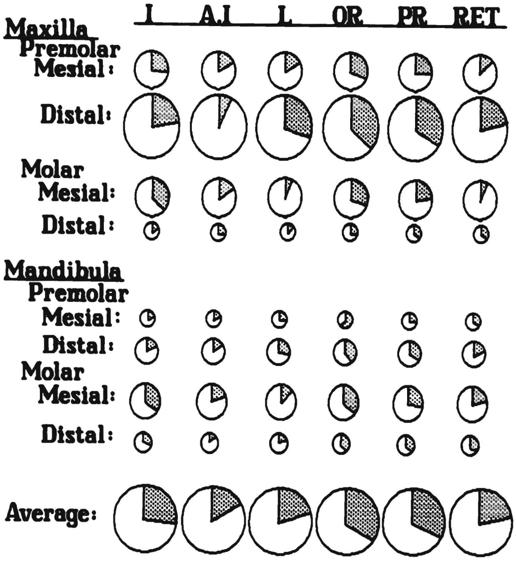

Fig. 12. Sector diagrams of the prevalence of internal discrepancies and lack of retention tabulated in accordance with tooth surfaces. The size of the circles represents the number of surfaces in each tooth category. The extent of the shade in each circle indicates the percentage of discrepancies. I = acute occlusal line angles; A.I = acute isthmus; L = poor gingival lock; OR = lack of occlusal retention; PR = lack of proximal retention; RET = lack of retention.

Fig. 13. Examples of a cavity preparation with an inclined gingival floor (arrow) and locking, which has resulted in unsupported enamel (double arrow) at the distal surface in a lower second premolar.

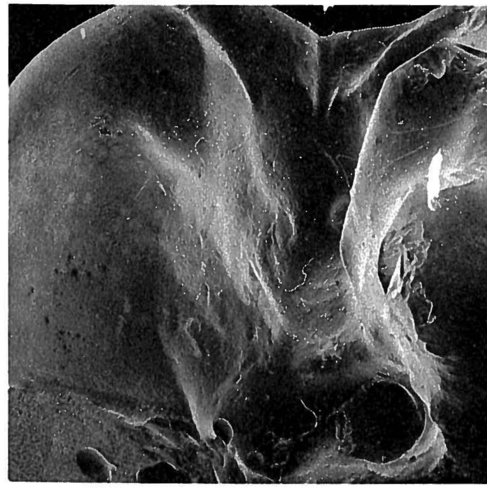

Fig. 14. Example of a cavity preparation with diverging buccal and lingual walls occlusally and distally in an upper premolar. Note also the poor occlusal external definition.

lack of occlusal retention was higher in the lower teeth (Fig. 12).

Lack of retention in the proximal part was observed in 30% of the models. The incidence of lack of proximal retention was equally distributed throughout the dental arch (Fig. 12).

Lack of retention in both parts was seen in 20% of the models (Fig. 14). Lack of both occlusal and proximal retention occurred most frequently in the distal parts of the upper and lower molars and in the mesial part of the lower premolars (Fig. 12).

Operator variance

Significant variation in the various cavity features was observed between the operators (Figs. 15 and 16). Table 3 summarizes the prevalent locations of unsupported enamel for the operators.

Discussion

The external features of a cavity may be characterized by means of many criteria. Much focus has been directed on the qualities of the cavosurface margins. Scanning

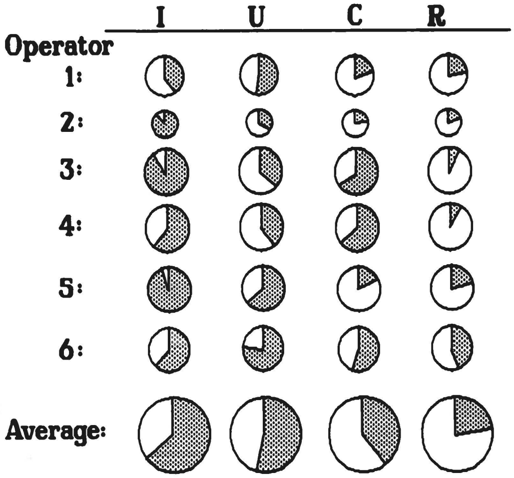

Fig. 15. Sector diagrams of the prevalence of external discrepancies tabulated in accordance with operators. The size of the circles represents the number of cavities made by each operator. Operators 7 and 8 are not included owing to the low number of preparations. The extent of the shade in each circle indicates the percentage of discrepancies. I = indistinct cavity definition; U = unsupported enamel; C = cusp reduction > 2/3; R = remaining parts of enamel <1 mm.

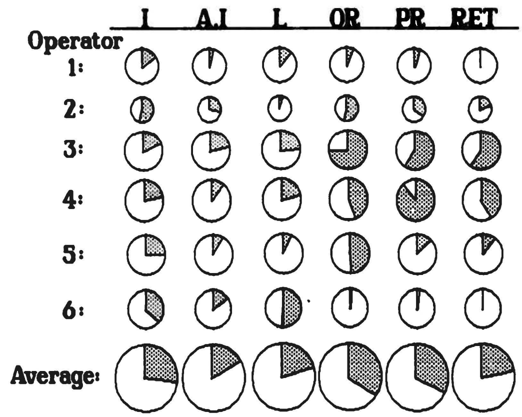

Fig. 16. Sector diagrams of the prevalence of internal discrepancies and lack of retention tabulated in accordance with operators. The size of the circles represents the number of cavities made by each operator. Operators 7 and 8 are not included owing to the low number of preparations. The extent of the shade in each circle indicates the percentage of discrepancies. A = acute occlusal line angles; A.I = acute isthums; L = poor gingival lock; OR = lack of occlusal retention; PR = lack of proximal retention; RET = lack of retention.

electron microscopy studies abound in the dental literature (27). The technique enables ranking of discrepancies at the margin, such as by the CMI system. The CMI scoring has previously been applied in studies to evaluate the finishing properties of burs and hand instruments (26, 28). However, these studies were conducted under optimal conditions on phantom models (26) or on extracted teeth (28). The many ratings into the unacceptable category in this study indicate that the system may be too finely graded, and thus unsuitable for the present type of design of clinical evaluation.

The finish of the cavosurface margin can be characterized by descriptors applied perpendicular to the cavosurface margin. Common descriptors are the distinction of the margin, the degrees of the cavosurface angle, and the variation of degrees of this angle

Table 3. The prevalent location of unsupported enamel tabulated for the different operators

	Proximal				
	Gingival, %	Buccal, %	Lingual, %	Occlusal, %	Total, %
Operator 1	35	3	11	3	52
Operator 2	3	16	10	5	34
Operator 3	19	11	7	1	38
Operator 4	22	7	7	7	43
Operator 5	6	37	22	3	68
Operator 6	34	19	13	11	77
Operator 7	—	42	11	16	69
Operator 8	11	11	—	—	22

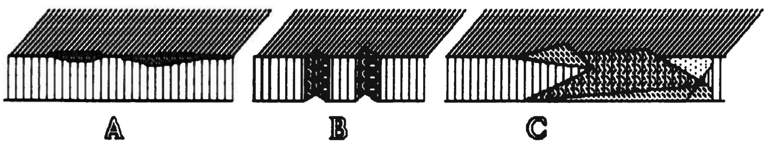

Fig. 17. Modes of describing the qualities of a cavosurface margin. 17A. Enamel fractures with variable degrees. 17B. Grooves and external sharp corners. 17C. Facets produced by changing the work angle of the bur.

(Fig. 17). It is, however, also necessary to assess the three-dimensional continuation of the margin—that is, a descriptor applied along the cavosurface margin—to describe fully the margins. It is difficult to define precisely an adequate three-dimensional continuation. The definition used in this study was 'All points within a 1 mm^2 wall or a 1-mm margin must be part of the same spatial plane or line' (25).

The poorly defined cavosurface angles predispose to imperfect carving of the amalgam (29). Cavosurface angles that change continually or a margin made up of many facets and planes also prevent a correct assessment of the margin (30). In addition, margins with a variable continuation inhibit optimal condensation of amalgam (31). Imperfect carving results in weak fringes of amalgam, which later may break off (32). The clinical significance of the marginal breakdown is disputable (33, 34). Marginal defects are, however, frequently used as a reason for replacement (13). There are few reports on the correlation between the combination of the degrees of the angle and the occlusal location of the cavosurface margin, and marginal defects (35–37). In this study it was impossible to measure accurately the angles owing to the many indistinct margins (Figs. 2, 3, 13, and 14).

The prevalent unsupported enamel along the gingival margin is often caused by an incorrect angle of the bur (38). Placement of excessive gingival locks, frequently observed in the cavities prepared by operator 6 (Fig. 16), may also have caused this discrepancy (Fig. 13). More regular use of enamel hatchets should be advocated to reduce the frequency of unsupported enamel in the proximal parts (39). It has been shown that the thin enamel edges later may break off—for example, during the placement of the amalgam matrix (40)—with a marginal ditch as a result. Plaque accumulation in these gingival ditches may have confounded the conclusions in studies of the effects of sub- and supra-gingival restorations on the periodontal condition (41–44).

The frequency of substandard margins did not increase in the areas with restricted access or without direct vision. It is possible that many operators—for example, operators 2, 3, and 5 (Fig. 15)—after having removed the tissue proceed to use the high-speed bur for finishing the margins (45, 46). Many investigators have compared the effects of burs and hand instruments on hard tissue. High-speed burs may produce excellent margins (47–49). However, this is under ideal conditions. Under clinical conditions the intraoral access of the bur and the handpiece varies. During the cavity preparation the continual changing of the angle between the bur and the contact area on the tooth results in manifold facets. Consequently, impaired margins often result unless special finishing burs or hand instruments are applied later.

The indication for capping the cusps is a cavity that involves >2/3 of a cuspal incline (50–53). In accordance with this criterion, cusp capping was indicated in 3/4 of the distobuccal cusps in the lower molars, the distolingual cusps in the lower second premolars, or the distopalatinal cusps in the upper molars. Other clinical elements, such as the morphology of the antagonist, the occlusion, and the patient's bite force, influence this treatment decision but were not considered in this study. Despite the clear indications, it is clear that many operators omit capping cusps, as the cusp usually can endure much strain. The worst possible clinical consequence is that the cusp may break off later. Operators 3, 4, and 6 obviously questioned this logic of avoiding cusp fractures by simply removing the cusps (Fig. 15).

Segments of enamel <1 mm between the cavity and previous restorations occurred in 1/5 of the models (54). In some new textbook editions the suggested minimum width of enamel slices is reduced to 0.5 mm (see, for example, Ref. 50). However, the authors introduce no data to warrant the reduction. The worst possible clinical consequence of preserving a thin enamel segment is identical to that for weak cusps: it may break off later. It is unknown whether the enamel indeed does fracture under these conditions. The prevalent thin enamel segments next to the preparations indicate that, for example, operator 6 downgrades the clinical significance of this cavity feature (Fig. 15).

The present method for studying plastic models cannot distinguish between noncarious and carious or demineralized fissures. All the deep fissures were therefore registered as potential discrepancies. There are conflicts of opinion on how to handle deep fissures that extend from the cavity margins. Because secondary caries seldom develop on the occlusal surface, many investigators refrain from full removal of the fissure system (55). Others believe that the deep occlusal fissures represent stagnation areas and must be eradicated (56) or included in the preparation (50).

The internal morphology of the cavities varied among the tooth categories (Fig. 11) and the operators (Fig. 16). Black (57) recommended preparing a horizontal pulpal floor at right angles to the tooth axis. This should prevent a potential rotation of the amalgam restoration. The clinical gain of flattening the pulpal floor has not been documented. On the other hand, the finding that 2/3 of the models included a flat pulpal floor indicates that dentists continue to apply the principle in cavity preparations. The many flat floors thus demonstrate that operators frequently remove sound hard tissue besides the carious soft tissue.

Locks cut into the occlusal bucco- and linguo-pulpal line angles were earlier considered favorable for retention (58). At present, after photoelastic studies and finite element stress analyses, the placement of occlusal locks has been discouraged (59), and beveled axiopulpal and occlusal internal line angles are now advocated in most textbooks (50–53, 60). The many sharp occlusal internal line angles were therefore probably not intended. The prevalent acute internal line angles and isthmus made by operator 2 may be the result of the use of a bur with an unsuitable design. The prevalent sharp isthmus mesially in the molars results from neglecting to correct the angle in the frequent enlarged cavities in these teeth.

Proximal retentive grooves were earlier placed to prevent proximal marginal fractures and extrusion of the amalgam. Later studies showed that the presence of grooves did not reduce the degree of extrusion (61), and the design feature disappeared in many textbooks. On the other hand, the proximal locks also increase the axial retention (62) and the strength of the restoration at the isthmus (63, 64). Although the procedure has now reappeared in most textbooks, some investigators discourage the placing of retentive grooves and undercuts (65). The argument of the opponents is that locking frequently leads to unsupported enamel, which in fact was frequently observed gingivally in the cavities of operator 6.

There are no data in the dental literature on the significance of the degrees of wall convergence for the clinical performance of amalgam restorations. Occlusal convergence is assumed to be necessary to avoid the displacement of a restoration under tensile strain and to reduce material expansion (66). In spite of this, one-fifth of the cavities included diverging occlusal and proximal walls. Most of these were made by operators 3 and 4. The operators may have ignored this design feature because of good clinical experience in placing amalgam in cavities with parallel or diverging walls. It is possible that these operators were accustomed to using modern high-plasticity amalgams (67) and that the wave-like grooves in the cavity walls, produced by the diamond grains (68), may have been sufficient to retain restorations made from these materials (Figs. 3 and 9).

In accordance with established criteria the frequency of cavity discrepancies registered in this study seems high. Furthermore, many of the discrepancies occurred on surfaces with easy access and visibility. After the completion of the cavity preparation the operator evaluates the result before the cavity is filled. It is possible that dentists may be uncertain of how to perform a critical examination of a cavity, because this is often not emphasized in the student–instructor relationship in dental schools (69). There is also little attention to precise descriptions of adequate cavity morphology in the dental literature, other than cavosurface angles (70) and marginal finishing (71). The dental school curricula and the systems used in dental care programs should therefore include guidelines for assessment of cavity morphology. These should also describe typical cavity deficiencies and their prevailing locations.

The prerequisite for a durable restoration is a cavity that does not reduce the optimal physical properties of the restorative material (72). Although there are diverging opinions of optimal cavity morphology, the results of this study indicate that typical class II cavities for amalgam restorations are seldom optimal by any standard. The cavity features may therefore directly or indirectly have caused the reported flaws and failures and the limited durability of the amalgam restorations. The reduction in terms of number of years can only be assessed by controlled clinical trials (73, 74). However, a longitudinal analysis of the causes of replacement of amalgam restorations should also encompass an appraisal of the morphologic aspects of the cavities.

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