The dimensions of everyday class-II cavity preparations for amalgam

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Six hundred and ten epoxy plastic models, made from impressions of permanent teeth in which class-II cavity preparations for amalgam restorations had been prepared by eight Scandinavian dentists, were examined. The outlines of the cavity preparations were relatively large, with mean buccolingual extensions occlusally of 50% of the intercuspal distance and proximally of 40% of the length of the circumference of the proximal surface. There was a gradual increase in the size of the cavities towards the distal part of the dental arch, measured both in millimeters and in relation to the anatomic structures. The amount of hard tissue being removed varied among the operators and was possibly influenced by the dentist's ability to handle the cutting instruments. The large cavity preparations may be the result of using procedures for cavity preparation which are not adjusted to the tremendous cutting potential of modern dental instruments to produce stereotyped 'ideally designed' cavities. □ *Cavity measurements; operative dentistry; techniques*

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The operational steps of cavity preparation for amalgam restorations are to a large extent based on the guidelines suggested by Black (1) at the turn of the century. These guidelines introduced the concept of 'extension for prevention'. This concept stemmed the current clinical practice of removing minimal quantities of hard tissue (2, 3). Although Black later recommended smaller cavity preparations for patients with improved oral hygiene (4), the concept for many years formed the basis for operative techniques.

In the dental literature there are numerous modifications of Black's cavity designs (5–7). Most of the modifications were never substantiated by clinical research data but rather by other developments in dentistry: the invention of restorative materials with superior physical qualities and handling properties (8); the advancement of preventive methods and oral prophylaxis (9–11); the increased use of fluorides and better oral health in the population (12–15); the increased knowledge of the biologic effects of materials on oral tissues (16–19); the application of biomechanic principles (20, 21); the improved access to dental services (22); and the technologic changes of the equipment in the dental office (23–28).

The general guideline in the teaching of operative dentistry today is to maintain a maximum amount of tissue (29–31). It is not known to what extent the dentists in general practice have adopted the principles of conservative operative dentistry.

The aim of the present examination was primarily to assess the morphology of routine cavities prepared for amalgam restorations.

The physical properties and the chemical stability of amalgam give indications of a possible extensive function period as a restorative material in an oral environment. Clinical experience does, however, show that amalgam restorations after a relatively short time exhibit properties not predicted by the results from the standardized measurements in the laboratory. It is not clear to what extent the morphology of the cavity preparation influences the long-term prognosis of the restoration. A second aim of this study was therefore to identify dis-

Table 1. The frequency and location of 610 examined cavity preparations

Upper 383 (62.8%)									
	Molars		Premolars		Premolars		Molars		
	Dis	Mes	Dis	Mes	Mes	Dis	Mes	Dis	
	12	48	77	44	55	80	53	14	
Right	(9.8%)		(19.8%)		(22.1%)		(11.2%)		Left
308									302
(50.5%)	28	55	33	11	15	33	31	21	(49.5%)
	(13.6%)		(7.2%)		(7.8%)		(8.5%)		
Lower 227 (37.2%)									

crepancies believed to influence the prognosis of the restorations. The restorations are part of a longitudinal study of the clinical performance of amalgam.

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 clinical experience of the operators varied from 15 to 30 years. A total of 610 cavity preparations were examined (Table 1). The number of models returned by each operator varied from 19 to 108. The most usual locations of the cavity preparations among the operators are outlined in Table 2.

Each cavity was measured with a periodontal probe with millimeter marks (CGB, Hilming) and a flexible strip of squared millimeter paper. The measurements were made at various predetermined locations on the tooth. The occlusal buccolingual width was calculated as a fraction of the intercuspal width. The widths were measured at the axiopulpal line angle (isthmus) and at the dovetail (Fig. 1). The proximal buccolingual width was calculated as a fraction of the extent of the proximal surface. This was defined as the length of the circumference between the two utmost buccally or lingually located parts of the cusp. The buccolingual widths were measured at the axiopulpal line

Table 2. Operators and the location of the cavity preparations by surface. 15% of the preparations were MODs, which count as two cavity preparations

	Upper				Lower				
	Premolars		Molars		Premolars		Molars		
Operator	Mesial	Distal	Mesial	Distal	Mesial	Distal	Mesial	Distal	Total
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
	99	157	101	26	26	66	86	49	610

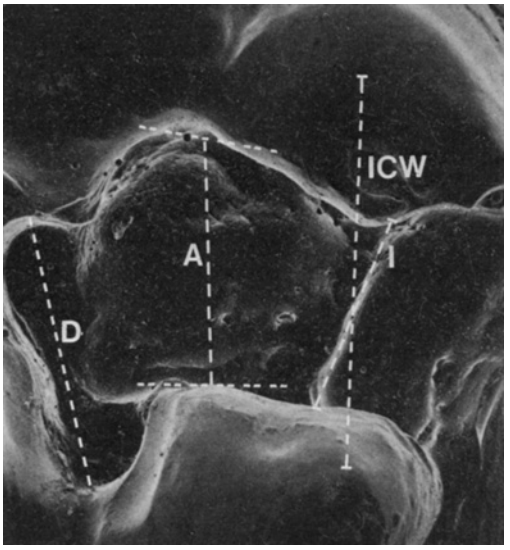

Fig. 1. Measurement of the mean occlusal buccolingual extensions of the cavity preparations. ICW = intercuspal width; I = width at the isthmus; A = width in average; D = width at the dovetail.

angles (isthmus) and at the gingival margins (Fig. 2). The proximal gingival extension was measured as the distance between the margin and the approximate location of the marginal ridge. The depth of the cavity was measured as the distance between the cavosurface margin and the pulpal floor or the axial wall.

The age of the patients varied from 8 years to 71 years, with a mean of 28 years. For operators 3, 4 and 6 the mean age of the patients varied from 36 to 40 years; for operator 1 it was 31 years; and for operators 2, 5, 7, and 8 it was 12–16 years. The operators were instructed to make an impression (Optosil/Xantopren, Bayer) of the tooth before condensing amalgam into the cavity. No instructions on preparation techniques were issued in advance; that is, no information on the presumed correct size or morphology of the cavity was presented to the operators. Although the clinicians knew that the cavity preparations were to be examined, they did not know what was to be measured and how. The cavities are therefore considered to reflect the clinical situation in everyday dental practice.

The Student–Newman–Keul procedure for one-way analysis of variance (ANOVA) was used at a significance level of 0.05. The procedure determined the extent of the deviation of cavity dimensions in the different tooth categories and between the operators.

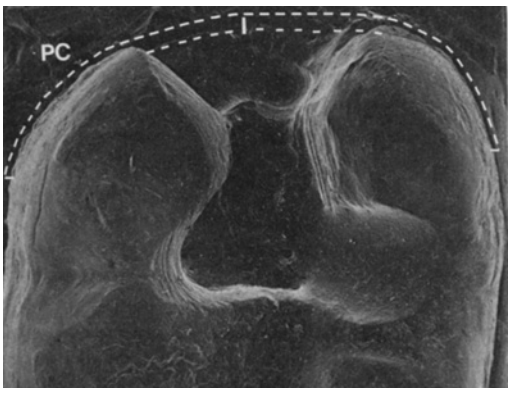

Fig. 2. Measurement of the mean proximal buccolingual extensions of the cavity preparations. PC = length of the proximal circumference; I = width at the isthmus.

Results

Occlusal surface

The mean buccolingual width was 0.5 (SD, 0.2) of the intercuspal width, varying from 0.1 to 1.0. The width was <0.2 in 4% of the models, primarily upper premolars, and >0.8 in 13% of the models, mainly lower molars (Fig. 3). Fig. 4 illustrates the occlusal extensions in the different tooth categories. The buccolingual widths were, in general, enlarged in the lower molars (0.7) and the distal widths in the upper molars (0.6), compared with in the upper premolars (0.4) ($p < 0.05$).

The intrasurface buccolingual extension narrowed slightly towards the axiopulpal line angle in the molars. The narrowing was most obvious mesially in the lower molars (Fig. 4). The extension broadened in the premolars, especially mesially in the upper premolars.

Proximal surface

The mean gingival extension was 3.6 mm (SD, 0.8 mm) from the marginal ridge, varying from 1 to 7 mm. The gingival extension

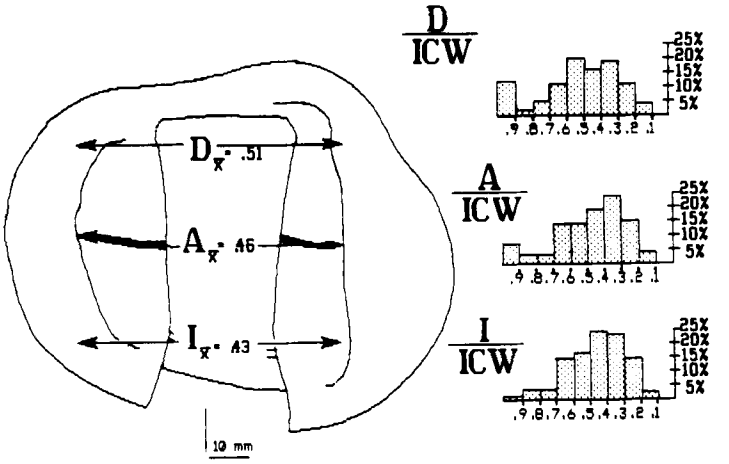

Fig. 3. The mean and prevalent occlusal buccolingual extensions of the examined cavity preparations. D/ICW = extensions at the dovetail; A/ICW = extensions on average; I/ICW = extensions at the isthmus; D_x = mean extension at the dovetail; A_x = mean extension on average; I_x = mean extension at the isthmus. All values are represented as fractions of the intercuspal width (n = 600) (the difference in the number of observations from n = 610 is due to model artifacts).

was <2 mm in 9% of the models, primarily the lower premolars, and >6 mm in 2% of the models (Fig. 5).

The gingival floor was either curved or stretched nonperpendicular to the tooth axis in 42% of the models. The gingival extension varied up to 2 mm for some preparations. The variable intrasurface gingival extensions prevailed on the distal surface of the upper premolars.

The mean buccolingual width was 0.4 (SD, 0.1) of the length of the proximal circumference, varying from 0.1 to 1.0. The width was <0.2 at the gingival margin in 5% of the models, primarily upper premolars, and >0.6 at the isthmus in 14% of the models, mainly lower molars (Fig. 5).

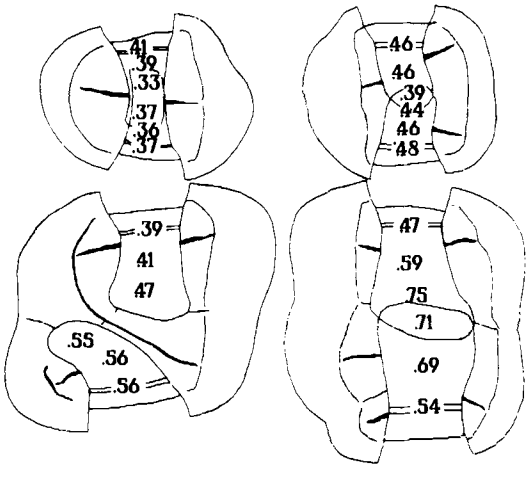

Fig. 4. The mean occlusal extension of the cavity preparations in the different tooth categories. The buccolingual extensions are represented as fractions of the intercuspal width.

The intrasurface buccolingual extension narrowed towards the axiopulpal line angle; that is, the walls converged. The angle between the facial and lingual walls and the gingival floor varied on the different surfaces. The walls were more parallel on the mesial surface of the upper molars than on the proximal surfaces of the upper premolars ($p < 0.05$).

Figs. 6 and 7 illustrate the proximal extensions in the different tooth categories. The buccolingual width and the gingival extension were increased on the distal surfaces of the upper (0.5 and 4.4 mm) and lower (0.5 and 4 mm) molars compared with on the other surfaces ($p < 0.05$).

Depth

The mean occlusal depth was 2.2 mm (SD, 0.6 mm) from the cavosurface margin to the pulpal floor, varying from 0.5 to 5 mm. The depth was <1 mm in 5% of the models, primarily lower premolars, and >5 mm in one model (Fig. 8).

The mean occlusal depth at the location of the axiopulpal line angle—that is, the isthmus—was 2.2 mm (SD, 0.6 mm). The intrasurface difference between the depth at

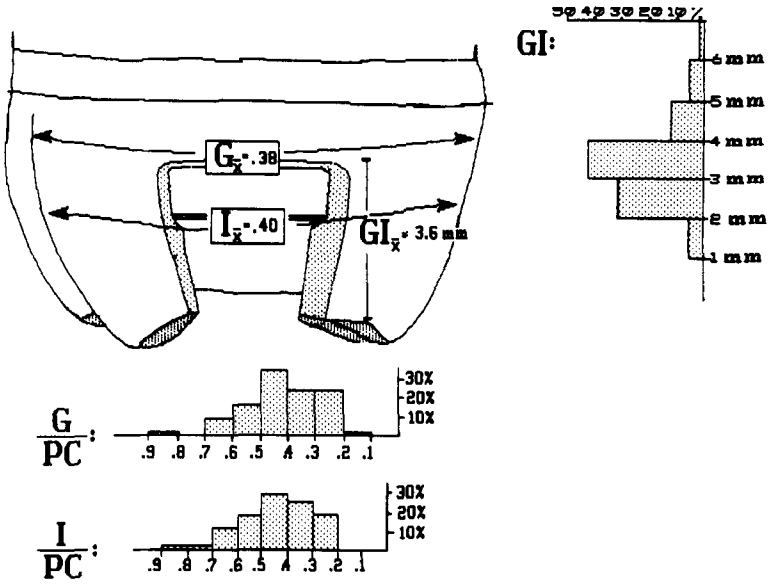

Fig. 5. The mean and prevalent proximal extensions of the examined cavity preparations. G/PC = buccolingual extensions at the gingival margin; I/PC = buccolingual extensions at the isthmus; G_x = mean extension at the gingiva; I_x = mean extension at the isthmus. All values are represented as fractions of the proximal circumference. GI = gingival extensions, and GI_x = mean gingival extension, measured from the marginal ridge to the gingival margin (n = 605) (the difference in the number of observations from n = 610 is due to model artifacts).

the isthmus and the rest of the pulpal floor varied from −3 to 1.5 mm. A shallow depth at the isthmus relative to the pulpal floor was more pronounced mesially in the upper molars than in the other surfaces ($p < 0.05$).

Fig. 9 illustrates the occlusal depths in the different tooth categories. An increased depth was observed in the upper molars (2.3 mm mesially, 2.5 mm distally) and distally in the lower molars (2.4 mm) compared with in the lower premolars (1.8 mm) ($p < 0.05$).

The mean proximal depth was 1.7 mm (SD, 0.5 mm) from the cavosurface margin to the axial wall, varying from 0.5 to 3.5 mm. The depth was <1 mm in 17% of the models, mostly premolars, and >2 mm in the premolars and >2.5 mm in the molars in 4% of the models (Fig. 8).

Fig. 9 illustrates the proximal depth in the different tooth categories. The depth was greater in the lower (1.8 mm) and upper (1.9 mm) molars than mesially in the lower (1.4 mm) and upper (1.6 mm) premolars ($p < 0.05$).

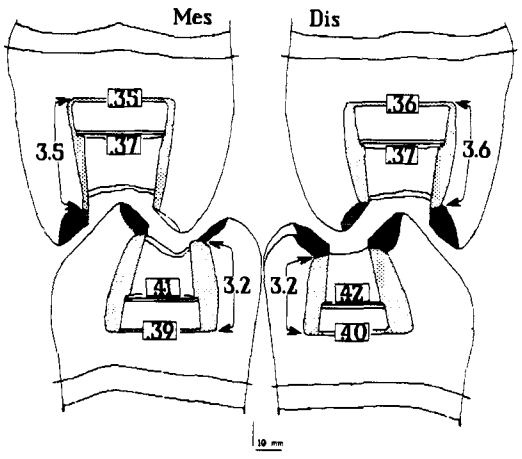

Fig. 6. The mean proximal extension of the cavities prepared in the premolars. The buccolingual extensions are represented as fractions of the proximal circumference. The gingival extension is measured from the marginal ridge to the gingival margin.

Operator variance

Significant differences from the average for certain variables was observed between the operators: operators 4 and 5 prepared large and deep cavities, and operators 6 and 8 prepared small cavities ($p < 0.05$). Broadening of the occlusal buccolingual extension towards the axiopulpal line angle was observed for operators 5 and 8 ($p < 0.05$).

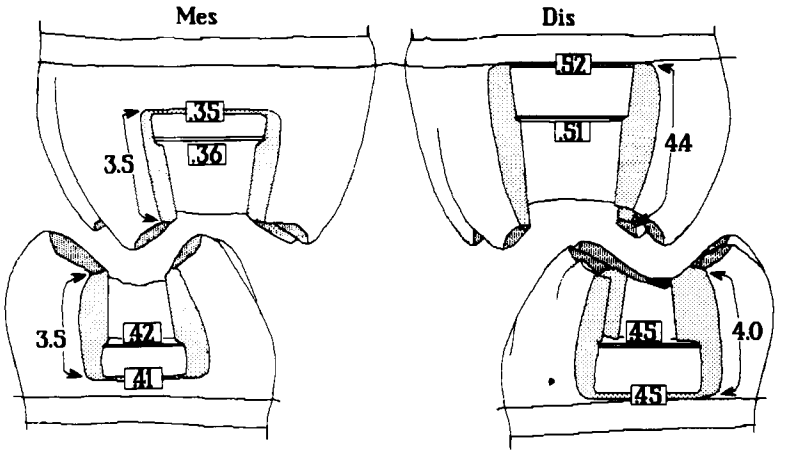

Fig. 7. The mean proximal extension of the cavities prepared in the molars. The buccolingual extensions are represented as fractions of the proximal circumference. The gingival extension is measured from the marginal ridge to the gingival margin.

Converging proximal walls were seen for operator 6 ($p < 0.05$). Operator 2 provided most of the cavity preparations with a shallow occlusal depth at the isthmus relative to the pulpal floor. Fig. 10 illustrates the outline of the mean cavity preparation of a few operators.

Discussion

Vale (32) suggested, after strength measurements on premolars, that the occlusal buccolingual width should not exceed one-fourth of the intercuspal extent. Later investigations have shown that in vitro cusp fractures are caused by a complex interaction among the load application, the occlusion, the tooth type, and the extent of the cavity preparation (33–35). The relationship between cusp fractures in vivo and occlusal and proximal widths and depths is unclear (36). It is therefore questionable to assume that the clinical prognoses of the restorations placed in these cavities are reduced because of the relatively large extensions. On the

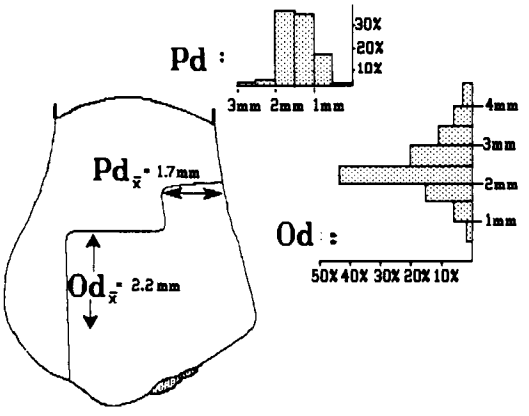

Fig. 8. The mean and prevalent depths of the examined cavity preparations. OD = occlusal depths; PD = proximal depths; OD_x = mean occlusal depth; PD_x = mean proximal depth. All depths measured from the cavosurface margin to the pulpal or axial wall ($n = 604$) (the difference in the number of observations from $n = 610$ is due to model artifacts).

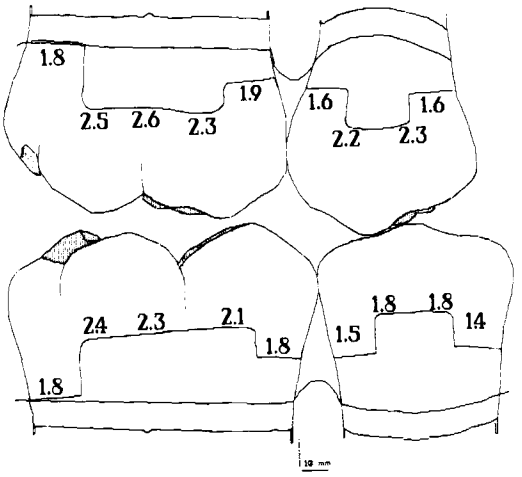

Fig. 9. The mean of the cavity preparations in the different tooth categories. The depth is measured from the cavosurface margin to the pulpal or axial wall.

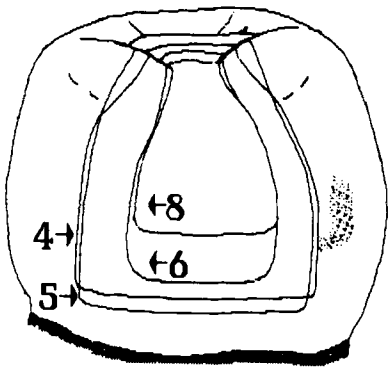

Fig. 10. The external outlines of the cavity preparations of operators 4, 5, 6, and 8.

other hand, the risk of macro- and microfractures of the restoration increases if the occlusal width is enlarged (37–39). Wide cavities render the remaining tooth structure more susceptible to strain during the cavity preparation (40), the placement of the matrix band (41–43), or the condensation of amalgam (44, 45). Stress generated in the tooth at this stage may later cause fractures of the remaining tooth (46–51).

The occlusal and proximal bulk fractures of amalgam restorations that develop after some years occur most often in the lower molars (52). This may be caused by a different cusp morphology, higher functional forces in the molars, or the lateral movements of the jaw. In the present study the mean buccolingual extension was larger in the lower molars than in the other teeth. The occlusal walls also converged more distinctly towards the isthmus. A decrease of the buccolingual extension towards the isthmus reduces the strength of the restoration at this point. It is therefore possible that the high prevalence of bulk amalgam fractures in the lower molars can be explained by the generally higher frequency of large restorations with the affiliated narrow isthmus parts.

The extent of the caries determines primarily the dimension of the prepared cavity. If the patients, as in the present study, are checked regularly, the caries is usually minimal. The proximal extensions are in these cases governed mainly by the anatomy of the proximal surface of the adjacent tooth—that is, the margins are located free from contact with the surface. The characteristic morphology of the proximal surfaces in the different tooth categories may explain the observed variation in cavity outlines. The increased buccolingual extension in the posterior teeth may be explained by the broadened contact areas (53). This is in agreement with the prevalent cavity preparations, with parallel proximal walls on the relatively flat mesial surface of the upper molars. The mean gingival extension increased in the molars. This is in harmony with a decreased axiogingival convexity but in conflict with the shorter clinical crowns throughout the arch (53).

The axiogingival convexity is more pronounced and also located more gingivally on the distal surface. On the other hand, the distal surface is usually lower (53). The identical mesial and distal extensions in the premolars are therefore expected. However, the difference between the mesial and distal extensions in the molars cannot be explained by the surface anatomy. Assuming that the extent of the carious lesions governed the extensions insignificantly, factors other than the surface anatomies influenced the amount of tissue removal.

It is not possible on models to assess the position of the margins in relation to the adjacent tooth or in relation to the anatomical root. The probability of contact between the proximal margins and the neighboring tooth can therefore only be assumed. Tentative minimum mean values are <2 mm from the marginal ridge or a buccolingual width <0.20% of the length of the proximal circumference. Ten percent of the cavity preparations in the present material include margins that are, according to these values, in contact with the adjacent tooth.

The distance between the marginal ridge and the cementoenamel junction is approximately 6 mm for premolars and molars (54). The distance from the alveolar crest to the gingival sulcus is 0.7 mm and to the dentinoenamel junction 2 mm (55). On the basis of these values, 2% of the gingival margins are placed on the anatomical root, 4% within the junctional epithelium, 19% in the sulcus, and 84% supragingivally. This differs from

surveys indicating that gingival margins mostly are located subgingivally (56–59). The variation may be explained by a different mean age of the patients or a different proportion of restorations due to primary caries versus secondary caries.

Proximal secondary caries and marginal crevices develop primarily in the line point angles (60–63). The detection of these defects depends to a large extent on the use of bitewing radiographs. It is recognized that gingival defects will appear on the film at an early stage if the gingival margin is parallel to the X-ray beam. It was therefore unexpected to discover that 40% of the cavity preparations included a gingival margin with a variable extension. The restorations placed in these cavity preparations will project potential defects only at the most gingival section of the margin onto the film, owing to the radiopaque shadowing of the amalgam. The influence of a variable gingival floor on the radiographic diagnosis of secondary caries should be assessed. This would especially be pertinent for the new filling materials, since these entail new radiographic opacities and cavity preparation designs.

Depth

The enamel thickness and the cemento-enamel junction cannot be detected on plastic models. The relationship between the pulpal and axial walls and the pulp can therefore only be assumed. The mean thickness of enamel occlusally is 2–2.5 mm. The distance between the occlusal fissures and the pulp is 5 mm for premolars and molars (64).

The minimum thickness of amalgam to withstand the chewing forces has previously been set at 1 mm (65). Most textbooks recommend a depth to the dentinoenamel border, although it has also been proposed that restorations may be placed entirely in the enamel (66). The clinical minimum occlusal depth is also influenced by the occlusal and proximal buccolingual widths, the form of the antagonist, and the patient's bite force. It is therefore difficult to anticipate the prognosis of the 5% of the restorations placed in cavities prepared with an occlusal depth <1 mm.

One-third of the models displayed a variable occlusal depth. This should be avoided, according to data from in vitro studies. The clinical significance of this cavity feature remains unknown, however, except when there in addition is no dovetail, converging occlusal walls, or a sloping pulpal floor towards the isthmus.

The thickness of the enamel proximally, and the in-depth anatomy of the occlusal fissures, is identical in premolars and molars (54, 64). Moreover, the etiology and the progress, and the detection of caries, are presumably identical in the tooth categories. This contrasts with the observed increase of the cavity depth in the more distal teeth.

Operator

In the present material the morphology of the cavity preparations varied among the operators. Although some can be attributed to the different age compositions of the patient groups, certain cavity features could be recognized as characteristic for the individual operator. Variations were noted for grooves axiogingivally and/or proximally, parallel or converging proximal walls, rounded or acute internal line angles, and cavity extensions. It is possible that the numerous publications of more or less clinically successful modifications of design have made the profession reluctant to adopt new techniques in operative dentistry. It could also be observed that to various extents the operators prepared larger and more unconventionally designed cavities posteriorly. The amount of hard tissue removed is thus influenced by the dentist's ability to handle the cutting instruments. This factor can parallel the observations of variable detection capabilities and caries treatment decisions among operators (67–70).

The reason for the cavity preparations—that is, primary caries or the failure of a previous restoration—was not registered. Nor was the extent of the caries or the dimensions of any previous restorations registered. It is therefore imprecise to describe the cavity preparations as overextended. The general impression was, however, that a considerable amount of hard tissue was being

removed in the posterior teeth. This contrasts with the general guideline in modern operative dentistry, which is to preserve as much tissue as possible (71, 72). Perhaps the tremendous cutting potential of modern dental instruments (73–75) has made the 'inherited' procedures for preparing cavities inappropriate.

Many of today's procedures for cavity preparation were developed at a time when dental instruments rotated relatively slowly. A reasonable cutting efficiency could therefore only be obtained by a large diameter of the bur (76). Using these large burs often resulted in an excessive removal of sound tissue (77). The observation that the extension could be reduced by initially completing the outline of the cavity before removing the caries was an important consideration in Black's textbook (78). Today, a high peripheral speed of the bur can be obtained, and the size of the burs has decreased radically. Yet dental students and dentists continue to prepare the outline form initially instead of focusing on the removal of caries (6, 72, 79).

During the preclinic courses at many dental schools the students are taught to prepare cavities with 'ideal designs' (80). The training of students to prepare ideal cavities may be valuable for educational purposes. It is possible, however, that instructors have focused too much on teaching stereotyped ideal designs, instead of teaching principles to meet certain physical requirements of the material. The training in operative dentistry may thus have created the belief that the cavity prepared with an ideal design is without exception the optimal cavity preparation.

Using Black's sequence of operative procedures with high-speed burs together with the concept of 'ideal design' will result in large cavities even after moderate caries attacks. A preferable approach would be initially to remove the carious tissue, followed by a 'locking' of the cavity and finishing of the margins (81). This method will result in tissue-conservative cavity preparations (82). The approach is furthermore logical and thus easier to apply on smaller or modified cavity preparations and for various restorative materials. Focusing on the caries and then adjusting as little as possible after it has been removed should be the goal for the future education in cavity preparation techniques.

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