Cavity designs for class II amalgam restorations

A literature review and a suggested system for evaluation

Asbjörn Jokstad and Ivar A. Mjör
Department of Anatomy, School of Dentistry, University of Oslo, and NIOM, Scandinavian Institute of Dental Materials, Oslo, Norway

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A classification system for variations in cavity design and finish has been developed for application on models of teeth with class II cavities for amalgam restorations. The system was based on a review of the literature, on principles for clinical studies, and on examination of models of 623 teeth in which routine class II cavity preparations had been made. Preliminary data on the agreement of rating of evaluators indicated that the classification system can be used with good consistency for assessment of variations in cavity preparations. Longitudinal clinical studies on the performance of restorations will be decisive for the validity of the selected criteria and for a relevant differentiation between acceptable and unacceptable preparation features. □ *Conservative dentistry; failure of restorations; longevity of restorations; operative dentistry*

Asbjörn Jokstad, Department of Anatomy, Dental Faculty, P.O. Box 1052 Blindern, University of Oslo, N-0316 Oslo 3, Norway

Many investigators have reported the need for frequent and possible premature replacement of amalgam restorations (1–5). In spite of continuous preventive programs and development of better materials, the replacement rate has remained unchanged (6–9). The physical properties of the dental amalgams are generally appraised as adequate for a dental restorative material (10).

Much research on dental amalgams has been focused on marginal degradation of amalgam restorations. However, occlusal marginal degradation has limited value as a criterion for the general clinical quality of amalgam restorations in terms of effects on rate of replacement (11, 12). The degree of occlusal marginal breakdown does not correlate with the frequency of secondary caries proximally (13). In spite of these observations, recent data indicate an increasing use of this criterion as decisive for replacement of restorations (14).

Various reasons for replacement of restorations has been suggested (15–21). The main reason for replacement is secondary caries, which most frequently occurs proximally/gingivally (22, 23). On the basis of studies of secondary caries and the tooth/restoration interface, Mjör & Smith (24) have emphasized the importance of details of the cavity design when assessing causes of failure of amalgam restorations. No attempts have been made to measure variations in cavity preparations and effects on amalgam restorations in longitudinal clinical studies. Identifying the critical factors of a cavity design would be of significance for the perception of clinically optimal preparations.

Evaluation of the effect of variation in cavity preparation on the longevity of restorations must be based on a definition or classification of the variations in cavity design and finish. Textbooks describe only the ideal preparation. Little or no attention has been focused on descriptions of deviations from the ideal, except for obvious factors like undermined enamel and incomplete removal of caries.

Systems for evaluation of class II cavity preparations described in the literature have had different applications:

1. In dental education as a basis for an assessment of students' competence and as a basis for feedback information to the students (25–27).

2. As information to the faculty staff about the success of teaching and quality of health care provided to patients in the dental school clinics (28, 29).

3. As part of quality assessment systems for use by peer review committees or for future dental care programs (30–36).

The structure and performance criteria of each evaluation system is optimally designed to conform with the intended applications. This specificity reduces the adaptability of each system for other applications. The different systems are intended solely for cavity evaluation or form part of comprehensive schemes for assessment of the total dental care. An operationally based method for assessing clinical performance, the USPH (Ryge) system (37), forms the basis of a scheme for evaluation of cavity preparations developed by Charbeneau (38).

Charbeneau's system for assessment of cavity preparations consists of four dimensions and a five-point scale (39). However, the descriptive performance criteria frequently include characteristics such as 'moderate' and 'slight', which are ambiguous terms, and leads to biased rating (40). The subjectivity in clinical evaluation has been considered the main factor contributing to the low reliability associated with evaluation of clinical performance (41). The complicating factor of low inter- and intra-reliability of evaluators has also been commented on in many clinical studies (42–44). Attempts to avoid this subjectivity by constructing objective evaluation methods have been reported (45, 46), but their use has been limited.

The present report will focus on the development of an evaluation system optimally designed for longitudinal clinical studies. It is intended to be applied on models of teeth in which class II cavities for amalgam restorations have been prepared.

Method

A thorough literature study of previous attempts of developing evaluation systems for cavity preparations was initiated. Textbooks in operative dentistry were also reviewed. In addition, epoxy plastic models of 623 teeth in which routine class II cavity preparations had been prepared were examined for characteristic variations and measures, including an evaluation at ×10 and ×20 in a stereomicroscope (Spencer American Optical). The measurements were performed with a standardized periodontal probe with 2-mm markings engraved (CGB, Hilming). The descriptive criteria, characteristics, and dimensions obtained were incorporated into cavity designs on plaster tooth models and photographed. For each dimension a set of instructions was prepared to describe the correct recording procedure. These are described in Tables 1–5, including references to photographs of cavities in plaster tooth models. The photographs and the accompanying descriptive criteria are intended as instructions for evaluators.

Definition of criteria

External outline (Table 1)

Procedure occlusally:

1. Measure in millimeters the width of the intercuspal distance and the width of the preparation at the isthmus—the maximum and the minimum width of the preparation. Assess relative widths of preparation to the intercuspal distance. The minimum or maximum extension of the preparation indicates the correct category. A minimum width of 1 mm must prevail to classify code R, S, and M.

2. Measure in millimeters the mesiodistal extension relative to the marginal ridge.

3. Assess the relative placement of the buccal and lingual margins on the cusp surfaces.

4. Measure in millimeters the width of enamel remaining adjacent to fissures, grooves, or previous restorations.

5. Assess the continuation of fissures from the cavosurface margin.

Procedure proximally:

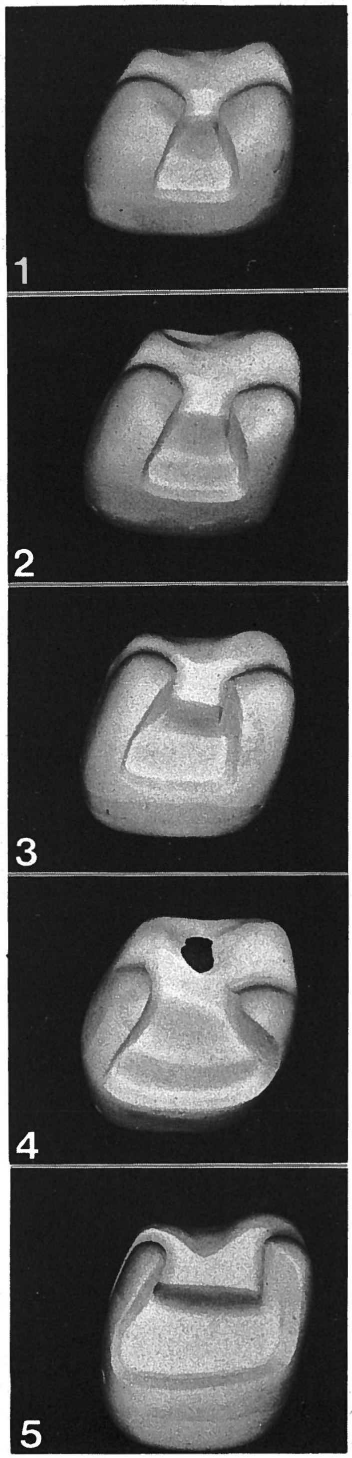
1. Apply a plane through the relevant buccal and lingual cusp tips. The part of the

Table 1. External outline

Rating	Quality evaluation (39)	Performance criteria	
		Occlusal part	Proximal part
R	External outline extended for convenience and Removal of contiguous fissures	Buccolingual extension: width between cusps > 1 mm and < 2:5 (Figs. 1, 14) and Preparation includes fissures only	Buccolingual extension: buccolingual contour > 1:3 and < 2:5 (Fig. 1) and Gingival margin 4 mm from the marginal ridge
S	Slightly under-extended or Slightly over-extended	Buccolingual extension: width between cusps >1 mm and < 1:2 (Figs. 2, 15) or Buccolingual extension beyond the fissures for small areas < 2/3 of cusp surface	Buccolingual extension: buccolingual contour > 1:4 and < 1:2 (Fig. 2) or Gingival margin > 3 mm and < 5 mm from the marginal ridge
M	Moderately under-extended or Moderately over-extended	Buccolingual extension: width between cusps >1 mm and < 3:5 (Figs. 3, 16) or Buccolingual extension beyond the fissures in larger areas < 2/3 of cusp surface	Buccolingual extension: buccolingual contour > 1:5 and < 3:5 (Figs. 3, 16) or Gingival margin > 2 mm and < 6 mm (7 mm for molars) from the marginal ridge
T	Contiguous fissures not removed or Decidely under-extended or over-extended	Buccolingual extension: width between cusps < 1 mm or > 3:5 (Figs, 4, 6) or Buccolingual extension > 2/3 of cusp surface or Fissures remain, or < 1 mm enamel remain next to filling/defect or Mesiodistal extension < 2 mm from marginal ridge (Fig. 7)	Buccolingual extension: buccolingual contour > 1:6 and < 2:3 (Figs. 4, 6) or Gingival margin < 2 mm from or > 6 mm (7 mm for molars) from the marginal ridge
V	Grossly under-extended or over-extended	Buccolingual extension: width between cusps > 2:3 (Fig. 5) or No mesiodistal extension beyond marginal ridge (Fig. 8)	Buccolingual extension: buccolingual contour > 1:6 or < 2:3 (Fig. 5)

tooth circumference bisected by this plane is referred to as the interproximal circumference. Assess the buccolingual extension relative to the interproximal circumference. Measure the width at the marginal ridge and at the gingival margin. The minimum or maximum extension of the preparation indicates the correct category.

2. Measure in millimeters the maximum and minimum gingivoocclusal extension of the cavosurface margin relative to the marginal ridge.



Figs. 1–5. Variations in external outline of class II preparations. Fig. 1 is considered ideal and is rated *R*. Fig. 2 is rated *S*; Fig. 3, *M*; Fig. 4, *T*; and Fig. 5, *V*. A detailed description of each rating is given in Table 1.

Depth of preparation (Table 2)

Procedure:

Trace a periodontal probe parallel to all walls, perpendicular to the tooth surface. Measure the distance in millimeters from the tooth surface to the bottom of the cavity (the pulpal and axial walls). The minimum or maximum depth of the preparation indicates the correct category.

External cavity definition (Table 3)

Procedure: Cavosurface angle:

Trace a periodontal probe parallel to all walls. Visually assess the angle between the probe and the tooth surface. Check the angle for continuity.

Procedure: Definition of cavity walls and margins:

Evaluate visually the degree of continuity of walls and margins. All points within a 1 mm^2 wall or a 1-mm margin must be part of the same spatial plane or line to be defined as continuous.

Margin roughness (Table 4)

Procedure:

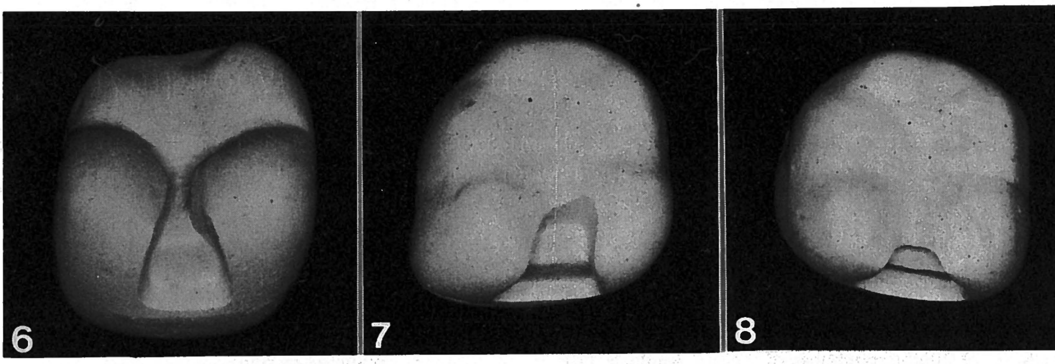
Assess roughness at ×20. Rate all proximal margins in accordance with photographs and criteria. The occlusal margins are not rated.

Internal cavity definition (Table 5)

Procedure:

1. Assess the shape and continuity of the occlusal and proximal internal line angles and the pulpal/axial line angle (isthmus).

2. Align the periodontal probe occluso-gingivally. Compare the diameter tip of the probe with the size of the groove in the buccoaxial, linguoaxial, and gingivoaxial line angle.



Figs. 6–8. Variations in external outline of class II preparations. Fig. 6 has a narrow isthmus and minimal occlusal and proximal extension. Fig. 7 has remaining fissures, and the mesiodistal extension occlusally is minimal. Fig. 8 has no mesiodistal extension occlusally beyond the marginal ridge.

Retention (Table 6)

Procedure:

Inspect tooth directly occlusally. Assess the degree and extent of discernible buccal, lingual, and axial walls.

Discussion

Rationale for a cavity evaluation system

All operative procedures in the mouth aim to maintain the integrity of the teeth to ensure extended longevity. This concept can

Table 2. Depth of preparation

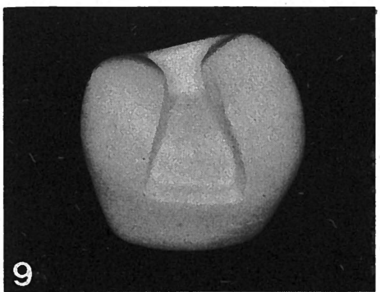
Rating	Quality evaluation (39)	Performance criteria: Occlusal part	Performance criteria: Proximal part
R	Depth of preparation extended into dentin	Cavity depth 2 mm	Cavity depth 1–1.5 mm
S	Pulpal or axial walls slightly shallow or Pulpal or axial walls slightly deep	Cavity depth > 1 mm and < 4 mm	Cavity depth > 1 mm and < 2 mm
M	Pulpal or axial walls moderately shallow or Pulpal or axial walls moderately deep	Cavity depth > 1 mm < 6 mm	Cavity depth > 1 mm and < 2.5 mm (molars, 3 mm)
T	Pulpal or axial walls with much enamel or Pulpal or axial walls require base unnecessarily	Cavity depth < 1 mm or > 6 mm	Cavity depth < 1 mm > 2.5 mm (molars, 3 mm)
V	Pulpal floor or axial wall in enamel or Mechanical pulp exposure	Mere scratching of enamel or Pulp exposure	Mere scratching of enamel or Pulp exposure

Table 3. External cavity definition

Rating	Quality evaluation (39)	Performance criteria	
		Cavosurface angle	Definition
R	Enamel walls parallel to rod direction and Walls and margins smooth and Cavity well-defined	Angle 110° occlusally and 90° interproximally and Angle uniform (Fig. 9)	Walls/margins are distinct and straight or smoothly curved
S	Slight roughness of cavity walls or Slight lack of cavity definition	Angle > 110° occlusally or >90° interproximally in a few areas (Fig. 10)	Walls or margins ragged in a few isolated areas
M	Moderate roughness of cavity walls or Moderate lack of cavity definition or Enamel walls deviate slight from rod direction	Angle >110° occlusally or >90° interproximally over larger areas or Questionable presence of angle <90° in some areas (Fig. 11)	Walls or margins ragged over larger areas and No external sharp corners of margin
T	Enamel unsupported or Cavity walls or margins rough or Cavity ill-defined	Angle <90° in some areas or Angle varies continuously (Fig. 12)	Walls or margins ragged and consist of many facets/planes or External sharp corner of margin
V	Enamel grossly undermined or Cavity devoid of form	Part of or entire tooth weakened owing to angle <90° (Fig. 13)	Walls or margins irregular or variable and difficult to differentiate

also be adapted to operative cavity preparations, by defining the ideal cavity as the design that will ensure the best prognosis of extended longevity of the restored tooth. The prognosis of restored teeth has been shown to depend, among other clinical procedures, on certain cavity features. The concept can be applied to cavities caused by primary (new preparations) or secondary caries (replacement preparations), regardless of the cavity size, extension, surface, or the type of tooth involved. The objective of a cavity preparation is to stop the carious process and to remove soft, carious tissue. Any other removal of hard tissue is performed to ensure that the remaining tooth and the new restoration will withstand the physical forces and the the long-term influence of the oral environment. The extent of the carious lesion and, in the case of secondary caries, the previous restoration, is

Figs. 9–13. Variations in the cavosurface angle and internal and external cavity definition. Fig. 9 is considered ideal and is rated *R*. Fig. 10 is rated *S*; Fig. 11, *M*; Fig. 12, *T*; and Fig. 13, *V*. A detailed description of each rating is given in Tables 3 and 5.



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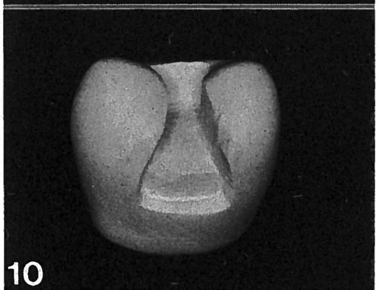

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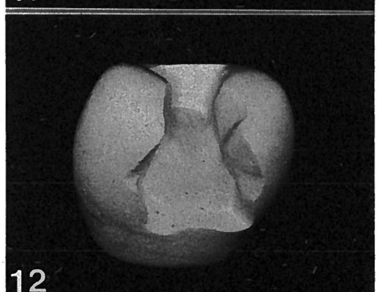

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the main factor governing the fundamental design of the preparation. Besides the extent of the carious lesion, factors such as oral hygiene, bruxism, and the dental history of the patient are considered by the clinician when preparing a cavity (47).

A clinically optimal preparation is seldom in concordance with ideal textbook designs. An evaluation system based on degrees of 'mismatch' to the textbook ideal may, therefore, be applicable for educational purposes but is not relevant for rating cavities in most clinical situations. An evaluation system based on measuring variables that may influence the expected prognosis of the restored teeth should, however, be clinically relevant. The identification and measurement of these variables can form the basis for an assessment of the relevance of cavity preparation for restoration longevity.

General description of the system

Scale points (categories). A nonlinear ordinal rating scale was sought when designing the evaluation system for cavity preparations. It is based on design factors which, considered isolated, are expected to affect the prognosis and longevity of the restored teeth (37).

Five categories of cavity features have been distinguished:

1. A defined ideal preparation. The design will provide the best prognosis of extended longevity of the restored tooth (Code *R*omeo).
2. Preparation feature that deviates from the ideal to a small extent in a few areas. (Code *S*ierra)
3. Preparation feature that deviates from the ideal to a small extent in large areas and/or to a marked degree in a few areas. (Code *M*ike)
4. Preparation feature that deviates from the ideal to such an extent that damage to the restoration or tissue is likely to occur in the near future. (Code *T*ango)
5. Preparation feature that causes damage to the soft or hard tissue. (Code *V*ictor)

For convenient auditory differentiation by the recorder, the five categories are indexed by the letters *R*, *S*, *M*, *T*, and *V* in the

Table 4. Margin roughness: CMI index

Rate 0:	All margins smooth and perfect
Rate 1:	Slight roughness. Acceptable margin. Few, isolated, small chips at the enamel edge
Rate 2:	Moderate roughness. Imperfect margin. Continuous row of small chips and/or a few larger chips at the enamel edge
Rate 3:	Wall or margin rough. Unacceptable margin. Many large chips and/or a continuous fracture of the enamel edge

international phonetic alphabet (ICAO code).

The number of scale points is a function of clinically identifiable levels of a particular feature. The optimal number of scale points for maximized operational feedback instructions to students is from three to five points (41, 42). Increasing the number of criteria produces differentiation problems among the levels and thus decreases the accuracy of scoring (48). Precise description of performance criteria would be necessary to decrease misinterpretations. In addition, the need for extensive training of evaluators would become a necessity, or the use of sophisticated measuring devices would have to be introduced. The precision could possibly be improved, but the information gained would add unproductive costs to the measurement process (49). The correct place-

Table 5. Internal cavity definition

Rating	Quality evaluation (39)	Performance criteria: Occlusal part	Performance criteria: Proximal part
R	Cavity well defined	Internal line angles distinct and continuous (Fig. 9)	Discernible grooves in the internal line angles
S	Slight lack of cavity definition	Internal line angles indistinct or discontinuous in a few areas (Fig. 10)	Groove absent or exceeded >×2 in a few areas
M	Moderate lack of cavity definition	Internal line angles indistinct or discontinuous over larger areas or Slightly rounded line angles with no grooves (Fig. 11)	Gingival floor at right angles to tooth axis and no grooves or Groove exceeded >×2 over larger areas
T	Cavity ill defined	Internal line angles indistinct and discontinuous or Sharp line angles or grooves placed in internal line angle (Fig. 12)	Gingival floor slopes apically and no groove or Groove exceeded >×2 (Fig. 17)
V	Cavity devoid of form	Line angles cannot be differentiated (Fig. 13)	Depth of preparation <1 mm and gingival floor slopes markedly apically (Fig. 18)

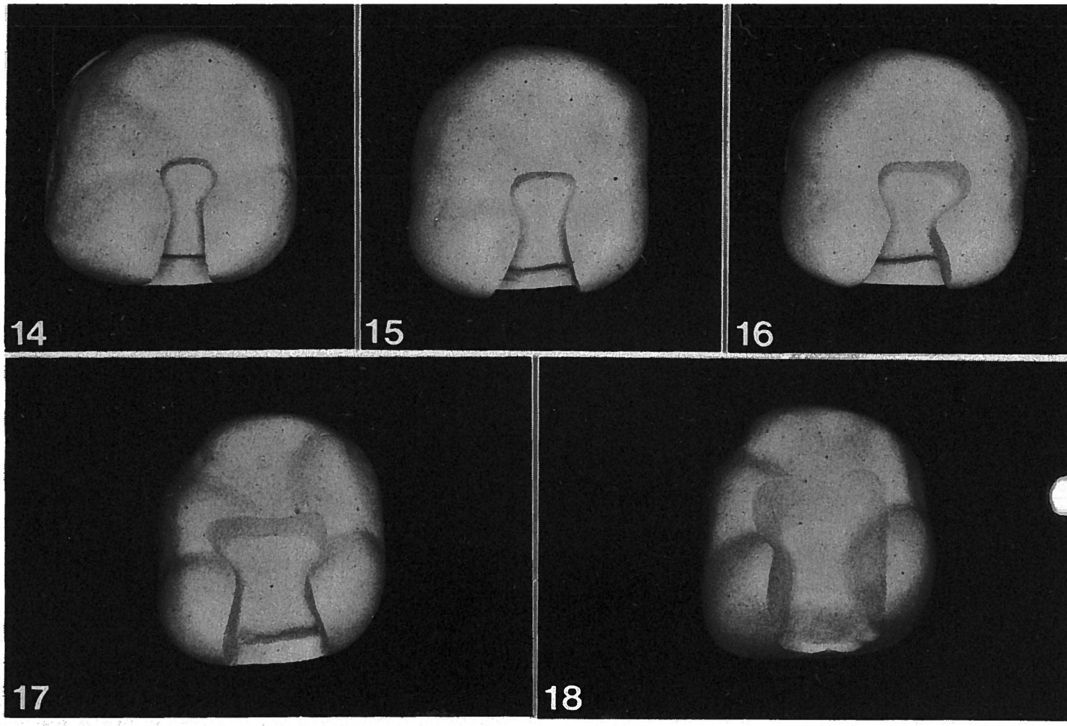
Table 6. Retention

Rating	Quality evaluation (39)	Performance criteria: Occlusal part	Performance criteria: Proximal part
R	Retention conspicuous visually and tactually	Cavity walls cannot be seen when viewed occlusally	Cavity walls cannot be seen when viewed occlusally (Fig. 14)
S	Retention evident, but insufficient or Retention slightly excessive	One cavity wall seen in some areas when viewed occlusally	One cavity wall seen in some areas when viewed occlusally (Fig. 15)
M	Retention moderately lacking or Retention moderately excessive	One or both cavity walls seen in some areas when viewed occlusally	One or both cavity walls seen in some areas when viewed occlusally (Fig. 16)
T	Retention absent in one or more areas	Both cavity walls seen when viewed occlusally or Dovetail not widened and progressively deeper preparation towards isthmus	Both cavity walls seen when viewed occlusally (Fig. 17)
V	Retention not evident or Retention results in gross loss of tissue	Loss of cusps owing to divergent walls or excessive grooves	Loss of cusps due to divergent walls or excessive grooves (Fig. 18)

ment of a feature variation cannot be ascertained without using the defined categories in a longitudinal clinical study. The longevity of restorations and the reasons for failure will be decisive for the establishment of the importance of type and degree of deviations from the defined ideal base line.

Number of dimensions and weighting. A clinically relevant system for evaluation of cavity preparations must include aspects decisive for the longevity of restorations. The design of a prepared cavity in a tooth is complex and may be described by a combination of both qualitative and quantitative measurements. A compilation of cavity features indicated by various authors as clinically important has been the main basis for the selected criteria. The use of many dimensions can make the system impractical and time-consuming. However, no clinical studies of the combination effects of different cavity designs and restoration prognosis have been published. The present system consequently included many dimensions to assess the relative importance of each and a possible combined effect. A revision of the system after longitudinal clinical studies may be necessary to ascertain its feasibility in practice. Some cavity features are considered under different dimensions. For example, the occlusal 'dovetail' is evaluated both under external outline and retention. Proximal 'locking' resulting in unsupported enamel is evaluated both under external cavity definition and retention. Various features of the gingival wall are assessed under the dimensions, depth of preparation, internal cavity definition, and external cavity definition.

It has been suggested that it is feasible to



Figs. 14–18. Variations in retention form. Fig. 14 is considered ideal and is rated *R*. Fig. 15 is rated *S*; Fig. 16, *M*; Fig. 17, *T*; and Fig. 18, *V*. A detailed description of each rating is given in Table 6.

quantify multi-dimensional criteria into one unified index with the help of canonical correlation (46). However, such an evaluation index may not be clinically correct. If a cavity preparation includes one single crucial error, even if excellent in all other aspects, a unified index will obscure this error. This is taken into account in the evaluation system by making the lowest registered code determine the overall code of each dimension.

Performance criteria. The present evaluation system is based on both quantitative and qualitative descriptive criteria. All the measurements are relative to anatomical structures or previous restorations. While describing the performance criteria, importance was attached to precise and comprehensible wording, as it was considered difficult to register high inter- and intra-rater reliability if the criteria lacked coverage or precision. Consistent interpretation also reduces the time and resources for evaluator training and facilitates the utility of the system. The performance and objectivity of any evaluation system is primarily related to the descriptive precision of its performance criteria (50). Even presumptive expert evaluators have shown little agreement if there are no performance criteria or if the performance criteria are imprecise (51). Maintaining a constant decision criterion is an important aspect for evaluation. A review of research on sensory discrimination indicates that decision criteria change with time and are influenced by various factors such as verbal instructions on the degree of strictness to be used (52). The wording and base from which evaluations begin also lead to different behavior of the evaluators (53). This rating scale is based on a defined base line and increasing levels of deviations from the base line.

Preparation aspects

At the turn of the century G.V. Black

described designs for cavity preparations on the basis of studies on secondary caries of extracted teeth (54). His conclusions were based on the current state of the oral health in the population and his own experiments on alloy compositions. Since then various perceptions of optimal cavity designs have evolved. The rationale for modifying cavity designs reflects results from different dental research areas. The changes are motivated by the development of new improved materials, traditional materials with better physical properties, better oral health in the population, the use of fluorides, assessments of biological effects on oral tissues, and improved equipment in the dental office. One of the consequences of the continually changing descriptions of 'ideal textbook preparations' is that clinicians develop individual sets of standards of performance, often reflecting the contemporary clinical procedures of their student years. The registered cavity preparations show a great diversity of different designs and design features. Consequently, each dimension had to specify all relevant possible variations of a feature, although it was realized that discrimination problems were induced.

External outline (Table 1)

According to Black (54), the margins of the cavity should be placed in the 'immune' areas to avoid secondary caries. For convenience of operation, the cavity should be as broad occlusally as gingivally. This resulted in a relatively extensive external outline. The motivations for extensive tissue removal were early questioned (55, 56). However, the reduction of Black's extensive designs has evolved relatively slowly (57–67), and the designs advocated in today's textbooks are only slight modifications of Black's principles (47, 68–74). The basic concept of these preparation designs has only recently been questioned, resulting in radical solutions, such as the facial slot amalgam preparations and other tooth-conservative designs (75–77). There is doubt that the traditional cavity design is associated with long-lasting restorations (78).

Occlusal part

Suggested buccolingual intercuspid extensions in the literature have varied from 1/3 (54) to 1/8 (78) of the intercuspal dimension. A wide occlusal extension, such as >3:5 or >2/3 of cusp incline, reduces the strength of one or both cusps (79). A buccolingual extension less than 1 mm is considered too narrow for optimal condensation, resulting in porosities and a poor adaption of the restoration. The extension is also coded as a T if less than 1 mm enamel is left next to a remaining restoration or an anatomical defect (47). There are diverging views on the necessity of removing non-carious fissures in continuation with the cavity. It is not possible to evaluate degrees of demineralization of the fissure system on models. Consequently, if remaining fissures are present, code T is indicated, although it is realized that this judgement may not be correct for all preparations. There are no reports of the clinical success or failure of modern slot designs or designs with minimal occlusal mesiodistal extension. The categorization of these were therefore tentatively coded T.

Proximal part

For many years clinicians favored cavity preparations with the gingival extension below the free margin of the gingiva. The cavities were also extended into the embrasures to be well removed from contact with the adjacent tooth. There is still controversy with regard to the degree of extension both gingivally and buccolingually. Since it is not possible to relate the cavity extension to embrasures or gingiva on plastic models, the buccolingual extension is measured relative to the bisected circumference line. A wide buccolingual extension, such as >3:5, may reduce the strength of the cusps (79). If the buccolingual extension <1:5, or the occlusogingival extension <2mm, there is a high probability that the cavosurface margins are in contact with the adjacent tooth. The maximum and minimum extensions for code M are consequently 1:5>M<3:5. The occlusogingival extension is measured relative to the marginal ridge. According to

Wheeler (80), the mean distance from the marginal ridge to the cementoenamel junction is 5 mm for premolars and 6 mm for molars. The ideal gingival extension was defined as 4 mm (5 mm for molars) with ± 2 mm as the range of variations. Preparations with gingival extension >6 mm (7 mm for molars) are considered to extend onto the anatomical root. Consequently, the restored tooth has poor prognosis for extended longevity, and the feature is thus rated code T.

Depth of preparation (Table 2)

The thickness of enamel occlusally is 2–2.5 mm. The total distance from the occlusal surface to the pulp is approximately 5 mm. The distance from the proximal surface at the cementoenamel junction is 2 mm (premolars) or 2.5 mm (molars). All measures are average values (81). Most textbook authors suggest minimal penetration past the dentinoenamel junction. Since it is impossible to register on a model the enamel thickness and the cementoenamel junction, the depth is measured relative to the cavosurface margin. The placement of the pulpal and axial walls relative to the anatomy of the tooth can only be assumed. Consequently, code M is limited by the maximum depth considered to endanger the viability of the dental pulp (82) and the minimum depth of amalgam to withstand masticatory forces, set at 1 mm (83). The maximum depths for code M are, occlusally, 6 mm and, proximally, 2.5 mm for premolars and 3 mm for molars. Increased depth has also been shown to weaken cusps of teeth (84, 85). Results from force measurements required to fracture teeth and/or class II restorations indicate that isthmus fractures usually are related more to improper initial occlusal contact than to lack of bulk (86, 87).

External cavity definition and finishing (Table 3)

The dimensions cavosurface angle, margin roughness, and cavity definition are interrelated but will be discussed separately.

Cavosurface angle

Black advocated preparing the cavity walls as nearly at right angles to the pulpal floor as practicable. A cavosurface angle occlusally of 90° is incompatible with this design. A long bevel of 100–110° occlusally is recommended (90). Most preparations have angles well over 90° (91). The cavosurface angle is of importance for assessment of the adaption and the marginal degradation of the amalgam restorations (92).

Cavity definition

The integrity of the margins of the restoration may be affected by irregularities of the cavity walls (93, 94). The principle and importance of cavity finishing have been discussed for many years (95–99). Controversy still exists with regard to the best technique or instruments (100–110). Continuous smooth margins and walls give good adaption of the amalgam and may thus reduce marginal leakage (111). Cavity designs incorporating acute angles, such as buccogingival and linguogingival point angles, do not favor good condensation of amalgam (112) and are accordingly rated code T.

Margin roughness (Table 4)

A system previously used in the literature for qualitative and quantitative measurement of margin roughness is the CMI (cavity margin index) (113). To evaluate the system's adequacy for clinical studies, the index was used to assess the proximal margin roughness of the cavities. The margins were evaluated at ×20 magnification in a stereomicroscope.

Internal cavity definition (Table 5)

Acute angles cut into the buccal and lingual walls occlusally were previously considered favorably for retention (56). Application of conclusions from photoelasticity studies (114–119) and finite element stress analyses (120–122) have resulted in the incorporation of beveled axiopulpal and occlusal internal line angles. However, the clinical implication of some of these conclusions has been questioned (123–125). The need for proximal retentive grooves has also been controversial for many years. Locking the proximal portion was considered necessary for many years (126–128). However, studies showed that the adaption of amalgam into acute retentive grooves is poor (129). Other studies in which the presence or absence of grooves was correlated with the degree of creep and/or extrusion of restorations also did not support this procedure (130–132). The confusion is clearly present in the textbooks in the early seventies (133–135). Most investigators today recommend slightly rounded occlusal line angles and placement of proximal grooves for improved retention (47, 57–63).

Some clinicians adhere to Black's principle of preparing a flat pulpal floor at right angles to the tooth axis. There is reason to question the clinical relevance of the need to remove sound tissue to obtain a flat floor. The morphology of the pulpal floor was not included in the evaluation system as a separate dimension. The maximum and minimum depths of preparation and the occlusal internal definition indirectly reflect the morphology.

Retention (Table 6)

Black (54) advocated parallel occlusal and proximal walls for convenience of operating. Bronner (136) modified this concept and recommended converging walls for retention. The proximal box thereby became self-retentive and the need for an extended dovetail was reduced. This principle has since been adopted in most authorative textbooks (57–63). It is feasible to quantify degrees of retention by observing the cavity preparation directly from the occlusal aspect. The extent of visibility of the lingual, buccal, proximal, and axial walls indicates the correct category. Additional retentive features such as buccolingual widening occlusally ('dovetail') and 'locking' are directly or indirectly evaluated as features of the external outline and the internal cavity definition.

Training and aids for evaluators

The importance of training evaluators to improve the inter- and intra-reliability is controversial. Some authors place great emphasis on prior training of the evaluators (137, 138). Other investigators find little or no effect of the training (139, 140). It is possible that the measured variations more reflect poor precision of the descriptive performance criteria than the effects of training. The effect of different types of training can be assessed by various techniques. A basic strategy is to use pair-matching and divergent matched pair with various degrees of difficulties. These factors can be combined with other common training strategies such as review and discussion of the criteria before evaluation, evaluation practice, or discussions of disagreements and reevaluation (141). Competence in practice does not automatically lead to competence in evaluation (43). It is therefore believed that the evaluation system described in the present paper can also be usable for non-dentists. However, it is necessary that evaluators, both experienced clinicians and non-clinicians, must be calibrated by training to avoid generalizations and misconceptions concerning the criteria.

Testing of criteria

Preliminary data on the agreement of rating of evaluators indicate that the evaluation system for class II cavities can be used for assessing cavities with good consistency. Thus it is possible to use the present system to evaluate cavities with good inter- and intra-reliability. A longitudinal clinical study in progress on the performance of restorations will be decisive for the validity of the selected criteria and for classification of acceptable and unacceptable preparations.

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