The Influence of Mechanical Factors in the Design of Inlay Cavity Preparations

By Robert Harris, M.D.S.

(Thesis submitted for the degree of Master of Dental Surgery.)
The Influence of Mechanical Factors in the Design of Inlay Cavity Preparations

By Robert Harris, M.D.S.
Clinical Assistant, United Dental Hospital of Sydney; Caird Scholar, 1932; Graduated Bachelor of Dental Surgery, Class I Honours, 1932; Instructor in Operative Dentistry to Dental Board Classes, 1933, 1936, 1937, 1938; Demonstrator in Prosthetic Dentistry in the University of Sydney, 1935; Honorary Tutor in Radiology in the University of Sydney, 1935; Lecturer in Operative Dentistry in the University of Sydney, 1936, 1937, 1938.

(Thesis submitted for the degree of Master of Dental Surgery.)
The Influence of Mechanical Factors in the Design of Inlay Cavity Preparations

Preface.—In presenting this work, the aim has been to use diagrams, simplified models and large models (magnified approximately 8 diameters). The models are from the collection made by the author for demonstration purposes, and have been reproduced by the kind permission of the Dean of the Faculty of Dentistry (Professor A. J. Arnott).

The skull used for the photographs in Figs. 2, 3 and 4 was kindly lent by Professor A. N. St. G. Burkitt, of the University of Sydney, to whom I herewith express my sincere thanks.

The photography is the work of Mr. P. A. Peachey, to whom I am indebted for the patience and skill which he has displayed in the execution of this work.


Introduction.—The aim of this work has been (a) to investigate the problems of retention peculiar to inlay restorations, (b) to apply the results of the investigations to the designing of suitable types of cavities which may, in some cases, assist in surmounting the difficulties which frequently occur in this branch of operative dentistry.
If the case is one that has become immune to cure, that fact may have
If the case requires little criticism to accomplish it, that should be done
By separating the teeth and building proceedmental concordance, that is well
the finding of the mass of cartilage so near the nagle (of the teeth) to
the anterior for protection means only

Mechanical factors in intra-cavity preparations.
consideration.” In the application of the above principles the operator has to be guided by local conditions, age of the patient, habits of the patient and the general condition of the patient, for each individual case, and finally the ultimate outline of the cavity is determined by the line of cleavage of the enamel. In general, it will be found that the cast gold inlay can be designed to withstand all the demands set out above and, with suitable designing of the cavity preparation, to accomplish this with less wastage of tooth structure; too much cutting for retention is worse than too little, for, besides the pain occasioned thereby, the strength of the tooth is endangered. This view is supported by Gowan(6) and others.

The inlays constructed prior to Taggart’s era were made after the manner of Alexander,(7) whose method had as its basis the swaging of a thin gold or platinum foil to the cavity and then filling in the occlusal contour with an alloy or, alternately, soldering a thin pure gold foil across the opening. These methods somewhat restricted the application of the inlay principle to relatively simple cavities. The Taggart method, because of inherent physical characteristics of the materials used, did not always produce an accurately fitting casting, but, following investigations by Price(8) Van Horn,(9) Maves,(10) Meyer(11) and others, the probability of obtaining in every attempt an accurately fitting casting is greatly enhanced. With their more accurate methods yielding close fitting inlays, it should be possible to apply mechanical principles to the problems of retention and dislodgment and, from an analysis of these two factors, gain some information which may indicate a modification of cavity design. Any design which will economize tooth structure and minimize trauma is of vital importance. Fish(12) has shown that the subjection of dentine and enamel to external trauma frequently produces a marked reaction in the pulp which may be unfavourable to its longevity, and Applebaum and Bodecker,(13) in their investigations, have demonstrated that (a) “dentine and enamel are most permeable in the teeth of young individuals, (b) high permeability of the dental tissues appears to be a factor in rampant caries”, and therefore the reduction of the area of dentine exposed to the oral fluids and the reduction of any external irritation are highly desirable in such circumstances, so that the pulp may react favourably.

A factor which may be an advantage in using an inlay, as shown by Bodecker and Applebaum,(14) is that oxyphosphate cements produce a favourable reaction in the dentine, so that one may be disposed to use an inlay in preference to other restorations.

Because of the particular technique required for the restoration of a tooth with an inlay, the various mandibular movements influence to a marked extent the design of the prepared cavities. Within certain limitations, the inlay depends more upon the outline of the cavity for
The three groups are composed as follows:]

Section 1.

In dealing with the 376 possible preparations, no case has been omitted to avoid the repetition which would be intolerable. A discussion of the many combinations of the components, and the principles involved in these simple combinations of various forms of occlusion, together with those of the other.

Certain types of joints or methods of fixing two or more materials.

Mechanical factors in maxillary preparations.

With this selective the subject matter has been grouped as follows:

1. Movements of the mandible and the forces of occlusion.
2. Geometric forms of occlusion and allied subjects.
3. Application of the geometric forms to the teeth.
5. Diagnosis of certain lesions.

Abstract.

The movements of the teeth are affected by the presence of various forms of occlusion. When this selective the subject matter has been grouped as follows:

The movements of the mandible and the forces of occlusion.

Mechanical factors in maxillary preparations.
and the cubical, consisting of the bicuspid and molars. When the teeth are fully erupted it will be observed that in some cases the upper incisors and canines project obliquely over the lower teeth and the buccal cusps of the upper bicuspid and molars lie outside those of the corresponding lower teeth (see Fig. 2.).

The primary function of the teeth is the grasping and comminution of food; they are also used in conjunction with the lips, cheeks and

Fig. 1 shows diagrammatically the arrangement of the dental arches and the relationship of the lower to the upper teeth.

Fig. 2 illustrates the overhang of the upper teeth when the arches are in contact.
membrane of the tooth.

Absorption of these stresses during mastication, the peripheral
functional zones of the occlusal surface of the teeth, play a part in opposing stresses.

Angle of occlusal inclines of the teeth, when the jaws are closed: the teeth.

Mastication.

The occlusal surfaces of the teeth therefore include all surfaces which
afford the balance of the buccal and palatal shearing forces.

Furthermore, the occlusal zone of the buccal surface in mastication.

In other words, some areas of mastication occlusal surfaces usually lack a
portion of the occlusal surface as the tooth is closed. But very few
areas of the occlusal surface of the upper teeth which makes contact with
the buccal surface of the lower Crushing or prismatic action of the teeth, which
these actions have a tendency to shift the arches in shape.

The posterior teeth consist of two grooves, buccal and palatal.

For tearing tough and thick foods.

Which is continuous, or less formed, or less called upon
layer of the teeth, called the crown, are called
surfaces are called the buccal and palatal shearing forces.

Which is called the surgeon, or less called upon
surfaces, are called the buccal and palatal shearing forces.

The upper and lower canines are slightly more complex in shape.

The anterior teeth of both arches may be considered as prismatic.

Considered in this discussion.

When the crown of the tooth is closed. When the tooth is closed, the
apparent stresses on the tooth are called those affecting stresses in the
areas above, and those affecting stresses in the buccal and palatal shearing forces.

Angle of occlusal inclines of the teeth, when the jaws are closed: the teeth.

Mastication.
MECHANICAL FACTORS IN INLAY CAVITY PREPARATIONS.

The various regions of the mouth show a difference in the amount of stress received during the act of comminution of food, and Black\(^{(20)}\) has compiled a table showing this stress in pounds weight, giving an average of 171 pounds on the molars and considerably less on the bicuspid; he has also demonstrated that the force expressed in pounds weight necessary to crush usual foodstuffs is within 100 pounds.

Fig. 3 shows a view of the articulation viewed from the side.

Referring to Fig. 3, which represents the teeth in normal occlusion, it will be seen that each arch describes a curve, and that the teeth are arranged in one arch in such a way as to be in harmony with the opposing teeth in the other arch. The mesio-buccal cusp of the upper first molar is received in the buccal groove of the lower first molar. The teeth posterior to the first molar engage with their antagonists in a similar manner, those anterior interlock with one another in the inter-spaces, the lower second bicuspid between the upper first and second bicuspids, and the lower first bicuspid between the upper first bicuspid and canine until the anterior teeth are reached. The upper central incisor being broader than the lower, it necessarily extends beyond it distally, overlapping in addition about one-half of the lower lateral incisor; the upper lateral occludes with the remaining portion of this tooth and with the mesial incline of the lower canine; the mesial incline of the upper canine occludes with the distal incline of the lower canine, the distal incline of the upper canine occluding with the mesial incline of the buccal cusp of the lower first premolar. In the same order the series of buccal cusps of the premolars occlude, the mesial incline of each upper occluding with the distal incline of the corresponding lower teeth.
The relationship which exists between the various surfaces becomes evident as wear introduces facets upon the antagonistic surfaces. In the antagonistic surface, the occlusal relationships exist between the upper and lower central incisors and upper third molar. In the opposite jaw, however, it is observed that each tooth of both jaws has two antagonistic surfaces in the occlusal relationship, except the lower central incisor. This interaction of the occlusal surfaces of the masticatory system and the teeth is shown in Figure 9.

The cusps of the molar teeth project beyond those of the upper molars. This arrangement is known as the interocclusal relationship except that the interocclusal third molar has no occlusion.

Towards the palate, as shown in Figure 9, the distal incline of the disto-buccal cusp of the upper third molar is the distal incline of the disto-buccal cusp of the lower second molar. This case is illustrated with the bucal cusp of the second and the mesio-buccal cusp of the first upper molar; the distal inclined of the mesio-buccal cusp of the upper first molar occludes with the mesial inclined of the mesio-buccal cusp of the lower first molar. The mesial inclined of the mesio-buccal cusp of the lower second molar occludes with the mesial inclined of the mesio-buccal cusp of the upper second molar.
buccal and lingual cusps of the lower posterior as shown in Fig. 6. In this way the grinding surfaces of the teeth obtain an increase in efficiency.

The important movements of the mandible, and hence of the mandibular teeth, are\(^\text{(21)}\) (a) a hinge movement, (b) a protrusive movement preparatory to incision, and (c) a right and left lateral movement.

(a) The hinge movement is employed in opening and closing the mouth for the introduction of food, and also in the crushing of brittle foods. In a normal arch relationship the lower incisal edges approach the upper incisal edges, pass through the food, meet them on the lingual line angles, and then shearing through the food, glide along the marginal ridges of the palatal surfaces of the upper incisors to a position
Right and left lateral movements are employed, during which the incisor path is drawn forward or posteriorly in the path, while the other one contracts in drawn forward or posteriorly in the path, which

Fig. 7

iments the movements of the mandible.

The opposite arch is drawn forward or posteriorly in the path, while the other one contracts in the movements of the mandible.

The opposite arch is drawn forward or posteriorly in the path, while the other one contracts in the movements of the mandible.

A protraction movement is employed in the elevation and incising of the teeth. The deeper into the bone the mandible moves the incisors may slide pass the roots of the teeth with ease, since the base of the tooth is reduced to a sliding motion in the process of the reduction to small particles. The mandibular grooves in the process of the reduction to small particles.

In all these factors, the action of the mandible without pro-

is MECHANICAL FACTORS IN ORAL CAVITY PREPARRATIONS.
Fig. 8.—The pivotal centre of the mandible during lateral movements.

ridges of the upper teeth (see Fig. 9). The amount of side movement necessary to bring the teeth into this relation to form the masticatory space, was designated the "differential limit" by T. W. Pritchett. Used in this sense, it means the limit of side movement of the teeth for doing-effective work.

Fig. 9.—a. shows the bucco-lingual relation at rest. b. shows the bucco-lingual relation in lateral protrusion.

In some cases when a lateral movement is made, the marginal ridges and cusps of the pivotal side maintain a contact and form the masticatory groove, the arches on the moving side make contact at a position in the molar region, and a space occurs in the bicusp and canine and first molar regions. Fig. 10 illustrates this space with models from the skull mounted on an anatomical articulator. During mastication, the opportunity is taken at this stage for the tongue and cheeks to force more food between the teeth, and as the mandible is brought back to its centre position further crushing of the food on this side is possible.

Playing a large part in the efficient trituration of food in these lateral movements is the masticatory or rectangular groove, a very complex groove developed during lateral movements and formed from
Mechanical Factors in Inlay Cavity Preparation:
MECHANICAL FACTORS IN INLAY CAVITY PREPARATIONS.

groove and finally emerge with those from the adjacent pairs of cusps, and enter into the formation of grooves which represent arcs of circles developed from the same rotation centre. This arc-like bucco-lingual arrangement of cusps and grooves of the upper teeth permits the cusps and sloping planes of the occluding lower teeth, which bear a similar relation to the rotation centre, to be moved freely back and forth in the lateral swing of the mandible without cusp interference.

The masticatory or rectangular groove consists of the mesio-distal grooves of the posterior teeth, and results when the mandible is rotated laterally so as to bring the buccal cusps and marginal ridges of the lower teeth on the pivotal side outward from the central sulci of the upper teeth and directly under the corresponding cusps and marginal ridges of the latter; a fairly close and unbroken line of contact between these wedge-like ridges is effected in this movement. At the same time the lingual cusps and marginal ridges of both lower and upper teeth on the same side are brought into similarly close contact. Fig. 11 is an attempt

![Figure 11](image)

Fig. 11.—a. illustrates the approximate relation existing between the upper cusps and lower cusps at rest. b. illustrates the approximate relation when the mandible is moved into lateral protrusion so as to form the masticatory groove.

to illustrate the relation existing between the cusps of the lower first molar and the upper first molar during these movements. A rectangular space is formed bounded above and below by the occlusal surfaces of the upper and lower teeth and laterally by their buccal and lingual marginal ridges. This groove extends from the first bicuspid to the third molar inclusive and forms the receptacle in which food is held and crushed as the mandible is drawn back to normal resting position.
The stress is in the direction of the arrow (Fig. 12), that is, towards the amount of overjet decreases there will arise a greater need for resistance to stress, until in a normal overjet the direction of resistance no longer affects the upper incisors. Therefore, the lower incisors, therefore, on stress arises as a reaction to the various teeth as follows: In extreme overjet there is no contact of the lower incisors against the upper incisors. The condition which may exist, that the lower incisors overlap and occlude may exist at the same time, with or without overlap of the lingual surfaces of the upper incisors. It will be seen that the condition of the lower incisors may make contact with some portion of the upper incisors in varying degrees. Depending upon a number of separate conditions, the anterior teeth may or may not impinge upon the lingual surfaces of the lower incisors. The greater the parallelogram of force the mucosal pressure of the tongue is within normal limits, the greater the parodontal approximation is likely dependent on the mechanical factors in intra-cavity preparations.
the lingual. In extreme protrusion of the mandibular incisors, there is again an absence of contact, but, as the amount of protrusion decreases, there will arise the need for resistance to stress in the direction of the arrow (Fig. 13, b), that is, towards the labial. Between these two sets of conditions there is the “edge-to-edge” relationship where the incisal edges contact with stress directed along the long axes of the teeth (Fig. 13, c).

There are extreme conditions of overjet or micrognathism\(^{(23)}\) and protrusion or prognathism\(^{(24)}\) in which normal movements of the mandible do not cause any contact of the incisor teeth, and defects which may require restoration with inlays do not make so many demands on the cavity design in these cases. With normal overbite (Fig. 13, a), the direction of stress upon the lower anterior considered as a group is shown by the arrows in Fig. 14, a. The direction of stress upon the upper anteriors is shown in Fig. 14, b, with the direction in each individual tooth marked by an arrow; the stress would appear to be resisted in those regions in which facets of wear appear (cf. Fig. 5). The direction on the posterior teeth is shown in Fig. 14, c.

![Fig. 14.](image)

2. Sliding contact of the planes and cusps arising during acts of protrusion and retraction of the mandible. Here, the inclined planes form a sliding impact as the mandible is protruded, the general direction of the stress being similar to that indicated for the hinge movement, but the force may have greater magnitude, and therefore greater stress
Traces the mandible as a second class lever system.

\[ \begin{align*}
P &= \text{muscular force} \\
W &= \text{load or work done to crush food} \\
I &= \text{inertial load} \\
L &= \text{length of lever}
\end{align*} \]

In the figure, the mandible is a third class lever system.

1. The incisors close against each other by pressure of the masseter muscle.

2. The force of the masseter is transmitted to the mandible through the masticatory muscles and transmitted to the condyle.

3. The force is transmitted to the condyle through the masticatory muscles and transmitted to the condyle.

Mechanical factors in cavity preparations:

- Remember that the buccal side and first molar region may not be

- will be done by the teeth in those movements, especially when it is
MECHANICAL FACTORS IN INLAY CAVITY PREPARATIONS.

agent and produces the lateral protrusion of the teeth on the pivotal side whilst those teeth are held in contact with the masseter and temporal muscles. When food is filling the morsal space or masticatory groove (Fig. 16), and thus offering some resistance to the force of the masticatory muscles, it is crushed by a force which may be applied by two lever systems. In the hinge movement, the mandible belongs to a lever of the third class (Fig. 15, a), so that the masticatory force is at a disadvantage; during lateral movements that side performing the actual movement becomes portion of the power arm working on the pivotal side, and in this case the lever system belongs to the second class (Fig. 15, b). The stress is taken up by the buccal slope of the lingual cusps of the upper posterior teeth and the lingual slope of the buccal cusps of the lower posterior teeth. Fig. 16, a, shows the direction of stress in the morsal space when the mandible acts as a third class lever, and Fig. 16, b, shows the direction of stress in the morsal space when the mandible acts as a second class lever.

Fig. 16.—The arrows illustrate the direction of force in the morsal space during the crushing of food during the two sets of conditions seen in Fig. 15, a and b.

Since force is a necessary associate of function, it follows that the forces arising during functional movements will play an important part in the stability and permanency of any functioning inlay restoration. As this is true in the complete dentition where an harmonious inter-digitation and sliding relationship exists during function, then, in the numerous conditions which may be found between the edentulous and the complete dentition, modification of the stresses may occur, increased
When the impact of the occlusal surfaces consists of slipping and sliding, the tooth force may then be resolved into two components at right angles to each other, each component being a force acting on a surface at an angle with the normal. The magnitude of each component is equal to half the magnitude of the tooth force. The normal to the surface at the point of contact is perpendicular to the direction of the tooth force at that point. The magnitude of the component perpendicular to the normal is equal to the component parallel to the normal.

When the impact of the occlusal surfaces consists of slipping and sliding, the tooth force may then be resolved into two components at right angles to each other, each component being a force acting on a surface at an angle with the normal. The magnitude of each component is equal to half the magnitude of the tooth force. The normal to the surface at the point of contact is perpendicular to the direction of the tooth force at that point. The magnitude of the component perpendicular to the normal is equal to the component parallel to the normal.

**Section 2: Mechanical Principles**

The tooth force, when the teeth are in occlusion, is the sum of the forces acting on the teeth from all directions. These forces include the forces of the muscles of mastication, the forces of gravity, and the forces of occlusal contact. The magnitude of the tooth force is determined by the size of the occlusal surfaces, the angle of occlusion, and the contact pattern of the teeth. The direction of the tooth force is determined by the direction of the occlusal forces and the position of the occlusal surfaces.

**Mechanical Precautions in Inlay Cavities**

Mechanical precautions should be taken to support occlusal cavities. The tooth force should be directed parallel to the long axis of the tooth. The occlusal cavity should be oval in shape with the long axis parallel to the long axis of the tooth. The depth of the cavity should be sufficient to provide a stable base for the inlay. The cavity should be prepared with a smooth outline and a shoulder to distribute the forces. The margins of the cavity should be parallel to the long axis of the tooth. The inlay should be made of a material that is compatible with the tooth and has good retention and resistance to wear.
one another, one of which is at right angles to the surface (28) (see Fig. 18, a). Fig. 18, b, shows the application of a force to a marginal ridge, the force being resolved into two components, A and B; B is the important component because this resultant has a "moment" about the point 0.

"The moment of a force about a given point is the product of the force and the perpendicular drawn from the given point upon the line of action of the force." (27) In Fig. 19, a, if a force X is applied at A in the direction AO, the moment of the force X about D is XOD units. The greater the force X, or the greater the length OD, the greater the moment of the force X about D. This moment of force may reach sufficient magnitude to cause dislodgment of an inlay in which the retention form is of little value. The action of a force upon a body tending to produce rotation about a certain point is called torque; (28) this torque action will depend upon the magnitude of the force and the distance between its line of action and the axis or centre of rotation of the body; the torque action depends, therefore, upon the moment of force about the axis of rotation. An example of torque
is called the mechanical advantage of the system. Where possible, an applied force or power, as it is called, and the resisting force or weight resisting force are called the arms of the lever. The ratio between the applied force and the arm of the lever is called the moment. The perpendicular distance between the fulcrum and the point at which the lever is balanced is called the moment arm.

There are three types of levers: (a) The lever consists of a rigid bar which may be straight or bent, and has one fixed point about which the bar rotates. (b) The lever consists of a rigid bar or beam. (c) A lever system is the combination of any two or more levers joined together to form a single system. The lever system may be demonstrated in a restoration having aidental look similar to that shown in Fig. 2. It may be demonstrated in a restoration having a similar look similar.
attempt should be made to utilize a system in which the applied force has a mechanical advantage greater than unity.

**Levers.**—*Class I.* This system is arranged so that the power $P$ and the weight $W$ act on opposite sides of the fulcrum. Fig. 20 shows a diagram of the lever principle and two types of inlay restorations using

![Class I Diagram](image)

**Fig. 20.**—Diagram to illustrate Class I lever principle. The inlay preparations are drawn for proximal views of an upper lateral incisor; the fulcrum or axis of rotation is shown by $<$ in both cases.

the Class I lever principle in their retention forms. The post inlay has a power arm equal to the length of the post, the fulcrum being at the gingival margin; the other type shows a lingual lock inlay preparation without a gingival floor at right angles to the axis of the tooth, the only
Class I: This system is arranged so that the lever acts at the fulcrum and the weight W acts at the same side of the fulcrum, but the power acts at a greater distance from the fulcrum than does the weight. Fig. 21 shows a diagram of the lever which utilizes its principle.

Class III: This system is arranged so that the power P and the weight W act on the same side of the fulcrum, but the power acts at a shorter distance from the fulcrum than does the weight. Fig. 22 shows a diagram of the lever and a proximo-incisal inlay restoration which utilizes its principles in the lingual lock retention form. The arrow in each type of inlay indicates the direction of the masticatory force represented by W.
MECHANICAL FACTORS IN INLAY CAVITY PREPARATIONS.

Class I systems are seldom used in inlay restorations, whilst Class II occur in the proximo-occlusal and proximo-incisal restorations, i.e., Black's Class II and Class IV cavities, and Class III is the system found in proximo-incisal restorations using a lingual lock.

Whenever a lever system is used in which the retention form has a mechanical disadvantage, it is important to design carefully and accurately the retention form, because dislodgment under those conditions becomes more probable. The following example will illustrate the importance of this.

In Fig. 22, if P< is 2 units, and force W 75 pounds, W< is 4 units, then the power necessary to resist this force at P may be represented by X in the following:

\[75: X :: 2: 4, \text{ giving } 2X = 300. \quad X = 150 \text{ lb.}\]

By placing the retention closer to the incisal edge so that the power arm is 3 units, the equation becomes under similar conditions:

\[75: X :: 3: 4, \text{ giving } 3X = 300. \quad X = 100 \text{ lb.}\]

From this example the importance of selecting carefully the position for the lingual lock is apparent.

In the case of an inlay restoration using some retention from such as a lingual lock situated midway between the incisal and gingival limits and having the gingival floor prepared so that it does not oppose tendency to rotation about K, the rotation centre (see Fig. 23, a), little resistance to rotation exists other than that afforded by the lingual step, and the value of the inlay as a permanent restoration is reduced. Several methods may be used in which the difficulties due to extensive caries in the gingival region may be overcome.

1. Rotation may be prevented by retaining tooth structure and forming a wall along the dotted line shown in Fig. 23, a, thus intro-
Sometimes a compromise between these methods is necessary. If a right triangle is introduced, the second principle is satisfied, and if the length of the hypotenuse is increased to $L$, the length of $KL$ is increased to $L'$, and this point is shown at $P'$, so that the length of $KL$ is increased to $L'$. If the method is shown at $P'$, the second principle is satisfied, and if the length of the hypotenuse is increased to $L'$, the length of $KL$ is increased to $L'$, and this point is shown at $P'$, so that the length of $KL$ is increased to $L'$.

Where possible, remove some of the lateral wall to that a lateral wall.

Figure 1.4

The lateral and pertinent issue is that the angle and the potential issue. If the angle is increased to $L'$, the length of $KL$ is increased to $L'$, and this point is shown at $P'$, so that the length of $KL$ is increased to $L'$. If the method is shown at $P'$, the second principle is satisfied, and if the length of the hypotenuse is increased to $L'$, the length of $KL$ is increased to $L'$, and this point is shown at $P'$, so that the length of $KL$ is increased to $L'$.
If the stress which may occur during incision and lateral protrusive movements is considered in relation to the anterior teeth, where this stress is one tending to dislodge the inlay restoration towards the proximal, it will be found to consist of two components: in Fig. 26

represented by B acting in the axial direction and A acting in a proximal direction; this latter force will have a tendency to rotate the inlay towards the proximal, M being the centre of rotation. With retention at K, a Class III lever system prevails.

Supposing rotation about M were possible, then with M as centre, arcs of circles with radii MK and MK₁ would indicate the approximate paths followed by the retention form during movement (see Fig. 27, a). The gingival wall of the retention form is within the arc having radius MK₁, and therefore K₁ passes along a path moving away from the
If the tooth is thick the retention form could be cut square in the incisal portion and at the same time give some support to the incisal portion of the tooth. If the tooth is thin the retention form should be cut square in the incisal portion some extent the met and a retention form outlined in Fig. 28 will prevent the occlusion relative to the retention form shown in Fig. 28. To this extent the occlusion will form a perfect arc passing through solid tooth structure which will prevent rotation. In this way the extent of the incisal wall will form the form an arc passing obtained by intersecting radius M, so that M becomes the new position removed by caries or operative procedures, resistance to movement is

Fig. 27.

Fig. 28.

By the shaded portion in Fig. 27, q, as removed, if this material is, the shaded portion in Fig. 27, q, is removed. If this material is removed, any other point selected on this wall M and since K is further than any other point selected on this wall K, in the case of the incisal wall, however, it is within the arc radius of the incisal wall which cannot exert any resistance to the movement of.
thereby reducing the mechanical disadvantage (see Fig. 29). The necessity for outlining this retention form in a "dovetail" shape is due to stress which may tend to rotate the inlay about the labial margin of the cavity, and methods of overcoming this tendency to rotation are discussed later.

In the case of the thick tooth it is often advantageous to use the Class II lever system and prepare an incisal anchorage as shown in Fig. 21; this type is similar to the occlusal anchorage as used for the posterior teeth. Fig. 21 illustrates the retention form, the dislodgment force acting in the direction W, the fulcrum or rotation centre at < and retention at P. Arm P< is greater than W<, so that retention at P has a mechanical advantage over stress at W. Careful designing and cutting of the retention form is needed to overcome any tendency to rotation about the labial margin. Fig. 5 shows the areas where greatest stress appears to occur; the marginal ridges appear to absorb a large amount of this stress, which is increased during lateral movements of
Section 3—Geometric Form of Retraction

When a decision has to be made in the selection of a type of retraction, the structural demands of the case will often require the selection of some form possessing a lower profile with a mechanical disadvantage, and it is necessary to realize this so that needless cutting may be avoided and the superior developed. In the construction of an accurately developed incision, the assistant is present, although the retraction arm is stronger and has more.

When a procedure is accurately induced in an assistant's arm, any continued action about the incision step of the line and therefore cut the assistance which is of another assistant's arm, is there.

In addition, the incision step has a supplemental dexterity step, which is in a function as an excellent retractor factor with a working arm, but if the dexterity step with some assistance when the dexterity is pneumatically extended, then a decision to support the incision. From the structural demands of the case (see Fig. 80), the incision developed from a satisfaction of any retraction in these areas about the lateral margin of the mandible; the lower incisors impacting with the ridge and to induce the mandible.
the inlay cavity and compare its characteristics with the methods of joining materials together. A cubical form for the posterior teeth and a pyramidal form for the anterior teeth have been used to illustrate the various types of retention (see Fig. 32).

![Diagram](image)

Fig. 32.—Geometric forms representing: a, posterior teeth; b, anterior teeth.

Passing from the field of operative dentistry to one in which great use is made of cutting special shapes for joining materials together, it may be shown that a marked similarity exists in the various forms used in both fields; by examining the mechanical principles used it is thought that modifications may be selected which may be applicable to inlay cavity design.

![Diagram](image)

Fig. 33.—a, dowelled joint; b, toggle joint; c, slate cramp.
either in a horizontal direction or in a vertical direction, and rotation through an angle. The representation of the shaded portion, shown in Fig. 34, is a simple step profile preparation. The vertical section, Fig. 34, a) Material, b) Single step profile preparation, c) Vertical section.

In wood-working types of joints and these characters may be applied to inlay cavities, there are available some of more or less the forms are of the "box" type. But the forms are of the "box" type. A plan of the joints only is shown, and the carpenter (see Fig. 34, c) dowelled joints, in Fig. 34, b) dowelled joints, which have a union between the forms of the walls, etc., which have a union between the forms of the walls, etc., which have a union between the forms of the walls, etc., which have a union between the forms of the walls, etc., which have a union between the forms of the walls, etc., which have a union between the forms of the walls, etc., which have a union between the forms of the walls, etc., which have a union between the forms of the walls, etc.
MÉCHANICAL FACTORS IN INLAY CAVITY PREPARATIONS. § 3

may occur if force is applied or if the resultant of forces act at a suitable point, the axis of rotation corresponding to the gingival margin (see Fig. 35).

Fig. 35.—Single step preparation without anchorage, showing rotation about the gingival margin.

2. Stump or stub tenon (Fig. 36).—In this type a square "box" is cut in the surface of one member to receive the other member, which has been reduced in size to form the "stump"; the stump is very short in relation to the length of the piece. This form of retention exhibits the characteristics of a Class I level system, and unless the material has sufficient strength to prevent fracture of the stump and the adaptation between the stump and box is perfect, this form of retention may not withstand excess stress. In actual practice the retentive value is improved by placing a small wedge in the end of the stump before glueing the parts; the stump is then driven into the box. The function of the wedge is to force the sides of the stump into very close contact with, and maintain pressure against, the walls of the slot.

In inlay practice a replica of this method is found in pin-lays and post inlays, etc., and it may be possible when use is made of a "casting...
without distortion of angles in the casting which may increase the dimensions of casting. Where the occlusal outline is of dovetail form (see Figure 37), a dovetail preparation is used. The reduction in the tooth is in the same surface single step preparation point. The reduction in the tooth is in the same surface single step preparation point. The reduction in the tooth is in the same surface single step preparation point. The reduction in the tooth is in the same surface single step preparation point.

A dovetail preparation is used. In this type of joint the lip has developed a dovetail. In this type of joint the lip has developed a dovetail. In this type of joint the lip has developed a dovetail. In this type of joint the lip has developed a dovetail.

3. Dovetail Preparation—In this type of joint the lip has developed a dovetail. In this type of joint the lip has developed a dovetail. In this type of joint the lip has developed a dovetail. In this type of joint the lip has developed a dovetail. In this type of joint the lip has developed a dovetail.

A dovetail preparation is used. In this type of joint the lip has developed a dovetail. In this type of joint the lip has developed a dovetail. In this type of joint the lip has developed a dovetail. In this type of joint the lip has developed a dovetail.

A dovetail preparation is used. In this type of joint the lip has developed a dovetail. In this type of joint the lip has developed a dovetail. In this type of joint the lip has developed a dovetail. In this type of joint the lip has developed a dovetail.

A dovetail preparation is used. In this type of joint the lip has developed a dovetail. In this type of joint the lip has developed a dovetail. In this type of joint the lip has developed a dovetail. In this type of joint the lip has developed a dovetail.
4. Open mortise and tenon (Fig. 38, a).—In this type of joint, which may be likened to a double lap joint, another development in retention form of a reciprocal nature is seen; this reciprocal resistance is developed by the two parallel arms of the mortise which oppose stress tending to cause rotation about the base lines. The replica in tooth form is shown in Fig. 38, b, and is known as an M.O.D. inlay, also termed a saddle inlay. Because of the increased internal surface area and complexity of this type of cavity, the cementing medium can be of greater assistance in opposing movement in a vertical direction; when the inlay has been cast and fitted to the cavity, grooves are cut in its sides so that

![Diagram](image)

Fig. 38.—c represents a section through the M.O.D. inlay. The auxiliary grooves for cement are cut in the mesial and distal portion of the inlay as marked by the dotted lines. The cement of this position acts similarly to a "key" holding a wheel and shafting fixed.

they are placed at right angles to the line of withdrawal of the inlay after the manner of Bodecker. These grooves become filled with cement which, when crystallized, acts in a similar manner to a key used to attach a pulley wheel to a round shafting, the cement with a high crushing strength being an advantage. This advantage is of no inconsiderable amount as shown by Head in a series of experiments conducted in 1905, in which he was able to demonstrate the value of altering
MECHANICAL FACTORS IN INLAY CAVITY PREPARATIONS.

In addition, grooves were cut in a corresponding position in the walls of the cavity and the inlay cemented in position. With a smooth inlay and no grooves in the cavity walls, the inlays were dislodged with a pressure equivalent to 8 ounces weight; with grooves in both the inlay and cavity, the pressure necessary was equivalent to 19 pounds weight. It, therefore, seems probable that the use of this type of grooving is a definite advantage in the retention of the inlay, especially when a cement with a high retentive strength is used. Grooves need not be cut in the walls of the cavity because their substitution by the minute irregularities attendant upon instrumentation of the dentine is unavoidable and the value of these irregularities as retention plus the adhesion of the cement is probably equal to that of the grooving.

There are numerous other joints used in woodworking which utilize the principle shown in the double lap or mortise and tenon, among which may be mentioned notching (Fig. 39, a), double notching (Fig. 39, b), and capping (Fig. 39, c). Rotation of the cut member in the notching...
may occur in a horizontal axis, and this has been overcome by introducing the box form to both members in double notching and cogging.

5. The groove, tongue and mortise (Fig. 40, a).—This type of joint is used for end grain joints and uses a supplemental groove in the one member; its replica in cavity preparation exists as a two surface preparation or single step using supplemental grooves in the floor of the occlusal step (Fig. 40, b). This form is an advantage when the retention form of the occlusal step cannot be obtained because of extensive caries of the proximal marginal ridge (Fig. 40; c). A groove, if necessary, can

Fig. 40.—b, d illustrate a cross-section through the two surface inlay using supplemental grooves for retention.

be cut in the gingival floor in addition to the one in the occlusal floor (Fig. 40, d). This gingival groove is advocated by McMath (36) and others. The danger of using this gingival groove alone would seem to be in that the masticatory force has a large mechanical advantage over any resistance supplied by the small gingival wall, which may collapse under stress; this gingival groove alone should not be depended upon for any resistance to masticatory stress; it may be helpful in holding the wax used for the inlay "pattern" in close adaptation with the cavity at this
FIG. 42—6. Pinhole. C. Pinkey

7. Dowelled Joint.—In this type of joint, the dowel is inserted by using a drill to project (fig. 41, a) holes are drilled in the other member and wooden rods glued into one member so that some length is left of a dowel. This type of joint is another end grain joint using the pinkey in the single step, orthodoxy type of two surface preparation.

FIG. 41.
and is found in the pinlay methods of Pincus and the pin-ledge of Burgess, the replica in tooth form being shown in Fig. 42, b, c; it seems to have a particular use where large portions of tooth structure have been lost and the presence of the pulp limits the cutting for "box" type of retention form.

The basic principle of retention in each type of joint, except that of the first type, i.e., the halving, would appear to be as follows. When two pieces are cut so that they may be brought together to form a joint, the one portion or positive, which receives the other portion or negative, is so formed that the negative can enter in one direction only; movement after the negative is actually in position can only follow in a direction opposite to that of insertion, the cementing medium being depended upon to prevent this latter movement.

Fig. 43, a, shows the simple lap joint (in cross-section), in which movement may occur in at least horizontal and vertical directions;

rotation also follows, as shown in Fig. 35, about the base line or gingival margin. If pressure is applied at A or if some force having a similar effect is applied in the direction A (Fig. 43, a), rotation about B follows, the negative portion takes up a position as shown in Fig. 43, b, until,
If the walls or the positive form diverge in a vertical direction so that the movement is a "proper" form, then it follows that

1. By increasing the vertical dimension of the extremity of the
   accommodates the positive position and cutting the positive position to accommodate the

2. By increasing the potential transverse dimension of the

3. By using dowels in the negative portion recorded by holes in the

The groove of a dowel (method 3) could be used, but may

In the first method a groove is cut across the positive portion.

In a posterior direction, so that this type of joint can be considered as

In a posterior direction, so that this type of joint can be considered as

In a posterior direction, so that this type of joint can be considered as

In a posterior direction, so that this type of joint can be considered as

In a posterior direction, so that this type of joint can be considered as

In a posterior direction, so that this type of joint can be considered as
possible with a very shallow and open mortise form; to overcome this tendency to rotate, the walls \( L_1M_1 \) and \( K_1N_1 \) should be made to converge rapidly, so that \( M_1N_1 \) is very much reduced; if this cannot be done, the modification shown in Fig. 44, \( d \), may be used.

![Diagram](image)

Fig. 44.

The open mortise and tenon is an extension of the principle outlined in method 1, and is shown in Fig. 45, \( a \).

The stump mortise and tenon and dowels may be considered to be more efficient because less material is removed for their preparation, and if adequate depth of the stump or the dowel is obtained so that the mechanical advantage of the dislodging force is reduced, a further increase in efficiency may be expected. Fig. 45, \( b \), shows the stump tenon. Pressure at \( A \) tends to cause rotation about \( B \); radius \( BK \) is longer than \( BK_1 \); therefore wall \( K_1K \) prevents rotation about \( B \). This is true for any length of \( K_1K \), but in practice the greater the length of \( K_1K \), the more efficient the retention. If the length of \( K_1K \) is very short, then great accuracy of fit must be obtained to have any retention.
This study of mechanical factors involved in a new joint would appear to support Worker's contention expressed in this statement:

...a new, being a single metal piece, is supported by the outer edge of the hillside itself, is to be smaller for an inlet than for a...
whole area covered by it; its hook-like hold in the occlusal portion of
the cavity is much stronger than that of a foil filling, so that unless
much dentine is lost by caries, little gingival wall is needed to support
the inlay against occlusal stress."

Section 4.—Application of the Geometric Forms to the Teeth.

The good qualities which should be found in an efficient inlay
design may be grouped as follows:

1. Aesthetics demand that the outline of the cavity should be
   pleasing in form, so that there will be displayed neither too much nor
   too little gold on those surfaces which can readily be seen.

2. The outlines of the cavity should be so arranged that they will
   occur in areas readily cleansed by the passage of foods across the
   junction between gold and enamel, and also that this junction will be
   readily reached by the bristles of the toothbrush.

3. The design should be one that will make possible the permanent
   retention of the inlay in its position.

4. The design should also be one which is arranged to give support
   to the tooth structure from which it derives its retention, so that its
   resistance form is a maximum.

5. The design should be one in which are found the above necessary
   good qualities, and at the same time the vitality of the pulp should not
   be endangered by operative and post-operative trauma, so that longevity
   of the tooth as an efficient organ may be assured. This important demand
   necessitates economy in cutting and removal of tooth structure.

This last requirement may be more easily satisfied by the use of an
inlay than by other methods; because of the strength of the casting,
the retention form and resistance form can be kept well within the
required outline and cut to an accurate shape. The extension of the
inlay to the "relatively immune areas" of the teeth is obtained by thin
wedge-shaped projections from the main bulk. The inlay permits the
use of a much longer bevel which favours the use of "slice" preparations
where possible.

In the preparation of cavities for inlays the general steps of
procedure, viz., outline form, resistance form, retention form and the
preparation of walls and margins, should be followed, although quite
often retention form will be linked up with resistance form, and the
attention bestowed upon the preparation of the margins of the cavities
for other types of restorations should in no way be diminished, but
rather increased, in order to permit the easy withdrawal of the thin
The following designs have incorporated into them the mechanisms which have been discussed in the previous sections.

Most of the designs which have been discussed will satisfy certain mechanisms which relate to certain conditions. These forms need to be considered in conjunction with the mechanisms of the system, and together, they assume the form of a model. It is possible that the design of the mechanism is not possible in all instances, and as such, it is necessary to modify the design. The designs in question, whether of the diaphragm or diaphragm-like, must be so arranged to receive a reaction in the direction of movement. As such, the need to receive a reaction from the diaphragm is significant. The need to receive a reaction from the diaphragm is important, as this will provide the design with a reaction which can be transferred to the diaphragm. The diaphragm can be so arranged to receive a reaction from the diaphragm-like mechanism.

In the case of the diaphragm, the diaphragm-like mechanism is necessary, as it provides the necessary reaction to the diaphragm. The diaphragm can be so arranged to receive a reaction from the diaphragm-like mechanism.
MECHANICAL FACTORS IN INLAY CAVITY PREPARATIONS. 48

higher in its centre than at its periphery. Increased retention may be obtained by the use of grooves on the walls of the inlay, as is done with proximo-occlusal and other forms of inlay (cf. Fig. 38).

![Figure 46](image)

**Fig. 46.**—Photograph of a simple box cavity in the occlusal surface of an upper bicuspid.

2. **Posted inlays** (Fig. 47, a and b). In these types of inlays generally little structure remains in the tooth which has lost its vitality, and therefore little help is likely to be obtained from the coronal remnants to retain the restorations. Two methods have yielded favourable results with this type of work, and they have been designed to overcome the tendency of the inlay to rotate about an axial plane. Fig. 47, a, shows the use of a recessed supplemental wall cut around the root canal, and the outline of the recess formed by this wall should be approximately rectangular. Fig. 47, b, shows the use of a slice cut diagonally from labial to lingual, so that the post may be arranged to

![Figure 47](image)

**Fig. 47:**
Mechanical Factors in Intrax Cavity Preparations.
in which much of the labial tooth structure is kept for retention as well as for aesthetic purposes.

Where heavy stresses occur, such as on the upper canine, the importance of the use of a wall to oppose stress is very necessary. Fig. 48, b, shows this type of cavity. The closer the pits are made to the gingival area, the greater the increase in the mechanical advantage of the pins of the casting. This type is readily adapted to posterior regions where broad flat surfaces can be prepared and pits widely spaced.

4. Dovetails. These types of cavities are developed for small restorations and are limited in their application; they are used for small proximal cavities on the anterior teeth and on the lower bicuspids, and occasionally, when developmental pits and fissures are not extensive, other teeth may be suitable for these cavities, otherwise full extension to "immune areas" is essential. Fig. 49, a, shows the geometric form for these dovetail inlays; an open cut is made from the occlusal with sufficient extension buccally and lingually; the retention is then developed by means of grooves cut along the junction of the buccal and lingual walls with the axial wall. The "inlay" is shown at the side of the model, and the extent of the grooving of the line angles is seen. Instead of the grooving the axial wall may be extended buccally and lingually. Fig. 49, b, shows this type applied to a bicuspid tooth, the extension in the proximal portion having been obtained by "slicing" the tooth; a modification is shown in this form which has introduced a "step", thus reducing the bulk of the metal close to the pulp, and the retention has been gained by a minimum of cutting at the expense of the buccal and lingual marginal ridges. The type and its modification is generally useful for lower bicuspids.
The axis of rotation of this type is in the middle, the exact plane of section being determined by the distance between the points of contact on the occlusal surface and the point of intersection of the plane of rotation with the occlusal surface.

By trimming the wax with a knife and adjusting the height of the wax form, the wax form is reduced to the point where the wax form of the restoration is in agreement with the restoration.

Fig. 50.
labial region and the lever system belongs to the Class II type, rotation under stress being prevented by the dovetail step; so that really this type of inlay form comes under the step group which is discussed later. A comparison of the geometric forms of this type and the step group (see Fig. 57, a) will confirm this, and the principles of retention are those discussed on pages 38, 39, 40 and illustrated by Fig. 44. The discussion of this type here is introductory to the larger lingual lock form which exhibits a more complicated mechanical system. As in the specifications set out for inlays, q.e., the retention and resistance form is kept as small as possible and extension is obtained by means of a broad bevel (Fig. 51, b); the geometric form shown in Fig. 51, a, has opposing labial and lingual walls with a gingival wall joining, and, where possible, this form improves the retention.

6. Lingual lock—B. This form shows the extension of the inlay to involve the restoration of the incisal angle; this extension introduces the problem of the Class III lever. With masticatory stress applied to the incisal portion, the axis of rotation is found at the gingival margin (Fig. 22), the power arm is relatively short, and therefore the mechanical advantage of the masticatory force is correspondingly increased, and the cutting of the retention form must be accurate so that movement under the influence of this force is neutralized. As in the previous type, an attempt has been made to preserve as much material as possible to form labial and lingual walls (Fig. 52, b); the geometric form with the inlay rotated out of the cavity (Fig. 52, a) shows this more clearly, and, where possible, this labial wall should be retained so that tendency...
compared with the long arm over which the force of immobilization acts.

than the walls of the lingual step which are of necessity very small.

factor to prevent rotation by a force exerted from the lingual, other

where a plain slice is made on the proximal surface, any gross
defects are filled in with cement and the slice is made straight through

is a disadvantage which is found in the form shown in Fig. 63.

this

for the inhibitory force under a force from the lingual is neutralized, and

FIG: 63
The result may be that the torque action is sufficient to dislodge the inlay from its seat, but the advantage of this form is the protection afforded to the pulp from thermal shock, the ease and speed of preparation in the tooth, and the probability of a more accurate casting result because of the simpler contours. A secondary feature in this form and in the preceding one is the development of a bevel on the incisal edge, so that the enamel in this region may have some protection.

Fig. 54 shows a modification which may be resorted to when extensive caries has caused loss of important areas of the tooth structure.

An extension of the step is made into the cingulum, a short dowel is placed at the base of the cingulum and cutting of the cavity is arranged to permit withdrawal of the wax more towards the incisal aspect. There is a danger in this modification due to the proximity of the pulp, and care must therefore be exercised during cavity preparation.

Fig. 55 illustrates a very important feature of the lingual lock preparations and the value of a correctly prepared incisal wall of the lock. The length of the proximal opening to the lock is about three-fourths of its distal width, but when a suitable force is applied to the incisal edge, rotation of the restoration about the gingival margin readily follows. The position of the gingival wall of the lock and of the inlay clearly demonstrate that these parts play no part in resisting movement of this nature. Fig. 27 demonstrated this point by geometric methods.

The position for the step so that adequate bulk can be given to it and at the same time protect the pulp by leaving sufficient dentine between it and the inlay, seems to be in the middle third incisogingivally. In cutting the cavities in practice it is better to restrict
somewhat the degree of convergence of the incisal and gingival walls of the lock, so that compensation for the distortion of the casting during shrinkage and solidification may be possible.

7. Steps. Grouped under this section are those inlay forms which consist of a step: they exist in proximo-occlusal, proximo-incisal, lingual-occlusal and bucco-occlusal situations; the group is subdivided into Group I posterior and Group II anterior.

Group I, Fig. 56, a, shows that the fundamental design of the lap dovetail is obtained in all other cases of the two groups, whereas retention is obtained by various modifications such as dovetails, supplemental grooves, and dowels. The axis of rotation is the gingival margin in this and in all other cases of this step restoring occlusal or incisal step and involving lingual and buccal surfaces; resistance to rotation is simple and is obtained from the angle at which the step meets the vertical portion and from sufficient depth in the occlusal portion.

Fig. 57, a, shows the use of the lap dovetail (Fig.) and is the fundamental principle underlying the retention form used for all proximo-
occlusal restorations. Fig. 57, b, shows the use of the form applied to a bicuspid tooth where retention is obtained from the triangular ridges of the buccal and lingual cusps, extension of the proximal caries is more extensive and greater loss of the marginal ridges has occurred, the dovetail step is not always possible and the use of a transverse supplemental groove is of excellent assistance in improving retention in the occlusal step. McMath has also advocated the use of a groove in the gingival wall which seems an advantage, especially if a soft alloy is used for the casting, the groove then preventing a spread of the gingival gold towards the proximal, but this is not of as great mechanical assistance as a groove in the occlusal step.
Fig. 58.—c shows a geometric form in which the supplemental groove is used in the occlusal step and is compared with the groove tongue and mortise. (See Fig. 40.) Fig. 58, b, and c, show two views of the application of the supplemental groove to a proximo-occlusal cavity in a bicuspid.

Fig. 59.—c illustrates the geometric form for a step cavity using the supplemental groove in the occlusal step. b, An occlusal view of the cavity prepared in a tooth. c, A proximal view of the cavity seen in b.

Instead of the grooves the use of a pin or dowel is advocated in the occlusal. (See Fig. 59.) To obtain retention equal in efficiency to the groove, the hole is generally cut much deeper than the depth of the groove, and this introduces a danger to the pulp.

Fig. 60 is a model of a proximo-occlusal cavity using a slice preparation, instead of the mortise form for the proximal portion, the retention being augmented by the use of a channel on the axial wall. This modification is generally applied to non-crowned vital teeth used as abutments in fixed bridgework.
Group II. This group uses identical mechanical factors in their retention forms, but differs somewhat, as the retention form itself is necessarily slighter in bulk owing to the reduced anatomical form of that portion of the tooth used to accommodate it. The axis of rotation to masticatory force on the incisal edge is the gingival margin; resistance to rotation about the labial and labio-gingival margins is not so effective as that offered in the lingual lock form and its use is restricted to thick teeth.

Fig. 59.  
Fig. 60.

Fig. 61, a, shows a geometric form of this type of cavity, the proximal form being similar to that of the lingual lock form; labial and lingual walls are formed where sufficient tooth structure remains. The main retentive factor is supplied by the short supplemental groove at the end of the step and the floor of the step is inclined towards the labial wall. The greatest difficulty experienced with this type of cavity is to obtain adequate resistance form in the incisal step if a lingual wall is retained; even if this wall is retained, it is generally too thin for adequate strength and also increases the difficulty of obtaining an accurate wax pattern in this region. The type of cavity applied to an upper anterior tooth is shown in Fig. 61, b, in which may be seen a groove placed at the junction of the axial and lingual walls, the groove being extended into the gingival wall forming a pit which receives a pin in the casting. This pin is placed in an advantageous position to prevent rotation of the inlay about the labial margin; Fig. 30, b, illustrates this position. The mechanical factor in this type of cavity is found to consist of a Class II lever. Fig. 21 illustrates the lever system.

In lower anterior teeth this type of preparation is limited in its application, their reduced bulk preventing anything but the smallest
the upper anterior. The design shown in Fig. 63 illustrates the use of
suitable material to do this in a cavity similar to the one described for
a groove or dowel, and because of the smallness of the tooth, there is seldom
resistance to this stress being developed by opposition. Instead, it is likely that
the direction of stress is shown in Fig. 77, resistance being developed by
the axis of rotation is found in the longosigular region (see Fig. 12). The
stress occurring in these regions is transmitted (see Fig. 12) to the
longitudinal axis of the tooth. It is transmitted from the tooth to the
external preparation, increases the possibility of
several reasons. The use of the mesial-distal form exposes a
step in the form of the preparation, and this step is successful in many cases
(Fig. 62), but is dangerous to the incisal. The use of a pit at the extremity of the
incisal retention form; the use of a bit at the extremity of the incisal
a groove cut in the axial wall and towards the gingival region; this groove is cut at approximately 45° to the axial plane, and deeper at its lingual region. The axis of rotation to stress from the labial becomes the linguo-gingival margin of this groove; the incisal wall of this groove is then directly opposed to any rotation about the linguo-gingival margin. Radiographs of lower anteriors reveal the marked constriction of the pulp chamber at this region which permits the use of the groove (Fig. 64, c). To prevent rotation about the gingival margin, a groove is cut through the incisal edge from labial to lingual; enamel and dentine is then removed from the labial surface, as shown in Fig. 63, so that the incisal step has no walls, but a flat surface opposed to the direction of stress, which
These are the three main types found in this form. They are impossible to separate and most of the features of the box or tooth structure is impossible to use. The retention of any integral model illustrates the axial and incisal of a lower incisor because of the direction of withdrawal of the wax, the retention of any integral model of the lower chamber, the anterior proximo-occlusal restoration; the inferior wall at the side of the axial groove which is in a composite axial groove which is in a composite.

Fig. 64 shows the geometric form of this phenomenon. A lower incisor was included in the composite axial groove where the inferior wall meets the inferior wall of the lower incisor. This is referred to the inferior wall of the axial wall. The direction of the inferior wall of the axial wall in the inferior wall of the axial wall.
group, the characteristic feature of which is the saddle-shape; the finished casting is composed of two larger masses joined by a portion of less bulk. The geometric form is shown in Fig. 65 and, compared with Fig. 38, is seen to exist as the open mortise and tenon; the lever system in (1) and (2) is a double Class II and there exists what might be termed reciprocal retention, the axial walls resisting alternate thrusts tending to cause rotation about the gingival margins; in addition to the axial walls, the buccal and lingual or labial and lingual, where present, also assist in retention and prevent movement in their direction.

Because of this excellent retention form it is possible to approach the "hopper" form of the cavity, especially in these two types, which minimize the possibility of distortion of the wax model of the inlay. The objection to the type (2) form is on aesthetic grounds and, where possible, its use should be avoided. Fig. 65, b and c, shows the two types applied
should be as broad as possible, as in Fig. 66, d.

The section joining the two proximal portions should be as broad as possible, as in Fig. 66, d.

The section joining the two proximal portions should be as broad as possible, as in Fig. 66, d.

The section joining the two proximal portions should be as broad as possible, as in Fig. 66, d.

The section joining the two proximal portions should be as broad as possible, as in Fig. 66, d.
Section 5.—Selection of a Classification for Cavity Preparations.

As shown by Schwartz, there are possible some three hundred and seventy-six preparations for inlay cavities to restore defective tooth surfaces. The grouping of these cavity preparations into various classes has been based on (a) the site of the carious lesion, (b) the number of surfaces involved, (c) the number of steps taking part in the preparation, (d) the shape of the retention form. A classification based upon the mechanical factors involved in the retention forms, as discussed in this work, is herewith given.

Class I.—Posted inlays (Fig. 47). This form of inlay is generally used for restoring large cavities on anterior and posterior teeth in which the main support is derived from a post placed in the root canal, the mechanical factor involved being a lever of the Class I type. See Fig. 20.

Class II.—Step inlays: (a) anterior, (b) posterior. This form involves a Class II lever (Fig. 21); and both types use a step on the surface which is subjected to the stress which they resist.

Type (a) restores the anterior teeth, in which a proximo-incisal restoration is made (Figs. 61, 62, 64).

Type (b) restores the posterior teeth, in which proximo-occlusal or bucco-occlusal or linguo-occlusal restoration is made (Figs. 56, 57).

Class III.—Lingual lock inlays (Fig. 52). This form involves a Class III lever (Fig. 22), and is used to restore the proximo-incisal defects in upper anterior teeth, and the retention form is placed on the lingual surface of the tooth. It should never be used on lower anterior teeth. See Fig. 17.

Class IV.—Saddle-shaped inlays (Figs. 65, 66). In these cavity preparations there is found a double lever system of the Class II type opposed to the main stresses. The M.O.D. and M.L.D. (Fig. 65) restorations belong to this class; the M.L.D. restorations, though using a double Class III lever, may still be placed in this group (see Fig. 66). As well as the M.O.D. restorations, more complex forms, involving the buccal and lingual surfaces, are found, but these types are extensions of the saddle shape with opposed axial walls.

Class V.—Dovetail inlays (Figs. 49, 50). This class has been used to group these types of inlay which are used to restore the proximal surfaces of anterior and posterior teeth; under favourable conditions only are these types used, and then only when the margins of the finished inlays may be laid in "immune areas". The lever system actually involved belongs to the Class II order, but no "arm" exists as in the other types. In place of the dovetail on anterior teeth, a form using a lingual lock (Fig. 51) is generally employed and is a precursor of the lingual lock restoring the incisal angle (Fig. 52).
in this way a reduction of the outline of tooth structures can be
directed from the communication with the most suitable height in mind.
Rejection is often done, through an operator error or may be
healthly tissue, leaving a carious lesion in which
To a degree the radiograph may be said to define the disease and
the examination of the pulp outline the demonstration.

the use of the "white wing" film (fig. 67) would seem a desirable

Section 6—Diagnosis of Carious Lesions

simplification of contour, having four walls and a flat seat.
occasionally the pulpal and periodontal margins are not even.

for axial bridge abutments, sometimes more than two

Mechanical Factors in Primary Preparations
Fig. 67.—Three examples of the assistance rendered by the use of "bite-wing" films in the radiographic examination of the mouth. (The above are prints made directly from radiographs.)

Fig. 68.—Group a shows wide pulp chambers or pulp chambers close to the incisal edge. Group b shows pulp chambers more favourably situated for the lower incisor restorations.
already in use. suggested an addition to, not as a substitution for, those classification
mechanical factors in each type. have been attempted and has been
shown. 8 A classification of intra cavity, mainly based upon the
effect of these been demonstrated.
7 The importance of economy of tooth substance has been stressed
readily perceived.
6 The application of these forces to simple geometrical models and
to the models of the teeth has enabled the comparison to be made
of which can be and are incorporated in newly cavity designs.
5 Certain types of retentive form are needed in other arts, the main
dependence upon the lower system to which each retentive form belongs.
4 Certain mechanical factors arise in the various retentive forms.
3 Can be resisted along certain planes., when the various inclusal retentions
may become a portion about the lingual or buccal gingival margins.
(2 The retentive forms in the direction of the forces the teeth to stress which tend to
treach in dispersion of the forces of retention, these alae-
are alone. 2 The lower inclined movements produce the necessary force into
the hinge movement the mandible functions as a lever of the second class.
In the hinge movement the mandible functions as a lever of the second class.
3 these inclusal movements produce the necessary force into
the hinge movement the mandible functions as a lever of the second class.
are alone as possible members.
(0) A right and left lateral movement in which the condyles
(1) The protractile movement
(2) The hinge movement
(3) The hinge movement
Relationships, the movements are as follows:
certain movements some of which give to an already occlusal
appearance during functional movements in the act of mastication, reveals
groups of teeth of the upper and of the lower also in these groups, the masticatory

Summary.

MECHANICAL FACTORS IN INTRA CAVITY PREPARATIONS.
Conclusions.

The aim of the work has been to examine various cavity designs and approve or modify them. In many cases it has been found that the form of the inlay and its cavity has been developed from, and maintains the excellent features of, other fundamental forms of joint; but the peculiar demands made upon restorations in operative dentistry sometimes produce deficiencies in the finished restorations which may be made good in the inlay whilst maintaining those retentive features. In general, the cavity designs in existence for other materials have been justified, but, because of the strength of the cast gold inlay, with its rigid whole, it is possible to reduce in amount the tooth structure which generally has to be removed to make adequate resistance and retention form for the plastic materials, and to achieve the necessary “extension for prevention” by the use of slice preparations without reducing the mechanical efficiency of the design.

In some cases it is possible to dispense with the use of the auxiliary step; in others it is necessary to amplify the methods of retention by means of supplemental grooves, dowels and dovetails, in the first case gaining retention without too great a sacrifice of tooth structure, and in the second case where loss of tooth structure through disease has been extensive.

In the case of the lower incisors an attempt, based upon mechanical concepts, has been made at a modification of the existing form; this attempt has in certain cases promised to lessen the difficulty of a problem in restorative work of this nature.

In practice, it has been found that grooves seem preferable to dowels or pins when the step formation does not admit of other retention forms; the groove has certain advantages such as the absence of any great depth, simple alignment with other walls of the cavity, absence of any difficulty in obtaining the wax pattern, and function for the full width of the step in which it is placed.

In general, I have found an accurate retention form, correct in outline and placed to advantage with a flat floor in the occlusal, or the incisal, or the lingual, to be the important feature in the design of the inlay cavity; and it would seem that the inlay is very much more dependent upon correct outline form than are the plastic materials which will withstand stresses when the internal dimensions of the cavity are greater than the external. The proximal portion of certain inlays does not help to increase retention very much, so that in extreme cases, if the tooth structure is not available, the retention of the inlay will not suffer as much as might be expected. In anterior teeth in which a lingual lock is used a slice preparation on the proximal surface requires some further assistance to prevent rotation about its pivotal centre, and in
Bibliography


Mechanical Factors in Inlay Cavity Preparations
MECHANICAL FACTORS IN INLAY CAVITY PREPARATIONS. 67

August, 1931, p. 759.


The Influence of Mechanical Factors in the Design of Inlay Cavity Preparations.

THESIS.
THESIS

submitted for the degree of

MASTER OF DENTAL SURGERY

by

ROBERT HARRIS B.D.S.

PREFACE.

In presenting this work, the aim has been to use diagrams, simplified models and large models (magnified approximately 8 diameters). The models are from the collection made by the author for demonstration purposes, and have been reproduced by the kind permission of the Dean of the Faculty of Dentistry, Professor A.J. Arnott.

The skull used for the photographs in Figs. 2, 3, and 4 was kindly lent by Professor A.N.St.G. Burkitt of the University of Sydney, to whom I herewith express my sincere thanks.

The photography is the work of Mr. P.A. Peachey, to whom I am indebted for the patience and skill which he has displayed in the execution of this work.

Sydney.

February 1938.

[Signature]
TABLE OF CONTENTS.

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Introduction</td>
<td>1 - 5</td>
</tr>
<tr>
<td>1</td>
<td>Movements of the mandible and the forces of mastication</td>
<td>6 - 27</td>
</tr>
<tr>
<td>2</td>
<td>Mechanical principles</td>
<td>28 - 44</td>
</tr>
<tr>
<td>3</td>
<td>Geometric forms of retention and allied subjects</td>
<td>45 - 62</td>
</tr>
<tr>
<td>4</td>
<td>Application of the geometric forms to the teeth</td>
<td>63 - 91</td>
</tr>
<tr>
<td>5</td>
<td>Selection of a classification for cavity preparations</td>
<td>92 - 93</td>
</tr>
<tr>
<td>6</td>
<td>Diagnosis of carious lesions</td>
<td>94 - 96</td>
</tr>
<tr>
<td></td>
<td>Summary</td>
<td>97 - 98</td>
</tr>
<tr>
<td></td>
<td>Conclusions</td>
<td>99 - 100</td>
</tr>
<tr>
<td></td>
<td>Bibliography</td>
<td>101 - 103</td>
</tr>
</tbody>
</table>
INTRODUCTION.

The aim of this work has been (a) to investigate the problems of retention peculiar to inlay restorations, (b) to apply the results of the investigations to the designing of suitable types of cavities which may, in some cases, assist in surmounting the difficulties which frequently occur in this branch of Operative Dentistry.

Although there are many and varied possibilities which the ravages of caries may present for restoration if the basic principles of the function of occlusion and the mechanical forces thereby injected into the problem are analysed, it should be possible to have a clearer conception of the special demands made upon this type of restoration and so relieve the operator of some of the anxieties and doubts which frequently arise in understanding restorative work of this nature.

Some aspects of this problem have been presented by Davis (1), Bronner (2), (3), and others, and the author has attempted to enlarge the scope of the problem with the hope of approaching the various difficulties encountered in mouth conditions with a rational technique.

Marshall (4) defines an inlay as a piece of any substance, like gold, porcelain, which is inserted in a cavity prepared to receive it; the distinction between an inlay and a filling being that the inlay is constructed away from the mouth and is inserted into the cavity in one homogeneous mass and retained in its position by means of cement, whilst the filling is introduced into the cavity in numerous small pieces which either cohere or are welded (in the case of cohesive gold foil).

(2) Bronner F.J. Dental Cosmos Vol. 73, No. 6, 1931, pp.577.
(3) Bronner F.J. Dental Cosmos Vol. 74, No.11, 1932, pp.1085.
to make a solid mass, or are held together by mechanical pressure or the interlacing of particles (in the case of non-cohesive gold foil), the completed filling being held in place by the close adaptation of the material to the walls of the cavity and with the assistance of the retentive form which has been given to it. The plastic filling materials, amalgam, silicates, and cements, differ in a similar manner from the inlay although the cements possess adhesive properties.

It may be said that the inlay has no retentive value when opposed to a stress which tends to move it in a direction opposite to the direction of insertion other than that of the crushing strength of the cementing medium. It is an advantage, therefore, to arrange the direction of insertion of the inlay to correspond, wherever possible, with the direction of greatest stress; that stress tends to maintain the inlay in its position provided the resistance form of the cavity is adequate. A complication which the introduction of the cast gold inlay by Taggart in 1907 brought to cavity preparation and design, was the difficulty of so shaping the cavity to permit withdrawal of the wax model of the finished inlay and at the same time to avoid weakening the tooth and endangering the pulp whilst faithfully observing Black's dictum of "extension for prevention". Black (5) has said "extension for prevention means only the laying of the margins of cavities so near the angles (of the teeth) as to obtain the benefit of cleaning in the excursions of the food. If this can be had in narrow cavities it is well. If it can be obtained by separating the teeth and building proximal contacts that is well. If the case requires wide cutting to accomplish it that should be done. If the case is one that has become immune to caries that fact may have consideration." In the application of the above

principles the operator has to be guided by local conditions, age of the patient, habits of the patient and the general condition of the patient, for each individual case, and finally the ultimate outline of the cavity is determined by the line of cleavage of the enamel. In general, it will be found that the cast gold inlay can be designed to withstand all the demands set out above and, with suitable designing of the cavity preparation, to accomplish this with less wastage of tooth structure; too much cutting for retention is worse than too little for, besides the pain occasioned thereby, the strength of the tooth is endangered. This view is supported by Gowan (6) and others.

The inlays constructed prior to Taggart's era were made after the manner of Alexander (7) whose method had as its basis the swaging of a thin gold or platinum foil to the cavity and then filling in the occlusal contour with an alloy or, alternately, soldering a thin pure gold foil across the opening. These methods somewhat restricted the application of the inlay principle to relatively simple cavities. The Taggart method, because of inherent physical characteristics of the materials used, did not always produce an accurately fitting casting, but, following investigations by Price (8), Van Horn (9), Maves (10), Meyer (11), and others, the probability of obtaining in every attempt an accurately fitting casting is greatly enhanced.

With their more accurate methods yielding close fitting inlays it should be possible to apply mechanical principles to the problems of retention and dislodgment and, from an analysis of these two factors, gain some information which may indicate a modification of cavity design. Any design which will economise

(7) Alexander C.L. Dental Cosmos, October 1896.
tooth structure and minimise trauma is of vital importance. Fish (12) has shown that the subjection of dentine and enamel to external trauma frequently produces a marked reaction in the pulp which may be unfavourable to its longevity, and Applebaum and Bodecker (13) in their investigations have demonstrated that (a) "dentine and enamel are most permeable in the teeth of young individuals, (b) high permeability of the dental tissues appears to be a factor in rampant caries" and therefore the reduction of the area of dentine exposed to the oral fluids and the reduction of any external irritation are highly desirable in such circumstances so that the pulp may react favourably.

A factor which may be an advantage in using an inlay, as shown by Bodecker and Applebaum (14), is that oxyphosphate cements produce a favourable reaction in the dentine, so that one may be disposed to use an inlay in preference to other restorations.

Because of the particular technique required for the restoration of a tooth with an inlay the various mandibular movements influence to a marked extent the design of the prepared cavities. Within certain limitations, the inlay depends more upon the outline of the cavity for its retention than upon the internal shape of the cavity; it differs in this from the plastic materials the peculiarities of which demand that the outline of the cavity cover less area than that covered by some plane within the cavity; this plane or planes generally being the axial and/or pulpal walls. The movements of the mandible and the stresses which the masticatory forces place upon the teeth during those movements are discussed so that a means may be devised to resist those stresses which may be applied to restorations placed in the teeth.

With this objective the subject matter has been grouped as follows:-

1. Movements of the mandible and the forces of mastication
2. Mechanical principles
3. Geometric forms of retention and allied subjects
4. Application of the geometric forms to the teeth
5. Selection of a classification for cavity preparation
6. Diagnosis of carious lesions

Summary

Conclusions.

Certain types of joints or methods of fixing two or more materials to form a rigid whole are used extensively in various crafts and the retention of many types of inlays is obtained by the use of similar formations in the tooth structures and consequently in the shape of the inlay. The conditions existing in both cases may not always be identical but there exists sufficient similarity between the methods for the mechanical factors of either to be applied to the other. The use of simple geometric forms, viz. cube and pyramid, as substitutes for the posterior and anterior teeth respectively after the manner of Schwartz (15) has been introduced to simplify the study of the problem.

Combinations of various forms of cavities frequently arise resulting in complicated designs, but the principles involved arise in their simple components and a discussion of the many combinations has in most cases been omitted to avoid the repetition which would be inevitable in dealing with the 376 possible preparations (15).