Mechanics in the Production of Mandibular Fractures: A Study with the "Stresscoat" Technique. I. Symphyseal Impacts

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A recent study of 319 case histories of mandibular fractures by Hagan and Huelke[1] has shown that certain areas of the jaw are fractured more often than others and that the incidence of certain mandibular fractures is greater when the blow is directed to specific regions of the jaw. Relatively little is known about the response of the mandible to impact, except that, when the magnitude of a blow is sufficient, the bone will break. How does the mandible fracture, and what are the mechanisms involved? These questions have not been answered because of the lack of experimental data. Obtaining these data is an engineering problem involving stresses, strains, impacts, energies, and forces, and thus engineering techniques must be used.

This report, the first of a series of studies on the mechanism of mandibular fractures, presents data on forces and impacts applied to the chin point of the mandible and the resultant deformations of the bone. The results of these tests are correlated with certain clinical findings.

Terminology.—Throughout this report certain terminology generally used in engineering will be employed. Some of these terms need to be defined. The term *force* is defined as a push or pull. The various types of force are illustrated in Figure 1. *Tensile* forces (tension) tend to pull an object apart; *compressive* forces (compression) push the particles forming an object together, while *shearing* forces make one part of an object slide over another part of the same object. When two parallel, oppositely directed equal forces with different lines of action are applied perpendicularly to the long axis of an object, a *torsion* or twisting effect is produced. Here one part of the object is rotated about another part. Forces are measured in mass units (kilograms, pounds, etc.).

Energy is simply defined as the capacity to do work. The magnitude of the energy applied is calculated by multiplying the weight of a falling object by the distance through which it passes.* Energy is then measured in mass-length units (kilogram-

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* Energy of a moving object is usually calculated from the formula $\frac{1}{2}MV^2$, where M is the mass of the object and V the velocity of its motion. Because of the principle of conservation of energy, energy may be determined from the potential-energy formula WH, where W is the weight of the object and H the distance the object has fallen. Because of the difficulty in determining the velocity of the falling sphere, the potential-energy method was used in calculating the energy of impact.

meters, inch-pounds). Force and energy are not synonymous. The term "energy" should be used in dynamic situations involving damaging levels of force, whereas force should be used when the load is statically (slowly) applied.

Stress and *strain* are terms that are often used synonymously and incorrectly. *Stress* is the intermolecular resistance of an object to the deforming action of external forces. It is measured in units of force divided by the area to which the force is applied (grams per square centimeter, pounds per square inch). *Strain* is the change in linear dimensions of an object due to an outside force that has been applied. Unit strain represents the change in length per unit of length in the object (inches per inch, etc.).

EXPERIMENTAL METHODS

Material.—For this study, 27 human mandibles* were used. Included were dentulous and edentulous mandibles and specimens with only the anterior teeth. In addition, each group had individual bones with an obtuse, intermediate, or acute gonial angula-

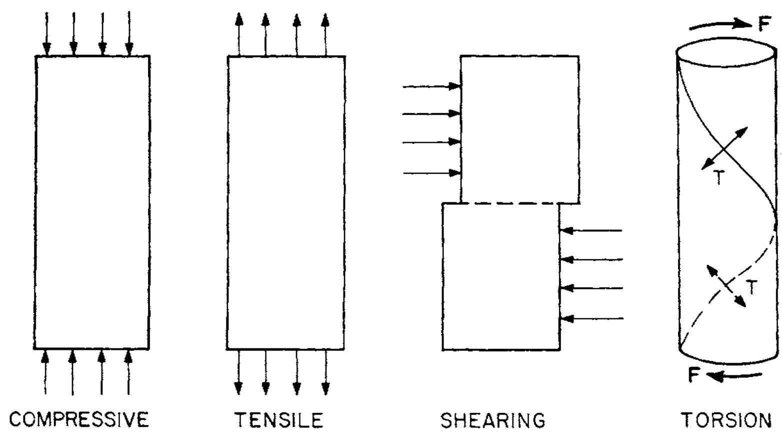

FIG. 1.—The various types of force to which a body may be subjected. Arrows indicate the direction of the force. *T*s on cylinder undergoing torsion indicate the direction of the tension produced by the twisting action. (Modified from Evans, *Ann. N.Y. Acad. Sci.,* **63**:586, 1955, and *Instr. Course Lect., Am. Acad. Orthop. Surg.,* **9**:264, 1952).

tion. Also, certain specimens had very obvious, well-defined, bony markings (ridges, tuberosities, etc.); others were generally quite smooth, with bony markings less heavily textured. No obvious bone pathology was noted. Information on age, sex, and race of the bones was not available.

Theory and technique.—In order to determine visually the areas of highest tensile strain concentration in bone due to a force or impact, the "Stresscoat" technique was employed. "Stresscoat"† is a trade name for a brittle, resinous lacquer developed by deForest and Ellis in 1940.[2, 3] The lacquer is sprayed on the bone and allowed to dry 15–20 hours before testing. Steel calibration bars are coated along with the test specimens. Just prior to the bone tests, individual bars are tested as a cantilevel beam and

* From the osteological collection of the Department of Anatomy, University of Michigan Medical School.

† Magnaflux Corporation, Chicago, Ill.

placed in a scale that gives a direct reading of the lacquer sensitivity in inches per inch (Fig. 2). It was assumed that the sensitivity of the lacquer was the same on both the bars and the bones, for both were dried under the same temperature and humidity conditions.[4] The sensitivity of the lacquer used in the tests varied from 0.005 to 0.013 inch/inch [500–1300 micro inches/inch (MII)]; the majority of the bones were tested with a lacquer sensitivity of 600–800 MII.

Stresscoat cracks in response to the tensile strain in the underlying material on which it has been sprayed, with the cracks lying perpendicular to the direction of the strain. The cracks always appear first in the area of highest tensile strain. When material such as bone breaks more readily in tension than in compression,[5] failure (fracture) will occur at a region of highest tensile strain. It has been found[6] that the Stresscoat deformation patterns on dry bones (skulls) are similar to those produced in living animals under similar test conditions. The major differences are that deformation patterns are more extensive in the living animals and the patterns tend to be interrupted by suture lines in the dry skulls.

Immediately before testing, the bone is coated with a penetrant fluid. When the force or energy is applied, the penetrant liquid flows into the lacquer cracks; after testing, the surface of the bone is wiped dry, the penetrant liquid remaining only in the cracks. The bones are then sprayed with an electrostatic powder,* which, attracted by the penetrant fluid, collects in the cracks, making them plainly visible. The patterns are then inked and the bones photographed.

* Statiflux, Magnaflux Corporation.

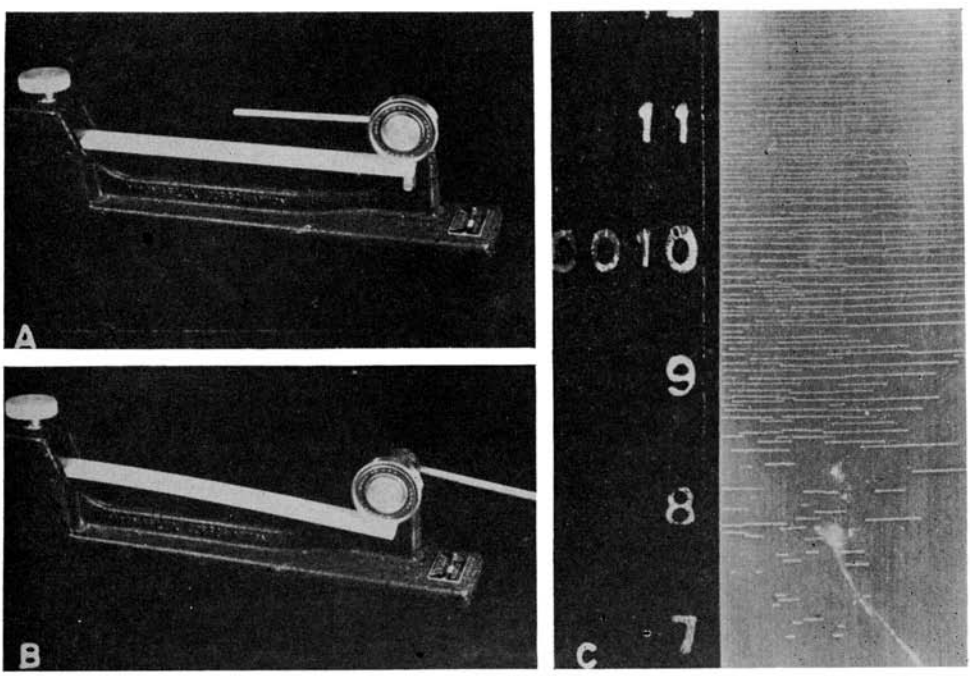

Fig. 2.—Method of determining lacquer sensitivity. *A,* Stresscoated metal bar ready to be tested. *B,* bar bent by deflection of handle. *C,* close-up of Statifluxed bar in scale; lowest lacquer crack at 7, indicating lacquer sensitivity at 0.0007 inch/inch.

In the static loading tests a force of 25–70 pounds was applied to the mid-line of the chin at the inferior border of the bone.The time of loading was 1 minute. All bones were oriented so that a line through the chin point and condyle was perpendicular to the horizontal base plate. Static loadings were carried out in a Riehle testing machine with an accuracy of 1.0 per cent (Fig. 3). The condyles were placed in cupped steel blocks and the chin point covered by a small strip of leather to prevent the bone from slipping away from the force applicator, which had a diameter of 0.68 inch. A total of 103 static loadings was made on the 27 mandibles.

In the dynamic testings the bones were oriented as above, but the method of condylar fixation varied. In one group of tests the condyles were imbedded in cupped base plates filled with clay. These base plates were mounted in tracks, so that, when necessary, the base plates could be moved according to the intercondylar distance of the individual test specimen. The tracks were welded to a $\frac{7}{8}$-inch steel plate weighing 94 pounds (Fig. 4). Because of the mass of the plate, the energy absorbed by it was negligible. In this manner, 191 tests were completed.

In another series of tests the condyles were imbedded in a solid bar of Woods metal —a low-temperature alloy—and placed in a 41-pound bench vise, which was also mounted to the steel plate (Fig. 4). Using this type of condylar fixation, 146 tests were performed.

In the third set of tests, an area of the Woods metal bar under the left condyle was

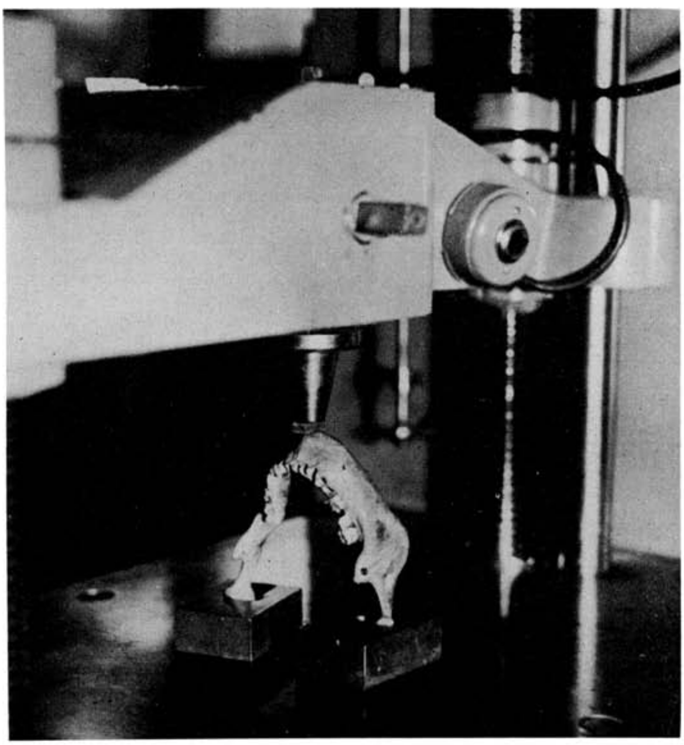

FIG. 3.—Close-up of Riehle testing machine, mandible under static load

removed and filled with clay, and the Woods metal bar was fixed in the bench vise (235 tests). Thus in these dynamic tests the condyles were free to move (imbedded in clay), firmly fixed (metal), or one condyle fixed, with the other free to move. The load was dynamically applied to the mandible by dropping a steel ball, 1 inch in diameter and weighing 0.146 pound, through a metal tube 0.69 foot in length. The energy applied was 0.101 foot-pound. The friction between the ball and tube was negligible. Preliminary testings indicated that this amount of energy, although small, was sufficient to crack the lacquer in the areas of high tensile strain. Experimental studies, using the Stresscoat technique, wire-resistant strain gauges, and loading the bone to failure, have shown that linear fractures of the skull, pelvis, and femur arise from failure of the bone due to tensile stresses and strain within it at the initial areas of high-

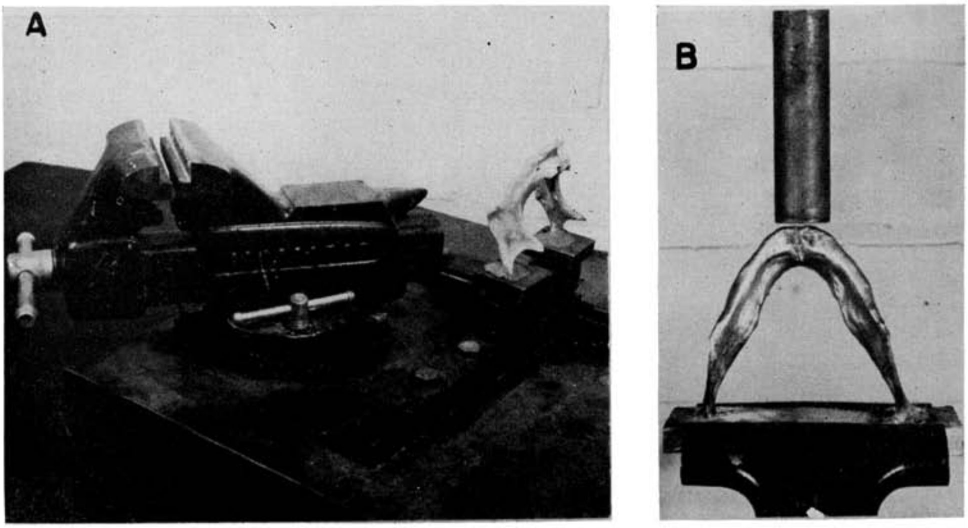

FIG. 4.—*A*, apparatus used in dynamic loadings. Note mandible in clay-filled base plates. *B*, close-up of mandible mounted in bench vise with tube, through which the weight was dropped, over the point of load application.

est tensile strain.[7–13] Therefore, only the minimal amount of energy required to crack the lacquer was used. When a greater magnitude of energy was applied, but not sufficient to break the specimen, extensive deformation patterns appeared, and it was not possible to determine which regions were the initial high tensile strain areas.

RESULTS

Although each region showing a deformation pattern will be described separately, it must be remembered that these strain patterns usually appeared on each individual bone. That is to say, the bone reacts to impacts as a unit, not as isolated parts. The areas involved are (1) subcondylar region, (2) lingual side of chin, (3) buccal or labial alveolar walls, (4) mental foramen, (5) miscellaneous areas.

Subcondylar deformation patterns occurred more frequently than any other. Most often the lacquer cracks were found on the lateral side of the condylar neck (Fig. 5), indicating that the condyles were bent medially, thereby producing high tensile strain on the lateral side. With an increase in load, the subcondylar patterns became more extensive and spread down the ramus by further outbending of this region (Figs. 5 and 9).

When the medial end of a condyle was in contact with the side of the base plates, only an outward bending of the condyle was possible. In these cases a deformation pattern was found on the medial side of the neck of the mandible (Fig. 6).

With both condyles imbedded in metal, a medial or lateral bending of the condyle was not always noted. In approximately 40 per cent of the tests, there were deformation patterns located on both sides of the neck, with the lacquer cracks on the lateral side parallel in direction to those on the medial side (Fig. 6). This indicates that tension was produced on both sides of the subcondylar area. With the condyles fixed in metal, they are unable to move. The movement necessary to produce these subcondylar deformation patterns must then be in the neck itself. In these cases there is an oscillation in the subcondylar area, which first bends in one direction and then in the op-

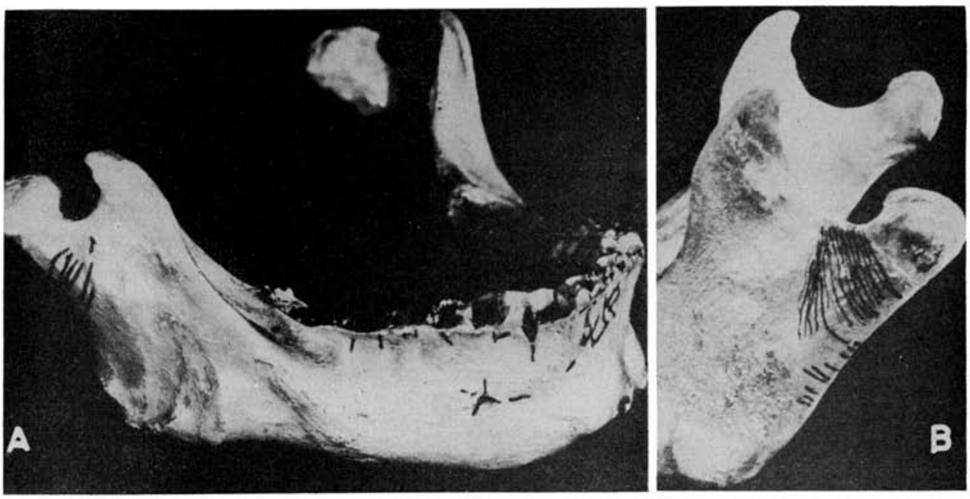

FIG. 5.—*A*, typical lateral subcondylar deformation pattern with other deformation patterns about the buccal alveolar walls, mental foramen, and lateral chin regions. *B*, extensive subcondylar deformation pattern.

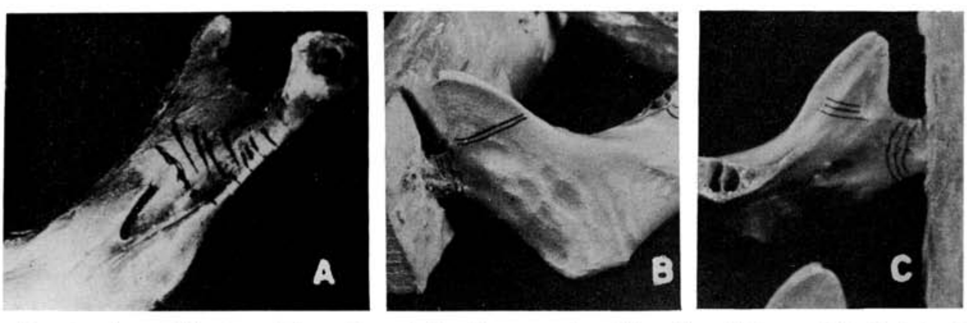

FIG. 6.—*A*, medial subcondylar pattern, indicating an outward bending of the condyle. *B*, lateral subcondylar and coronoid process patterns. *C*, medial subcondylar and coronoid process patterns from same bone as that shown in center picture. Medial and lateral deformation patterns on the same side indicate a vibration of the neck of the mandible and coronoid process.

posite direction, beyond the resting position of the bone. Also with this type of condylar fixation, the occurrence of deformation patterns on only the medial side of the condylar neck was quite high, in about one-third of the tests.

In addition to the subcondylar patterns described above, bones, with condyles imbedded in metal also had posterior subcondylar patterns (6 per cent), indicating a stretching of this area. This high tensile strain along the posterior border of the neck of the mandible is due to a forward bending of the condyle (Figs. 7 and 8). Rarely (3 per cent) was there a twisting of the condyle noted. Here the lacquer cracks of the lateral aspect of the neck are perpendicular in direction to those found on the medial side.

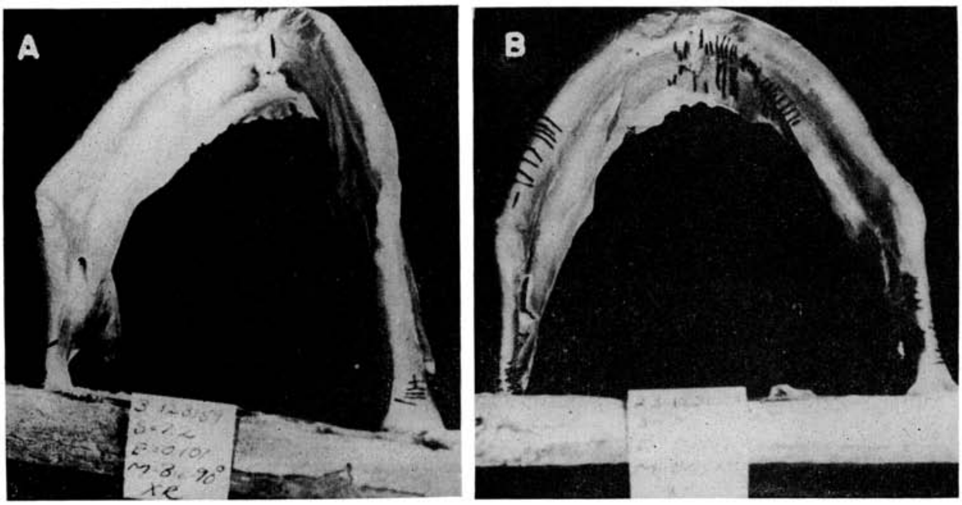

FIG. 7.—*A*, minimal posterior subcondylar and lingual chin deformation patterns, condyles fixed in metal. *B*, more extensive posterior subcondylar patterns, with inferior angle pattern on the right side and extensive lingual chin pattern on the left. In this case the right condyle was imbedded in metal and the left condyle in clay.

When one condyle was imbedded in metal and the opposite condyle in clay, the subcondylar deformation patterns were not always the same on the two sides. Usually both condyles had deformation patterns on their lateral sides, indicating a medial or inward bending. However, in about 20 per cent of these tests the subcondylar area of the metal-imbedded condyle vibrated.

Vertically oriented deformation patterns were found on the lingual aspect of the chin (Figs. 7 and 8). From the energy applied to the labial side of the symphysis, tensile strain was produced by an inbending (flattening) of the chin and a concomitant stretching of the lingual cortical plate. The cracks were not always grouped on the mid-line, but rather they were located adjacent to the mental spine and about it. The cracks rarely extended through the mental spine, although they were found on the apex of the spine. Occasionally, part of the deformation pattern continued from above the spine and around it to reach again close to the mid-line in the lower half of the chin. This indicates that the greatest amount of tensile strain in the chin area is not produced directly on the mid-line but is paramedian in location and that the symphysis is somewhat resistant to stretching, owing, in part, to the strengthening effect of the mental trigone labially and the mental spine lingually. With one condyle fixed in metal and the other free to move in clay, the lingual chin pattern was more extensive on one side—the side on which the condyle was free to move—indicating that a greater amount of tensile strain was produced here on this half of the bone and that the other half of the mandible was more rigid (Fig. 7).

The buccal alveolar walls tend to concentrate stresses. This is due to the sharp edges of the alveoli, the thinness of their walls, and the fact that the curve of the buccal alveolar wall is superimposed on the outer curve of the mandibular arch, which is, in general, the tensile side of the bone. Tensile strain cracks were found extending from

FIG. 8.—Typical posterior subcondylar and lingual chin patterns with minimal inferior angle deformations on the left side and an extensive angle pattern on the right side.

the edge of the buccal side of alveoli, indicating a mesial-distal compression of the alveoli, with stretching of the outer walls (Fig. 5).

High tensile strain was developed about the mental foramina, especially in static tests and dynamic tests in which the condyles were imbedded in clay. Here the deformation pattern appeared as cracks distributed radially about the foramen produced by a stretching of the bone in a circumferential direction around its margin (Fig. 9). Less extensive mental foramen patterns, where only a few cracks appeared, indicate that the stress concentration occurred in only one or two places on the edge of the foramen.

Less frequently—in 20–35 per cent of the tests—patterns were noted about the lateral chin region, oblique line and buccal shelf, alveolar ridge, lingula, and lingual tuberosity. Deformation patterns located between the chin point and the mental foramen—the lateral chin region—were usually found with patterns about the mental foramen. When the chin was flattened, high tensile strain was produced in this area near the mental foramen.

The oblique line, buccal shelf, and alveolar ridge showed deformation patterns produced by bending and/or twisting actions. In these areas, patterns perpendicular to the long axis of the bone indicate that high tensile strain was produced by an outward bending of the oblique line, buccal shelf, and lateral part of the alveolar ridge (Figs. 9 and 10). Obliquely oriented cracks in these areas (Fig. 10) indicate a twisting of the body on the ramus, with the alveoli or alveolar ridge turning downward and lingually. In addition, a slight amount of twisting was occasionally found in the subcondylar region, as noted previously.

Lacquer cracks about the lingula indicate a concentration of high tensile strain, although this area is on the compressive side of the mandibular arch. Likewise, the lingual tuberosity on the medial side of the third molar tooth had a deformation pattern,

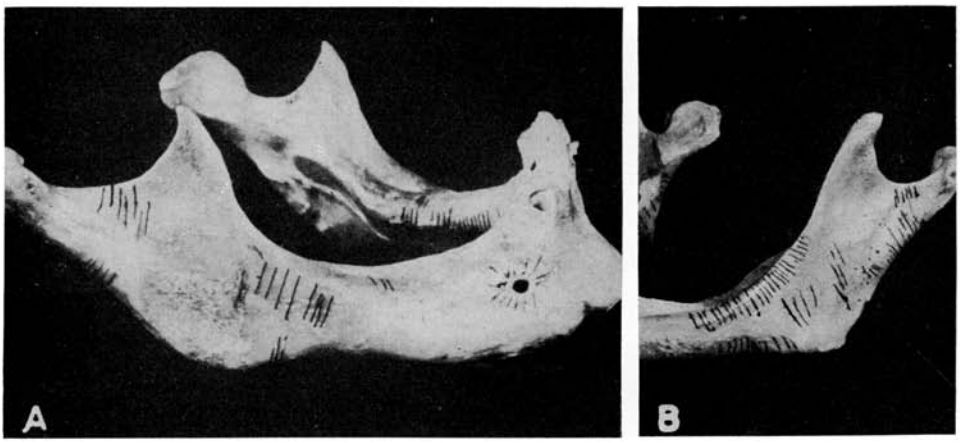

FIG. 9.—*A*, subcondylar, oblique line, and mental foramen deformation patterns. *B*, similar patterns but more extensive than those in *A*.

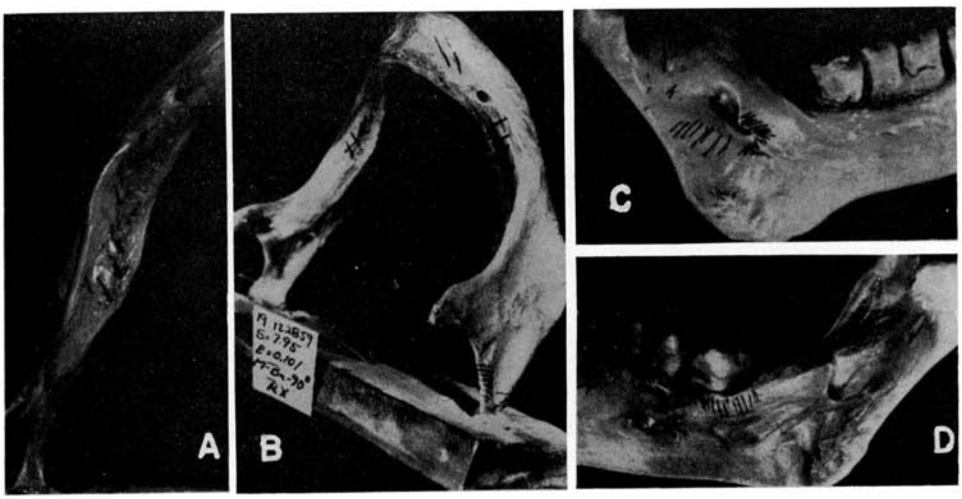

FIG. 10.—*A*, oblique buccal shelf and alveolar ridge deformation patterns. *B*, alveolar ridge patterns perpendicular to the long axis of the bone. Patterns about the lingula (*C*) and lingual tuberosity (*D*).

indicating that tensile strain arose from a bulging of this area lingually (Fig. 10). Deformation patterns at the base of the coronoid process were noted in testings with at least one condyle imbedded in metal. The patterns were found on the lateral or medial side or on both sides of the base of the coronoid process (Fig. 6). Here the process is bent either inward or outward, or vibration of the process takes place. The majority of the coronoid process deformation patterns were found on 10 bones, most of which were edentulous specimens. This vibratory phenomenon was noted more often when both condyles of the test specimen were imbedded in metal.

When both condyles were imbedded in metal, symphyseal impacts produced high tensile strain in the region of the antegonial notch (Figs. 7 and 8). These patterns were more frequent in edentulous specimens. In these cases the tensile strain is produced by a stretching of the bone parallel to and along the base of the mandible in the region of the antegonial notch, patterns which at times extended forward along the base of the mandible in front of the antegonial notch.

DISCUSSION

Up to this time, very few mandibles have been tested to determine their response to forces and impacts. In 1935, Küntschner,[14] using Colophonium (an early type of strain-sensitive lacquer), found deformation patterns about the mental foramen and adjacent buccal alveolar walls. These patterns were vertically oriented and were due to a "bending load." The method of application of the load was not stated; only one bone was tested. Evans,[15] using Stresscoat, statically loaded two mandibles; one specimen had unilateral subcondylar and inferior angle tensile strain deformation patterns produced by a static loading of 59 pounds. This force was applied to the chin point in a line parallel to the long axis of the body. In another specimen, a force of 175 pounds was applied to a brass rod laid across the inferior body of the mandible near the angle; in this test there was an extensive unilateral medial subcondylar pattern with a pattern on the lingula. DuBrul and Sicher[16] found high tensile strain patterns between the mental foramina, produced by squeezing the condyles of one mandible together with finger pressure. Ueno, Oka, Miyagawa, and Kobayashi,[17] using Stresscoat and strain gauges, tested mandibles and acrylic models by applying forces and impacts to the symphysis and angle regions. The number of tests is not indicated in their report. Static loadings applied to the symphysis of acrylic models revealed high tensile deformation on the lingual aspect of the chin and the lateral side of the subcondylar, ramal, and angle regions. These patterns are similar to those found in the present study. Sharry, Askew, and Hoyer,[18] using Stresscoat on dry skulls, found deformation patterns on the mandible, maxilla, and adjacent facial bones following simulated biting forces on complete dentures.

The energy of a blow to the symphysis causes the condyles to be seated in the joint cavities. The question now is, "Are the condyles movable?" There are several possibilities: (1) they may be firmly fixed; (2) although forced into the joint cavities, they may be relatively free to move as the condyle slides on the disk; (3) the condyle-disk unit may slide in the mandibular fossa. Experimentally, an attempt has been made to duplicate these possibilities by firmly fixing the condyles in metal or allowing the condyles to move by putting them in a soft medium (clay).

The response of the mandibles to symphyseal impacts is dependent, in part, on the method of condylar fixation. If the condyles are relatively free to move, i.e., imbedded in clay, the mandible behaves as an engineer's pin-jointed arch (Fig. 11). Application of the force at the center of the arch subjects the entire outer surface of the arch, except at the point of impact, to tensile stresses and strains. However, as found experimentally, the strain is concentrated in the subcondylar and mental foramen areas and along the buccal alveolar walls, the greatest amount of deformation occurring in the subcondylar areas. Tension also is developed on the inner aspect of the curve of the arch (the lingual chin area) as the result of the flattening of this region by the energy applied to the opposite side.

When the ends (condyles) of the arch are imbedded in metal they are unable to move, and the response of the bone is somewhat different. Although flattening of the chin area and outward bending in the mental foramen areas still occur, there is an inward bending of the limbs of the arch near its fixed ends (Fig. 12). In the dynamic tests, with the condyles imbedded in metal, this was evidenced by the medial subcondylar deformation patterns. Even more frequently observed was a vibratory phenomenon, evidenced by deformation patterns on both the medial and the lateral sides of the same subcondylar area, the result of an undulating movement of the subcondylar region itself.

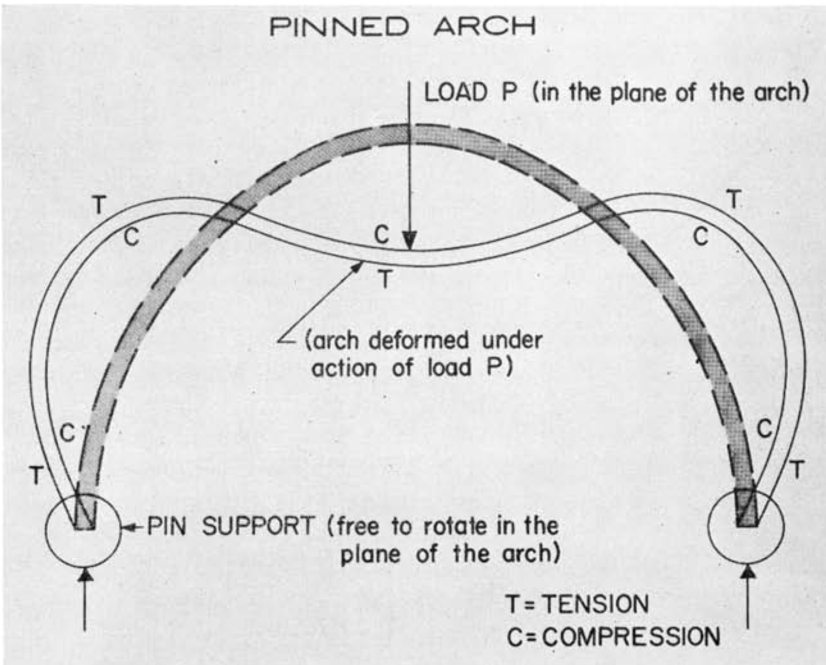

FIG. 11.—The effect of load on an arch the ends of which are free to move

When the right condyle is imbedded in metal and the left in clay, the response is in some respects similar to a combination of results of the other dynamic testings described above. In general, the entire arch shifts to the left—the side of least resistance. This occurs by a bending in three areas: the lateral aspect of the right and left subcondylar regions—as evidenced by deformation patterns located here—and by a flattening of the lingual aspect of the chin, especially on the left side of the mid-line. This latter pattern indicates that the entire left half of the arch is moving laterally, with the tension, produced by the movement, located in the left lingual chin region. When the bone rebounds from the impact, frequently the mandibular arch goes beyond its rest position, so that there are high tensile stresses developed on the medial aspect of the right subcondylar region.

Marked surface irregularities will tend to concentrate stresses. These irregularities take the form of projections (lingulae), bulges (lingual tuberosity, alveolar walls),

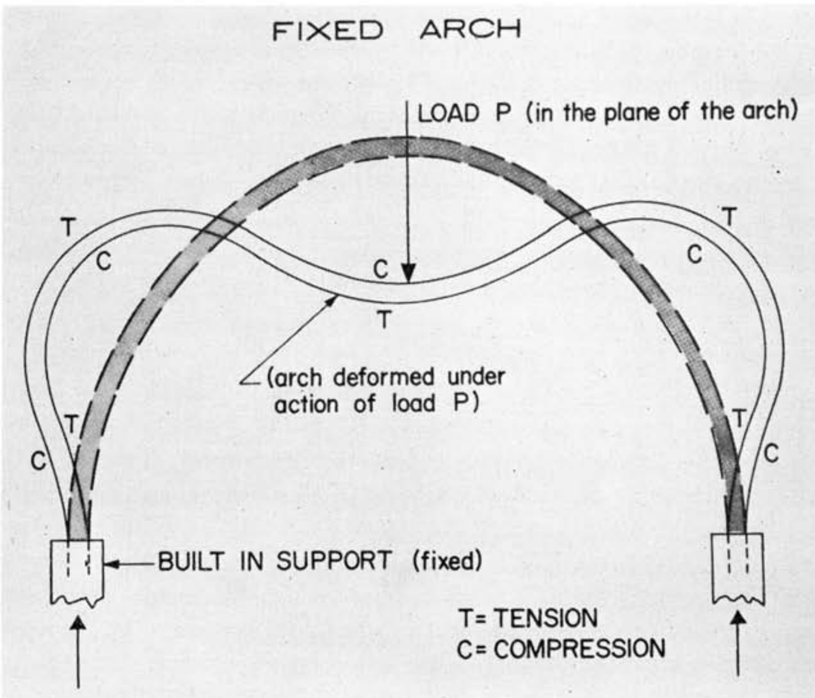

FIG. 12.—The effect of load on an arch with the ends unable to move

and foramina (mental foramen). They frequently have sharp edges, a short radius of curvature, discontinuities, and/or are usually the points farthest from the neutral axis of the bone. The lateral alveolar walls frequently had deformation patterns. Because of the sharp edges of the alveoli, the short radius of curvature of their walls, and their superimposed position on the mandibular arch, tensile stresses build upon only the buccal alveolar walls, the lingual side of the alveoli being on the compressive side of the mandibular arch. The deformation patterns indicate an outward bulging of the lateral alveolar walls or high tensile strain values produced in the lateral walls by a mesial-distal compression of the alveoli. Stresses develop about the circumference of the mental foramen because of the discontinuity of the material and concentration of stress in a localized region (Fig. 13). Reduction in the cross-sectional area through the foramen also gives a greater stress per unit area value, thereby increasing the amount of strain in this area. The lingual tuberosity and the trihedral eminence, located below the anterior extremity of the oblique line, tend to concentrate stresses. This is due to the fact that the stress is highest in regions that are farthest from the neutral axis.

When the load is applied to the symphysis and to the condyles (by the reactive load), the energy is transmitted into both limbs of the arch. The condyles are not directly beneath the point of load application; instead, the symphysis is medial to them. This type of eccentric loading at times produced a torsion somewhere along the limb of the arch. This appeared as the angulated, oblique course of the lacquer cracks along the oblique line and buccal shelf and in some of the alveolar ridge deformation patterns. At times this torsion appeared in the subcondylar area.

When at least one condyle is fixed, high tensile strain may be produced along the posterior subcondylar area, the antegonial notch, and to the base of the body of the mandible just anterior to the antegonial notch. These patterns indicate that tensile strain was developed in these areas because of a forward bending of the condyle and a bending of the mandibular body on the ramus.

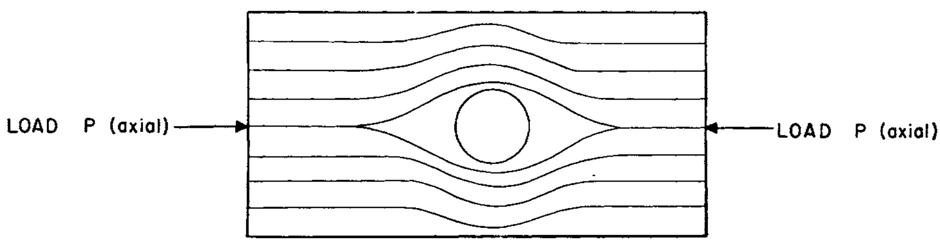

FIG. 13.—High-stress concentration about a hole due to discontinuity of material with same load, *P*, acting.

Certain deformation patterns were correlated with the state of dentition. High tensile strain patterns along the base of the mandible in the antegonial notch and adjacent base of the body were more frequent in edentulous bones and in specimens with only the anterior teeth. Likewise, only these specimens showed alveolar ridge patterns. Conversely, dentulous specimens had deformation patterns about the lateral alveolar walls.

In their study of 319 cases of mandibular fractures, Hagan and Huelke[1] showed that more than half (56.2 per cent) of the fractures resulted from impacts to the chin (between the mental foramina), with 22.8 per cent of all fractures due specifically to chin point (symphyseal) blows. In their study, the subcondylar area was the most frequently fractured region of the mandible (36.3 per cent). Furthermore, they have shown that all areas of the mandible can be fractured by impacts to the symphysis. In another study, Huelke, Burdi, and Eyman[19] have shown that the association between the site of trauma and the location of fractures, especially in individuals with complete dentition and those with only a few individual teeth missing, is highly significant and due only to chance in one out of 1,000 randomly selected cases. Experimentally, the results of the Stresscoat tests have indicated that high tensile stresses and strains can be produced in all areas of the mandible, depending on the method of condylar fixation. The analysis of clinical data indicates that there is a definite relation between the location of the fracture and the site of trauma. For example, most subcondylar fractures (71.4 per cent) are due to blows to the chin region, with 38.8 per cent due to chin-point impacts. In addition, impacts to the chin point cause more fractures per impact than those to any other region, the ratio between the two in the case of chin-point blows is 1:2.2.

Fractures of the coronoid process are rare (2.1 per cent) and are almost always associated with other mandibular fractures. Direct trauma to the coronoid process is secondary to fracture of the zygomatic arch or the maxilla of the same side. In these cases the process is forced against the bone of the infratemporal fossa or if the teeth are in occlusion, thereby holding the process stationary, by the force of the medially displaced zygomatic arch. Impacts to the ramus or body of the mandible of the same or opposite side can cause coronoid process fractures by producing fractures in other areas, so that the segment of the arch containing the coronoid process in question is displaced. This displacement forces the process against the bone of the infratemporal fossa or zygomatic arch and subjects it to a high bending moment. In this experiment, symphyseal impacts produced high tensile strain at the base of the coronoid process when at least one condyle was imbedded in metal in approximately 40 per cent of tests. In general, the patterns indicate that a vibration occurred more frequently than a bending either medially or laterally. It is assumed that in the living individual the temporalis muscle and tendon have a marked dampening effect on the bending or vibratory movements of the coronoid process due to impacts.

The factors involved in the production of mandibular fractures are similar to those producing cranial vault injuries. Blows or impacts producing fractures involve energy, velocity, and deceleration. "All injuries are the result of the absorption of energy."[12] This occurs whenever the head comes in contact with an object moving at a different velocity. This may occur under the following conditions:

(1) The resting head, although free to move, may be struck by a moving object and be accelerated, (2) the moving head may strike a resting object and be decelerated, (3) the moving head strikes or is struck by a moving object. In this instance the head may be accelerated or decelerated depending on whether the head or the object is moving the faster and also on the relative masses and directions of each. The injury to the head will be identical in each of the three conditions if the location of the blow on the head and also the relative velocity between the head and the object is the same.[20]

SUMMARY

Forces and impacts to the symphysis of the mandible cause deformations which are specific in their location. Most frequently these impacts cause a deformation of the neck of the mandible, the type of deformation depending on the method of condylar fixation. This deformation may be a medial or lateral bending of the condyle or a vibration of the subcondylar region itself. In addition, the lingual aspect of the chin tends to flatten because of the application of the force to the opposite side of the bone. Tensile stresses and strains tend to concentrate about the mental foramen, buccal alveolar walls, lingula and lingual tuberosity, oblique line, buccal shelf, and inferior margin of the mandible. However, following chin impacts, these areas are not so frequently involved either clinically or experimentally. Additionally, the coronoid process tends to vibrate because of chin impacts when the condyles are firmly fixed. Clinical data have shown that any area of the mandible may be fractured by impacts to

the chin region, with the subcondylar region being most frequently involved. The experimental results of the present study also indicate that all areas of the mandible may develop high tensile stresses and strains due to impacts to the chin and that the subcondylar region is most frequently involved.

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