Aside from the aesthetic judgments which our culture has placed on irregular alignment of teeth, malocclusions have been considered undesirable because of associated decreased efficiency in mastication of food, increased dental caries, and accelerated breakdown of the periodontal tissues. While the effect on occlusion of extraction due to caries has been documented, little evidence has been found to substantiate other relationships.

It became the object of this study to investigate the relation of malocclusion and two other variables: dental caries and masticatory performance. The specific objectives were to report on the reliability of a caries-examination procedure, to contrast information on caries activity for individuals with good occlusions and those with malocclusions, to determine frequency with which carious lesions appear where the teeth overlap and food is likely to be retained, and to determine whether individuals with malocclusions can chew as well as those with good occlusions.

PART I. CARIES EXPERIENCE AND OCCLUSAL STATUS

Of the studies which have dealt with malocclusion and caries, Brucker reported the number of carious lesions in a group of children, of whom some had erupted deciduous teeth only, some were in the mixed dentition stage, and some had completed eruption of the permanent teeth. The average number of cavities was larger for those with malocclusions than for those free of malocclusion. Adler also found the incidence of caries to be generally greater among young adults with malocclusions than among those with normal occlusions. The DMF index for Class III (Angle) malocclusions was no different from the normal occlusions, and the index for Class I malocclusions with a deep overbite and retruded incisors was significantly lower. On the other hand, Pelton and Elsasser found no relationship between DMF indexes and dentofacial indexes. Interpretation of these findings is difficult, since the dentofacial index included measures of facial morphology as well as measures of malocclusion.

MATERIALS AND METHODS

To study the assumption that maloccluded teeth influence caries activity, it was considered desirable to select a sample from a population in which the teeth had been exposed to the environment of the oral cavity sufficiently long to permit a pattern of caries activity to develop. To avoid the variables introduced by extraction of the teeth,
the subjects were selected from a young adult population in which the level of restorative dentistry was expected to be high.

A six-category classification was employed to rate the dental occlusion of each student entering the University of Iowa in 1955. This rating included an anteroposterior judgment of the relationship of the upper to lower first molars, a judgment of the alignment of the teeth within the dental arches, and a notation of missing teeth. The occlusion of each student was classified as a satisfactory occlusion or as a malocclusion. The satisfactory occlusions were subdivided into excellent, good, and fair, and the malocclusions were subdivided into moderate or severe Class I (Angle), Class II, or Class III. Those who were considered to have excellent occlusions had Class I molar relationship, with very minor crowding and/or spacing between the teeth, and no cross-

**TABLE 1**

**CLASSIFICATION OF OCCLUSIONS OF INCOMING UNIVERSITY STUDENTS AND AGE-SEX DESCRIPTION OF SAMPLE SELECTED FOR STUDY**

<table>
<thead>
<tr>
<th>Occlusal Judgment</th>
<th>Incoming Students</th>
<th>Sample Selected for Study</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Per Cent of Total</td>
</tr>
<tr>
<td>Class I malocclusion</td>
<td>183</td>
<td>12</td>
</tr>
<tr>
<td>Class II malocclusion</td>
<td>214</td>
<td>14</td>
</tr>
<tr>
<td>Class III malocclusion</td>
<td>99</td>
<td>6</td>
</tr>
<tr>
<td>Unclassified malocclusion†</td>
<td>102</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,567</strong></td>
<td><strong>99</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample Selected for Study</th>
<th>No.</th>
<th>Mean Age</th>
<th>Per Cent Male</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>106</td>
<td>18.3</td>
<td>61</td>
</tr>
</tbody>
</table>

* Subjects presenting good alignment of the teeth within each arch and good relationship of the arches to each other, including Angle Class I molar relationship.

† Subjects in these categories had mild irregularities in arch form, jumbling of the teeth, or rotations of the teeth.

‡ Missing first molars obscured classification.

The cases with severe malocclusions had a full-cusp Class I, Class II, or Class III molar relationship, with crowding of the teeth.

To provide contrasting groups for study, the extremes in occlusal status were then selected on the basis of the initial examination. One group was drawn from the 126, or 8 per cent, judged as having the best occlusions. From the 496, or 32 per cent, with classifiable malocclusions, those judged as severe were selected to represent the other extreme in occlusal status. To control certain variables, the two samples were limited to Caucasians who had received no orthodontic therapy and who had no missing teeth (except third molars). By also excluding a few individuals whose restorations included crowns and by ignoring third molars, it was possible to tabulate decayed and filled (DF) surfaces for each of the 28 teeth. It was assumed that other variables which might bias the incidence of dental caries were not affected by such a sampling procedure. Table 1 provides further description of the sample, and Figures 1, 2, and 3 illustrate "typical" cases selected for study.

The caries examination of the subjects selected for study included (1) direct oral
inspections with the aid of mouth mirror, sharp explorer, good light, and air syringe and (2) anterior and posterior bite-wing and roentgenograms. The extensions of all cavities and fillings were recorded on a standard form which designated four smooth surfaces for each posterior tooth and three for each cuspid and incisor. The occlusal surface of each posterior tooth and the lingual surface of each cuspid and incisor were treated as pit and fissure surfaces. In addition, each molar (except third molars) was considered as presenting two additional pit or fissure areas (a buccal pit and a lingual pit or distolingual groove), giving a total of 44 pit and fissure and 100 smooth surfaces for each individual.

The criteria for determining whether or not a surface was carious were established

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**Fig. 1.**—Two examples to illustrate the type of occlusion that was judged “excellent”
by the authors in a pilot study. A sharp explorer was applied with moderate pressure to all surfaces of the dried teeth. If the probe required a "definite pull" to be removed from a pit or fissure, the surface was considered carious. Doubtful areas were not counted. A smooth surface was considered carious only if a definite cavity was encountered by the point of the explorer.27–20 The roentgenographic films were examined with a magnifying glass over good illumination.20 Overlapping radiographic images of teeth, which tend to obscure small proximal cavities, were more frequent on the bite-wings of maloccluded teeth. This bias was minimized by not counting an area as carious unless the radiolucent area contacted the dento-enamel junction of the tooth.

![Fig. 2.—Two examples to illustrate the Class I malocclusions studied](image-url)
An estimate of the reliability of the caries examination procedure was obtained with a second and independent examination of 80 subjects (Table 2). Differences between investigators making independent examinations but utilizing the same bite-wings for the radiographic interpretation were somewhat smaller than differences obtained when the second examination was based on a different set of bite-wing films. The maximum disagreement between examinations for any subject was 4 affected pit and fissure surfaces (2 subjects), 5 affected smooth surfaces (2 subjects), 5 total surfaces (2 subjects), and 4 affected teeth (1 subject). The reliability of the present examination procedures was higher than reported elsewhere.27, 29, 31, 32 Probable contributing factors were (a) careful definition of the criteria for carious lesions, (b) standardized record-

![Fig. 3.—Two examples to illustrate the Class II malocclusions studied](image)
ing procedure, (c) a pilot study to test and apply these criteria, and (d) a relatively short (5-week) period for caries examination. For this study, when the results of two independent examinations differed, the average of the two was used.

RESULTS AND DISCUSSION

The findings on caries and occlusal status are summarized in Table 3. The malocclusion group exceeds the excellent occlusion group in caries experience by approximately 3 pit and fissure surfaces, 5 smooth surfaces, 3 DF teeth, and 1.6 proximo-occlusal restorations. These differences are all significant at the 1 per cent level of confidence. Differences between the classes of malocclusion did not show the pattern described by Adler and were not statistically significant. The means of the various categories were also tested for sex differences. Though the DF figures were slightly higher for males, the differences were not significant, and the data were grouped.

TABLE 2

NUMBER OF SURFACES AND TEETH EXAMINED AND PER CENT AGREEMENT (PER CENT AG.) BETWEEN INDEPENDENT OBSERVATIONS

<table>
<thead>
<tr>
<th>No. of Subjects</th>
<th>Pit and Fissure Surfaces</th>
<th>Smooth Surfaces</th>
<th>Proximo-Occlusal Restorations</th>
<th>DF Teeth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Per Cent Ag.</td>
<td>No.</td>
<td>Per Cent Ag.</td>
</tr>
<tr>
<td>30*</td>
<td>1,320</td>
<td>98.1</td>
<td>3,000</td>
<td>98.6</td>
</tr>
<tr>
<td>25*</td>
<td>1,100</td>
<td>99.7</td>
<td>2,500</td>
<td>98.5</td>
</tr>
<tr>
<td>25†</td>
<td>1,100</td>
<td>97.0</td>
<td>2,500</td>
<td>97.6</td>
</tr>
</tbody>
</table>

* Independent examinations, but the same X-rays were utilized by two observers.
† Second oral examination and second set of X-rays obtained after an interval of at least 1 week.

TABLE 3

CENTRAL TENDENCY AND VARIABILITY OF CARIOUS AND FILLED SURFACES (THIRD MOLARS EXCLUDED) FOR 106 INDIVIDUALS SELECTED FOR GOOD OCCLUSION AND 87 WITH SEVERE MALOCCLUSION

<table>
<thead>
<tr>
<th>Group</th>
<th>No.</th>
<th>Fissure Surfaces</th>
<th>Smooth Surfaces</th>
<th>DF Surfaces</th>
<th>DF Teeth</th>
<th>Proximo-Occlusal Restorations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>S.D.</td>
<td>M</td>
<td>S.D.</td>
<td>M</td>
</tr>
<tr>
<td>Excellent occlusion</td>
<td>106</td>
<td>9.3</td>
<td>5.2</td>
<td>10.1</td>
<td>8.1</td>
<td>19.4*</td>
</tr>
<tr>
<td>Total malocclusion</td>
<td>87</td>
<td>12.4*</td>
<td>5.8</td>
<td>15.0*</td>
<td>11.6</td>
<td>27.4*</td>
</tr>
<tr>
<td>Class I</td>
<td>37</td>
<td>12.5†</td>
<td>6.4</td>
<td>16.2*</td>
<td>12.1</td>
<td>28.5*</td>
</tr>
<tr>
<td>Class II</td>
<td>42</td>
<td>12.3†</td>
<td>4.9</td>
<td>14.1†</td>
<td>10.9</td>
<td>26.4†</td>
</tr>
<tr>
<td>Class III</td>
<td>8</td>
<td>13.1</td>
<td>6.4</td>
<td>14.6</td>
<td>12.5</td>
<td>27.7</td>
</tr>
</tbody>
</table>

* Differences from excellent occlusions significant at the 5 per cent level of confidence.
† Differences from excellent occlusions significant at the 1 per cent level of confidence.
restorations, the tabulation of affected pit and fissure surfaces would be affected by the number of restorations placed solely for the treatment of proximal caries. The number of affected pit and fissure surfaces was then adjusted by subtracting the number of proximo-occlusal restorations. Though this may overcorrect for involved pit and fissure surfaces, the adjusted means were 6.65 for the excellent occlusion group and 8.15 for the malocclusion group. This adjusted difference between the two groups for affected pit and fissure surfaces was not significant.

All distributions in Table 3 are skewed, as can be seen by comparing the magnitude of the standard deviations with the distance of the obtained means from zero. None of the subjects with malocclusions and 3 with good occlusions were caries-free. At the other extreme, 8 subjects with malocclusions and 1 with good occlusion had more than 50 DF surfaces.

The general hypothesis that individuals with malocclusions have more caries activity has been substantiated, and the difference appears to be primarily between affected smooth surfaces rather than affected pit and fissure surfaces. The obvious inference is that the areas of proximal contact between the irregularly aligned teeth are more susceptible to caries than are the areas with "satisfactory" proximal contact. To test this hypothesis, the available individuals comprising the Class I malocclusion group were re-examined, and casts were made from the 20 cases with the most crowded arches (Fig. 2, right).

The area of proximal contact for each pair of teeth was inspected on the cast and a judgment made as to whether the approximation of the two adjacent teeth was "satisfactory" or "irregular." In the anterior segments of the arch, a contact was considered as irregular when an adjacent tooth was malposed or malaligned to the extent that the rotation or lapping was equal to, or greater than, the thickness of the incisal edge. In the posterior segments of the arches a contact was irregular when the two adjacent teeth were not contacting each other at their greatest mesiodistal diameters. This included both inferior-superior and buccolingual displacements. Three independent judgments were made for each contact area. The judgment utilized was that recorded at least two of the three times. For purposes of analysis, each arch was divided into anterior and posterior segments, the anterior segment extending from the middle of one cuspid to the middle of the other. The incidence of decayed and filled proximal surfaces for the two types of proximal contact areas is given in Table 4.

Within the group, the upper posterior segment showed significantly more caries experience where the proximal surfaces were in satisfactory alignment than where they were considered irregular (Table 4). It was only in the lower anterior area that the incidence of carious surfaces was higher for irregularly aligned teeth than for the satisfactory contacts. Because of this unexpected finding, this subgroup of 20 cases was compared with the 106 cases with excellent occlusion whose contact areas would have been judged satisfactory in meeting the original classification requirements. This subgroup with malocclusion had experienced significantly more caries in all areas except the upper posterior segment, where no difference was noted (Table 5).

Thus, while these individuals with malocclusions experienced more proximal caries than those with good occlusions, the increased incidence did not appear to be greater for those surfaces with irregular alignment, except possibly in the lower anterior seg-
ment. In fact, in the upper posterior segment the satisfactory contacts were involved more frequently than those showing irregular alignment.

PART II. OCCLUSAL STATUS AND MASTICATORY PERFORMANCE

Of the many variables involved in mastication,34 efficiency of the chewing mechanism in relation to biting force, food platform area, tooth size, age, duration of chewing, and food selection has received attention.35-41 Two studies have dealt with the effect of malocclusion on masticatory performance. Manly and Hoffmeister42 reported that "masticatory performance of Class I and Class II cases were similar, but was lower for cusp-to-cusp cases by a significant amount." Their title implies that the term "Class I" was being applied to cases with Class I (Angle) malocclusion. Shiere and Manly43 reported: "Only the Class III [malocclusions] cases showed a low area and a corresponding low performance. Other malocclusions were similar to normal cases in their average masticatory function." It was the object of this portion of the study also to explore possible differences in masticatory performance between individuals with excellent occlusions and those with malocclusions.

TABLE 4*

PROXIMAL DENTAL CARIES PREVALECE BY ARCH SEGMENT
AND ALIGNMENT OF CONTACT AREAS IN 20 SUBJECTS
SELECTED BECAUSE OF EXTREME CROWDING

<table>
<thead>
<tr>
<th>Arch Segment</th>
<th>Irregular Contacts</th>
<th>Satisfactory Contacts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NC</td>
<td>DF</td>
</tr>
<tr>
<td>Upper posterior.</td>
<td>55</td>
<td>11</td>
</tr>
<tr>
<td>Lower posterior.</td>
<td>99</td>
<td>45</td>
</tr>
<tr>
<td>Upper anterior.</td>
<td>58</td>
<td>22</td>
</tr>
<tr>
<td>Lower anterior.</td>
<td>131</td>
<td>13</td>
</tr>
</tbody>
</table>

* NC = number of non-carious proximal surfaces; DF = number of decayed and filled proximal surfaces; Per Cent DF = per cent decayed and filled proximal surfaces. The $x^2$ values for the difference between the irregular and satisfactory contacts was significant for the upper posterior quadrant.

TABLE 5

PROXIMAL DENTAL CARIES PREVALECE BY ARCH SEGMENTS OF 106
SUBJECTS WITH EXCELLENT OCCLUSION AND 20 SUBJECTS
SELECTED BECAUSE OF EXTREME CROWDING

<table>
<thead>
<tr>
<th>Arch Segment</th>
<th>Excellent Occlusion</th>
<th>Extreme Crowding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NC*</td>
<td>DF</td>
</tr>
<tr>
<td>Upper posterior.</td>
<td>1,411</td>
<td>497</td>
</tr>
<tr>
<td>Lower posterior.</td>
<td>1,475</td>
<td>433</td>
</tr>
<tr>
<td>Upper anterior.</td>
<td>938</td>
<td>122</td>
</tr>
<tr>
<td>Lower anterior.</td>
<td>1,052</td>
<td>8</td>
</tr>
</tbody>
</table>

* For abbreviations see note to Table 4. The $x^2$ values for the differences in affected surfaces between the excellent occlusions and cases with crowding were significant at the 0.01 per cent level of confidence for rows 2, 3, and 4.
MATERIALS AND METHODS

The subjects were the same as those employed in Part I, i.e., samples of the best occlusions and the most severe, full-cusp malocclusions found in a group of college students not complicated by extractions, full crowns, or orthodontic treatment. Two additional restrictions were imposed: those who had erupted third molars on the side of the mouth preferred for chewing were eliminated for this part of the study, as were those who swallowed more than 30 per cent of the peanuts employed as a test food.

Following a trial for each subject, masticatory performance was measured as suggested by Manly and Braley. Fifteen grams of peanuts were divided into five equal portions, and each portion was chewed twenty times on the preferred side of the mouth and emptied into a detergent solution. After the final portion was chewed, the subject’s mouth was brushed and rinsed out. The suspension was poured over a No. 10 United States Screen. The particles retained by the screen were washed, air-dried, and weighed, while those passing the screen were centrifuged and filtered before drying and weighing. Weight loss from processing was less than 0.1 gm.

The size of the particle swallowed was unknown. On the assumption that the sizes of the swallowed particles were distributed in the same ratio as the peanuts recovered, Index A of masticatory performance was computed by dividing the weight retained on the screen by 15 gm. and subtracting this percentage from 100.

After a lapse of 1 month, 19 subjects were re-examined. Correlation coefficients between the two trials were as follows: \( r = 0.84 \) and 0.78 for Indexes A and B, respectively, as compared with an \( r \) of 0.92 obtained by Manly and Braley for an index similar to A in a more heterogeneous sample.

RESULTS AND DISCUSSION

The distributions for Indexes A and B are described in Table 6. No distinction could be made between the two Indexes, and no significant differences were obtained between the sexes. The means for Class I and Class II malocclusions were similar. Only when Classes I and II were combined was the difference between them and the excel-

**TABLE 6**

<table>
<thead>
<tr>
<th>GROUP</th>
<th>NO.</th>
<th>INDEX A*</th>
<th>INDEX B†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>S.D.</td>
</tr>
<tr>
<td>Excellent occlusion</td>
<td>42</td>
<td>69.6</td>
<td>8.5</td>
</tr>
<tr>
<td>Class I and Class II malocclusion</td>
<td>55</td>
<td>65.2‡</td>
<td>11.3</td>
</tr>
<tr>
<td>Class I</td>
<td>25</td>
<td>65.6</td>
<td>11.3</td>
</tr>
<tr>
<td>Class II</td>
<td>30</td>
<td>65.0</td>
<td>11.2</td>
</tr>
</tbody>
</table>

* Index A 100 minus (Wt. retained on No. 10 screen/total wt. recovered × 100).
† Index B 100 minus (Wt. retained on No. 10 screen/15 gm. × 100).
‡ Differences from the excellent occlusion significant at the 5 per cent level of confidence.
lent occlusions statistically significant. The large standard deviations in all groups emphasizes the variability that exists between individuals.

An attempt to supplement the number of Class III malocclusions introduced a few cases with cusp-to-cusp interdigation. Though this factor clouds interpretation, it should be noted that the means were 53 for Index A and 64 for Index B; a decrease similar to that reported by Shiere and Manly.

**SUMMARY**

Highly reliable results were obtained in recording caries experience over a short period of time following the establishment of the judgment criteria in a pilot study. When young adults with excellent occlusions were compared with those having full-cusp malocclusions, it was found that those with malocclusions had typically experienced more caries activity. When adjustments were made for the effect of Class II dental restorations, the difference appeared to be confined to the smooth surfaces. Within a subsample of 20 cases selected because of extremely irregular proximal contacts, caries activity was significantly less on the proximal surfaces of the upper posterior teeth with irregular contacts than where the contacts of adjacent teeth had a satisfactory relationship to each other. Only in the lower anterior area did the teeth with irregular contacts show a tendency toward more caries. Individuals with full-cusp Class I and Class II malocclusions were found to pulverize peanuts less well than those with excellent occlusions. Because cusp-to-cusp interdigitations were not studied and because of the wide variability between individuals, generalization from the small but significant difference is limited.

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37. MANLY, R. S. Factors Affecting Masticatory Performance among Young Adults, J. D. Res., 30:874, 1951.