Dental crowding as a caries risk factor: A systematic review

Hend Salah Hafez,a Sherif Mohamed Shaarawy,b Ahmed Awadh Al-Sakiti,b and Yehya Ahmed Mostafac
Giza and Cairo, Egypt

Introduction: The association between dental crowding and dental caries has long been accepted because of increased food accumulation and plaque retention in areas of crowding. The aim of this review was to evaluate this potential causal relationship systematically. Methods: Six electronic databases were accessed, supplemented by manual searching of the references of the relevant retrieved articles, peer-reviewed orthodontic journals, and gray literature. Search terms included caries, decay, crowding, and irregularity. Non-English articles were excluded from the review in the study-selection stage. Data extraction and evaluation of primary studies were performed independently by 2 reviewers. Results: The initial search retrieved 6914 citations. However, only 18 articles met the inclusion criteria. The qualitative systematic review included 8 studies, with articles of low or moderate quality. No association between crowding and caries was reported in 4 studies, a significant negative correlation was found in 2 studies, 1 study showed a direct and significant relationship, and another study showed a positive association in the mandibular anterior region but an inverse correlation in the maxillary posterior region. Conclusions: To date, there are no high-quality studies to resolve the possible association between dental crowding and caries; further high-quality longitudinal studies are needed to clarify this relationship. (Am J Orthod Dentofacial Orthop 2012;142:443-50)

The assumption that dental crowding is a risk factor for dental caries has long been made. Crowding disrupts normal proximal and occlusal dental contacts that provide proper embrasures, spillways, and self-cleansing. In turn, crowding leads to food accumulation and plaque retention.1,2 It is therefore intuitive that crowding will increase the incidence of dental caries. However, this belief has not always been supported by the literature.1,3

Studies evaluating the relationship between crowding and dental caries have shown contradictory results. Some authors have reported a positive correlation between malocclusion and the incidence of caries.3,4,5 Contrary to these findings, other authors failed to identify an association between crowding or its severity and dental caries.6,7 Others have even reported a negative correlation between crowding and caries, with a lower incidence of decay in subjects with crowding.8,9 Caries is a common oral disease, and its rehabilitation is a costly and time-consuming procedure.10 Strong evidence linking crowding and the development of dental caries would prioritize orthodontic treatment as a measure for caries prevention and improved oral health. If evidence were found to support this contention, dental health personnel—including general dental practitioners, pedodontists, and orthodontists—would assume a preventive role. Consequently, decision makers would be required to reevaluate orthodontic treatment needs of dental patients with crowding.

The aim of this systematic review was therefore to assess the relationship between dental crowding and the development of dental caries.

MATERIAL AND METHODS

This systematic review was performed in accordance with guidelines recommended by the Meta-analysis of Observational Studies in Epidemiology Group.11 Study designs included were observational studies analyzing the association between crowding and caries. Participants (intervention and control groups) included...
subjects with no crowding or crowding of various degrees. Eligible studies were intended to evaluate caries as an outcome measure.

To identify all studies examining the relationship between crowding and the incidence of caries, the following electronic databases were searched with no restrictions: Cochrane Library (May 9, 2011), NLM Gateway (searches Pubmed and Medline, from 1950 to May 15, 2011), LILACS (from 1992 to May 20, 2011), Google Scholar (from 1993 to May 20, 2011), and ISI Web of Science (from 1945 to May 27, 2011). The search terms were the following.

Search 1: Dental AND (crowd* OR irregular* OR imbricat* OR “arch alignment” OR malalign*).
Search 2: (crowd* OR irregular* OR imbricat* OR “arch alignment” OR malalign*) AND (caries OR demineraliz* OR decay).
Search 3: Search 1 OR search 2.

A manual search was performed of dental and orthodontic peer-reviewed journals (Journal of Dental Research, from 1960 to May 2011; Community Dentistry and Oral Epidemiology, from 1973 to May 2011; American Journal of Orthodontics, from 1980 to June 1986; American Journal of Orthodontics and Dentofacial Orthopedics, from July 1986 to May 2011; Angle Orthodontist, from 1980 to May 2011; and European Journal of Orthodontics, from 1980 to May 2011. The references of these articles were evaluated for relevant citations. Authors of studies requiring further clarification were contacted.

The search and article selection were performed by 3 researchers (S.M.S., A.A.A., and H.S.H.). Data extraction sheets were created. The primary studies were assessed independently by 2 reviewers (H.S.H. and Y.A.M.). Inconsistencies arose just twice. The first was a disagreement among 2 of the 3 researchers on the decision to include 1 article; the third researcher suggested excluding this article. The second was to assess whether the conclusion of 1 article represented the results reported. This was resolved by referring to the data extraction sheets and discussing the point of controversy until agreement was reached.

The inclusion criteria were (1) human studies; (2) studies reporting on the prevalence or severity of dental crowding and dental caries, and assessing the association between them; (3) only studies including a comparator, a control group with no or minimal crowding, or a comparator of varying severity; and (4) studies with statistical analysis.

The exclusion criteria were (1) animal studies; (2) literature reviews, books, and articles of expert opinion; (3) studies reporting on the prevalence of crowding or dental caries or both without assessing their associations; (4) studies using a nonspecific index of outcome measurement for caries or crowding (eg, dental aesthetic index of orthodontic treatment need, or collective index of malocclusion); (5) studies evaluating white lesions; (6) subjects with systemic diseases or dental or craniofacial anomalies that could affect the susceptibility to caries; and (7) non-English articles.

Quality assessment of the 8 included articles was performed. Points were allocated for the following criteria: study type, blinding, adequate reporting, comparator (group with no or minimal crowding), validity and reliability of recording method and index used for measuring crowding and caries, effect of confounding factors, and coding of subjects. The maximum quality score for any article was 24. Articles were designated as having low, moderate, or high quality according to their scores (low, 1–8; moderate, 9–16; high, 17–24). A detailed quality assessment is given in Table I.

No meta-analysis was performed because of the heterogeneity of these studies, inadequate reporting of the study designs, and other limitations in the quality of the articles (Table I). Also, a wide range of indexes was used to measure crowding and the prevalence of caries (Table II).

RESULTS

The initial number of retrieved citations was 6914; 6911 were derived from electronic databases and 3 from manual searching. A total of 3094 duplicates were removed (3079 internal and 15 external duplicates). The titles of 3820 articles were evaluated for relevance; abstracts of unclear studies were evaluated. After removing 3727 irrelevant citations, 93 articles were screened for eligibility.

The full texts of 19 articles were assessed. One article was excluded because it lacked a comparator. Therefore, only 18 articles met the inclusion criteria. Ten studies were subsequently excluded; the reasons for the exclusion are outlined in the PRISMA flowchart (Fig). Therefore, 8 cross-sectional observational studies were included in the qualitative synthesis.

No association between crowding or irregularity and caries was found in 4 studies. Significant negative correlations were reported in 2 studies. One study showed a direct and significant relationship between crowding and proximal caries scores, whereas another showed a positive association between crowding and proximal surface caries in the mandibular anterior region and an inverse correlation in the maxillary posterior region. The quality scores for the 8 studies are given in Table I.

DISCUSSION

According to the guidelines of the Meta-analysis of Observational Studies in Epidemiology Group,
systematic reviews of observational studies often have inherent problems. In particular, epidemiologic studies are highly heterogeneous. They encompass a wide range of study designs, methodologies, and subject criteria in primary studies and across studies assessing different populations with high heterogeneity. Studies of this nature have also been shown to be particularly sensitive to publication bias. Furthermore, primary observational studies are sensitive to a lack of blinding in the study designs. Attempts were therefore made in this review to grade the quality of the included studies by using a structured and comprehensive analysis.

Initially, strict selection criteria were considered to decrease the heterogeneity between studies and to allow the inclusion of high-quality studies only. However, the Meta-analysis of Observational Studies in Epidemiology Group advocated using broad criteria and analysis of studies in the light of the confounding factors. Therefore, despite identification of a significant number of potentially relevant studies, because of the high heterogeneity of the indexes measuring the outcomes, differences in the criteria in the studies (Table III), and inadequate reporting (Table I), a meta-analysis was not possible.

The confounding factors in the studies attempting to address the association between crowding and caries, and the limitations of the screened articles, are discussed to inform future research. A chief reason for exclusion was that some articles did not assess crowding. In addition, the indexes used were not specific for crowding but measured other features of malocclusions. One study also combined malocclusion and esthetics.

<table>
<thead>
<tr>
<th>Study</th>
<th>Study type</th>
<th>Blinding</th>
<th>Adequate reporting</th>
<th>Comparator</th>
<th>Validity, reliability of caries recording method</th>
<th>Validity, reliability of crowding recording method</th>
<th>Error of measurement</th>
<th>Confounding factors</th>
<th>Subgrouping</th>
<th>Coding</th>
<th>Score/grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hixon et al</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>3 race, missing teeth, sex; NS</td>
<td>1 crowding</td>
<td>16</td>
<td>moderate</td>
<td></td>
</tr>
<tr>
<td>Roder and Arensd</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>2 missing teeth, sex; NS</td>
<td>-</td>
<td>10</td>
<td>moderate</td>
<td></td>
</tr>
<tr>
<td>Katz</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>4 race, sex, missing teeth, baseline oral status</td>
<td>1 crowding</td>
<td>14</td>
<td>moderate</td>
<td></td>
</tr>
<tr>
<td>Addy et al</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>4 race, sex, missing teeth, baseline oral status</td>
<td>-</td>
<td>11</td>
<td>moderate</td>
<td></td>
</tr>
<tr>
<td>Helm and Petersen</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>3 age, sex, missing teeth</td>
<td>-</td>
<td>13</td>
<td>moderate</td>
<td></td>
</tr>
<tr>
<td>Stahl and Grabowski</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>1 missing teeth</td>
<td>-</td>
<td>8</td>
<td>low</td>
<td></td>
</tr>
<tr>
<td>Staufer and Landmesser</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1 crowding</td>
<td>3 age, missing teeth, baseline oral status</td>
<td>2</td>
<td>16</td>
<td>moderate</td>
<td></td>
</tr>
<tr>
<td>Alsoliman</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1 caries</td>
<td>2 missing teeth, sex; NS</td>
<td>-</td>
<td>1</td>
<td>11/moderate</td>
<td></td>
</tr>
</tbody>
</table>

NS, Not significant.

aLongitudinal study: 2 points; cross-sectional study: 1 point (maximum 2 points); bBlinding: 2 points; cAdequate reporting on subject criteria, subject distribution, and methodology: 1 point for each factor (maximum 3 points); dControl group of normal occlusion or minimal crowding (up to 2 mm): 2 points; control of different grades of crowding: 1 point (maximum 3 points); eRadiographic assessment: 2 points; visual examination: 1 point (maximum 2 points); fQuantitative index: 2 points; visual: 1 point (maximum 2 points); gError of measurement for caries detection and measurement of crowding: 1 point for each factor (maximum 2 points); hEffect of confounding factors considered (age, race, sex, missing teeth, and baseline oral status): 1 point for each factor. When there was no sex-related difference between caries incidence, 1 point was given because no correction was needed. When confounding factors had no effect (NS): 1 point was given for each factor (maximum 5 points); iSubgrouping subjects to compare the effect of age and severity of crowding: 1 point for each factor (maximum 2 points); jCoding of subjects and variables: 1 point.
Table II: Indexes of outcome measurement, results, and conclusions of the 8 studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Indexes used to measure crowding and caries</th>
<th>Results</th>
<th>Conclusions</th>
</tr>
</thead>
</table>
| Hixon et al4           | Crowding: visual assessment of anterior overlap and posterior teeth where contacts not at maximum convexity.  
                         | Caries: DFS index (all teeth). | 1. The maxillary posterior segment showed significantly more caries where the proximal surfaces were in satisfactory alignment than where they were considered irregular.  
                         |                                                                    | 2. Only in the mandibular anterior area was the incidence of carious surfaces higher for irregularly aligned teeth than for the satisfactory contacts.  
                         |                                                                    | 3. The subgroup with severe crowding had significantly more caries in all areas except the maxillary posterior segment, where no difference was found. | 1. Only in the mandibular anterior area did the teeth with irregular contacts show a tendency toward more proximal caries, and the maxillary irregular posterior segments were negatively associated with caries incidence. |
| Roder and Arend22      | Crowding: anterior (measured in 0.8-mm increments) and posterior (measured by 0, no crowding; 1, at least 1 mm of vertical or horizontal displacement; 2, crowding that prevents normal occlusion in centric occlusion).  
                         | Caries: DMFS index (maxillary anterior teeth) | 1. High caries and crowding scores in the maxillary anterior segments was found in 14- and 16-year-old students.  
                         |                                                                    | 2. A direct and significant association between crowding and proximal caries scores in the maxillary anterior segment was evident. | 1. Direct and significant relation of crowding to proximal caries scores in the maxillary anterior segment. |
| Katz8                  | Crowding: MIM and MIV.  
                         | Caries: DMFS index (for maxillary anterior teeth). | 1. A difference of 16 decayed, filled, and missing surfaces between the top and bottom quartiles of subjects with UANTCRD.  
                         |                                                                    | 2. Inverse relationship: the greater the UANTCRD score in millimeters, the lower the DMFS score. | 1. Inverse relationship: the greater the irregularity score of the maxillary anterior region, the lower the caries score. |
| Addy et al1            | Crowding: standardized technique for recording alignment of individual teeth index (for all teeth not including second and third molars).  
                         | Caries: DMS index (for paired contralateral teeth). | 1. Lower caries experience was found for the irregular teeth, but the difference did not reach significance. | 1. No significant differences in the incidence of dental caries between regular and irregular teeth. |
| Helm and Petersen20    | Crowding: anterior section (incisors) and 2 lateral sections (canine and premolars) deviation of at least 2 mm in any section.  
                         | Caries: DMFS index (for all teeth except third molars). | 1. DFS scores were higher in the subjects with maxillary and mandibular anterior crowding but did not reach statistical significance.  
                         |                                                                    | 2. The total DMFS scores were slightly, but not significantly, lower in the subjects with crowding, but they had significantly more untreated caries in the maxilla.  
                         |                                                                    | 3. The DMFS scores were not higher in the crowded dental arches.  
                         |                                                                    | 4. Only crowding in the incisor segments was associated with somewhat higher DMFS scores. | 1. Space anomalies do not predispose to caries; consequently, increased risk of caries need not be included in considerations of the indication for orthodontic treatment. |
Table II. Continued

<table>
<thead>
<tr>
<th>Study</th>
<th>Indexes used to measure crowding and caries</th>
<th>Results</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stahl and Grabowski21</td>
<td>Crowding: any tooth rotated or out of line for which space would have to be created to allow correction of malalignment. Caries: DMFT index.</td>
<td>1. No significant difference was observed between the prevalence of malocclusion in caries-free and carious mixed dentition. 2. Subjects with crowding in the posterior segments had significantly higher mean dmft scores compared with children with normal occlusion in the mixed dentition. 3. Although high percentages of children with increased caries risk had crowding (17%), no positive correlation could be established.</td>
<td>1. Statistically significant parallelism in prevalence of malocclusion and caries was found for posterior crossbite and mandibular overjet in children with mixed dentition.</td>
</tr>
<tr>
<td>Staufer and Landmesser6</td>
<td>Crowding: modified Lundström index (for mandibular anterior teeth). Caries: DMF index (for mandibular anterior teeth).</td>
<td>1. Crowding showed a nonparametric distribution. No sex-specific difference for the degree of crowding. No significant association between crowding and prevalence of caries. 2. Age-specific difference in the degree of crowding, with the older group showing a higher prevalence. 3. Prevalence values of caries were 39% in the older group and 19% in the younger group.</td>
<td>1. No statistically secured correlation between abrasions or caries and the degree of crowding was recorded. 2. The incidence of caries was twice as high in the older patients than in the younger patients.</td>
</tr>
<tr>
<td>Alsoliman9</td>
<td>Crowding: any tooth rotated or out of line for which space would have to be created to allow correction of malalignment. Caries: dmft index.</td>
<td>1. Crowding was found significantly most often in caries-free dentitions. 2. Crowding was correlated negatively with caries experience with significantly greater dmft values in uncrowded subjects than in crowded subjects.</td>
<td>1. Crowding and caries were negatively correlated with significantly greater dmft values in subjects with no crowding.</td>
</tr>
</tbody>
</table>

DFS, Decayed, filled surfaces; DMFS, decayed, missing, filled surfaces; DMFT, decayed, missing, filled tooth (permanent dentition); DMFT, decayed, missing, filled tooth (permanent dentition); dmft, decayed, missing, filled tooth (mixed dentition); MIM, malalignment index of Massler and Fränkel; MIV, malalignment index of VanKirk and Pennel; UANTCRD, upper anterior crowding.

Studies have shown an association between increased caries incidence and certain types of malocclusion. In comparison with a group with normal occlusion, Adler18 found that the decayed, missing, and filled index values were higher in Class II Division 2 subjects, and lower in Class I subjects and those with deep overbite. Also posterior crossbite, reverse overjet,9,21 and posterior crowding have been linked to a higher caries incidence.21 Yet, other studies have shown no association between malocclusion type and dental caries.12,20

The disagreements between studies can be attributed to the facts that crowding24 and dental caries24 are multifactorial and dynamic, increasing or decreasing over time. Their prevalence and severity are time-dependent. Crowding increases in early adolescence and early adulthood, and then decreases and progresses at a slower rate.23 The severity of crowding is controlled by various factors, including the sizes of the dental arches and teeth, dental inclinations, proximal attrition, overjet, and mesial drift of the teeth. Caries incidence and severity, on the other hand, are high in children and adolescents, and relatively low in adults. Caries susceptibility is also determined by the interaction of various local factors such as oral hygiene; salivary composition, pH, and flow rates; dental morphology; quality of enamel; oral microflora; and dietary factors. Also, systemic disease, genetic susceptibility, and immunologic factors have been shown to have roles in the etiology of dental caries. The time factor might complicate the evaluation of the possible causal link between crowding and dental caries and must be considered in future study designs. For most patients who experience dental caries, it can take years for caries to progress from the outer to the inner surface of the enamel.25,26 The WHO recommends that subjects be subgrouped according to age to allow evaluation of the time factor.27

There is disagreement on the impact of race and sex on the prevalence of crowding and caries. Some studies report that white subjects have a higher prevalence of
crowding, whereas others have shown no racial influence. Many studies have reported dental caries to be higher in female patients, but some have shown no difference.

Studies evaluating the prevalence and association between crowding and malocclusion are usually cross-sectional surveys assessing an association at a certain point of time. This does not assess causality, because the sequence of risk and occurrence cannot be proven; consequently, longitudinal observational studies with prolonged follow-ups are required. The WHO recommends that follow-up surveys be conducted every 5 to 6 years for main oral diseases.

A clear causal relationship between crowding and caries is also difficult to establish because of possible conditions that can lead to dental caries and malocclusion independently in the same patient. Consequently, data analysis should account for confounding factors and the interactions of risk factors by using multivariate modeling: eg, multiple-regression analysis rather than simple correlation analysis.

The inconsistencies between the included studies might be due to the multifactorial nature of both caries and crowding, and the numerous confounding factors involved. In addition, a strict definition of crowding should be established to differentiate between indexes measuring crowding and those measuring irregularity. Similarly, crowding and caries were only evaluated in local areas in some studies—eg, the mandibular or the maxillary anterior segment.

A noticeable limitation of the included articles was the inadequate reporting on the distribution of the

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**Fig.** Study inclusion flowchart.
subjects with caries and crowding. Although the studies reported the criteria of the overall subjects, they did not specify the criteria of the subgroups, which are the target subjects. Studies that reported the number of subjects in the subgroups had inadequate sample sizes. However, the studies with the highest quality scores were of questionable validity because of small sample sizes (Table III).

Studies with moderate quality (Table I) led to inconsistent conclusions. Roder and Arend found a direct and significant relationship between crowding and proximal caries scores in the maxillary anterior segment. Conversely, Addy et al reported no significant differences in the incidence of dental caries between regular and irregular teeth. Alsoliman reported that crowding and caries experience were negatively correlated. Helm and Petersen concluded that no relationship existed between malocclusion traits and caries prevalence, although crowding in the maxilla was significantly associated with higher untreated caries. Katz found an inverse relationship between crowding and proximal caries, with greater irregularity scores in the maxillary anterior region coinciding with lower caries incidence. The 2 articles with the highest quality scores showed differing results. Staufer and Landmesser reported that caries in the mandibular anterior segment showed no significant crowding-dependent differences. However, the prevalence of caries was significantly higher (almost double) in the older group of subjects. On the other hand, Hixon et al found that only in the mandibular anterior area did the teeth with irregular contacts show a tendency toward more proximal caries. Their results

### Table III. Subject criteria in the 8 studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Age</th>
<th>Sex</th>
<th>Race</th>
<th>Sample size</th>
<th>Baseline oral health status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hixon et al</td>
<td>Severe crowding: not reported</td>
<td>Severe crowding: not reported</td>
<td>White</td>
<td>Severe crowding: 20 Excellent occlusion: 106</td>
<td>Not reported</td>
</tr>
<tr>
<td>Roder and Arend</td>
<td>14-16 years</td>
<td>Girls</td>
<td>Not reported</td>
<td>Subgroups: not reported</td>
<td>Not reported</td>
</tr>
<tr>
<td>Katz</td>
<td>&lt;25 years</td>
<td>Not reported</td>
<td>White</td>
<td>Subjects: 160 Subgroups: not reported</td>
<td>Adequate condition of occlusion and teeth present</td>
</tr>
<tr>
<td>Addy et al</td>
<td>11.5-12.5 years</td>
<td>Role of sex is insignificant</td>
<td>Not reported</td>
<td>2656 pairs of contralateral crowded and uncrowded teeth</td>
<td>Not reported</td>
</tr>
<tr>
<td>Helm and Petersen</td>
<td>33-39 years (mean age, 35.5 years)</td>
<td>Not reported</td>
<td>Not reported</td>
<td>Maxillary incisor crowding: 33 Mandibular incisor crowding: 39 Maxillary crowding: 41 Mandibular crowding: 51 Control group: 27</td>
<td>Not reported</td>
</tr>
<tr>
<td>Stahl and Grabowski</td>
<td>Children with primary dentitions (mean age, 4.5 years) and mixed dentitions (mean age, 8.9 years)</td>
<td>Girls: 4306 Boys: 4558 Subgroups: not reported</td>
<td>Not reported</td>
<td>Subgroups: not reported</td>
<td>Not reported</td>
</tr>
<tr>
<td>Staufer and Landmesser</td>
<td>Age groups, 18-34 years (n = 63) and ≥ 35 years (n = 62)</td>
<td>Women: 63 Men: 62 Subgroups: not reported</td>
<td>Not reported</td>
<td>18-34 years (n = 63) ≥ 35 years (n = 62)</td>
<td>Occlusal stability for a physiologically supported jaw and good state of care of mandibular canines and incisors</td>
</tr>
<tr>
<td>Alsoliman</td>
<td>9-13 years</td>
<td>Subgroups: not reported</td>
<td>Not reported</td>
<td>Not reported</td>
<td>Not reported</td>
</tr>
</tbody>
</table>
also suggested that the number of noncarious teeth in the mandibular posterior and maxillary and mandibular anterior segments in subjects with excellent occlusions were significantly higher than in subjects with severe crowding.

On the basis of the limitations of the current evidence, additional well-controlled observational studies are required to resolve the question of a link between dental crowding and caries. Larger sample sizes should be included to better represent the general population and provide adequate statistical power. The confounding effects of differences in sex and race should also be considered, with grouping of subjects of varying ages and degrees of crowding. It is also important that caries diagnosis is undertaken in a standardized manner to permit comparisons. The decayed, missing, filled surfaces index is a reliable method of recording dental caries, although underestimation of interproximal caries is possible. Even though clinical diagnosis is not the most sensitive diagnostic technique, it is easily applied, inexpensive, and cost-effective and is therefore the most apt for large-scale observational studies.

CONCLUSIONS

To date, no high-quality studies confirm or refute a causal relationship between crowding and dental caries.

REFERENCES