Bone scintigraphy as a diagnostic method in unilateral hyperactivity of the mandibular condyles: a review and meta-analysis of the literature

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Abstract. Bone scan analyses and clinical assessment are used to diagnose unilateral condylar hyperactivity (UCH). This review compares the diagnostic accuracy of planar and SPECT bone scans. Studies diagnosing patients with possible UCH using bone scans, published between 1968 and 2008, were included in this review. Of 15 articles that met the inclusion criteria, 7 presented results in sufficient detail to calculate index test characteristics. Three control studies show that the difference in uptake values of the left and right condylar regions in the normal population does not exceed 10%. The pooled sensitivity of the planar bone scan (n = 130) was 0.71 (95% confidence interval: 0.57–0.82), which was significantly lower (p = 0.04) than that of the bone SPECT technique (n = 88), which was 0.90 (0.79–0.97). The pooled specificity of the SPECT scan was 0.95 (0.82–0.99), which did not significantly differ (p = 0.58) from that of the planar scan (0.92 (0.83–0.97)). Future studies should include a diagnostic analysis of the data, including two-by-two contingency tables, so the accuracy of the diagnostic test may be evaluated. Bone scans are best performed using SPECT, conducting a quantitative analysis by calculating the percentile differences between the left and right condylar regions.

Keywords: unilateral condylar hyperactivity; single photon emission CT scan; mandibular asymmetry; bone scintigraphy; unilateral condylar hyperplasia; bone scan.

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UCH is diagnosed on the basis of ana-
mnestic and clinical findings and by evalu-
ating conventional radiographs of the
patient. Cisneros was the first to use bone
scintigraphy to study patients with man-
dibular asymmetry. Radionuclide bone
scanning is an instant method of compar-
ing the differential activity between the
normal and abnormal condyles, reflecting
the relative growth rates at the time of the
investigation. Two frequently used scan-
ing techniques are planar bone scan-
ning and single photon emission com-
puted tomography (SPECT), both of
which use the same basic technology.
SPECT produces a tomographic bone
scan image that may be more reliable than
planar scanning. The 2 scanning
techniques can be analyzed in a qualita-
tive (subjective) and quantitative (objec-
tive) manner.

The objective of this study is to review
relevant studies to estimate the diagnostic
value of bone scans for the diagnosis of
UCH. The use of different methods of
quantification, and the possible use of
normal values in quantitative studies of
patients with possible UCH is reviewed.

**Materials and methods**

A comprehensive computer literature
search of the PubMed database was con-
ducted in November 2008. Planar and
SPECT bone scintigraphy were the 2 diag-
nostic imaging techniques reviewed. A
sensitive search strategy was used, using
key words, which yielded more than 1035
search results, which were checked for
relevance using their titles and abstracts
(Fig. 1). The reference lists of these stu-
dies and reviews were manually searched
to identify any additional eligible studies;
these references were also included in the
final study selection. The search was
restricted to articles published in the Eng-
lish language, human adult studies, and
studies in peer-reviewed journals with an
available abstract, that were published

The studies were considered eligible for
the literature review if they met the fol-
lowing inclusion criteria: clinical studies
that evaluated the diagnostic performance
of planar and SPECT bone scans in
patients suspected of having UCH; a study
population of at least 10 patients; and
studies reporting normal individuals or
patient studies presenting diagnostic accu-
racy (e.g. sensitivity and specificity) or
enough data to enable calculation of sen-
sitivity and specificity.

If more than one study by the same
author was included in the review, the
patient demographics were assessed to
rule out overlap. Studies with possible
overlap were excluded from the meta-
analysis. All studies of which the eligibil-
ity was unclear were retrieved and the final
decision was made on the basis of the full-
length article.

Relevant data (e.g. patient and study
characteristics) were extracted from the
studies and scored in a standardized man-
ner (Table 1). Data on diagnostic perfo-
mance, quantification methods, and the
inclusion of a control group with normal
values are given in Table 2. The studies
that evaluated a control group of patients
without a medical history of TMJ disor-
ders are given in Table 3.

A meta-analysis was performed for stu-
dies in accordance with the previously
determined criteria. The weight of
included studies was based on the popula-

![Fig. 1. Flowchart for the search strategy conducted.](image-url)
tion size. Pooling was performed using a random or fixed effect model, as described in earlier studies. Pooled values of sensitivity and specificity are presented with corresponding 95% confidence intervals. Pooled values for the studies using a planar technique were compared with the results of studies using a SPECT technique using -test statistics. A -value lower than 0.05 was considered to be significant.

Results

1036 studies were identified by the search strategy. The abstracts were checked for relevance, after which the full text articles were read. The inclusion criteria were applied, which narrowed the number of useful studies to 15. The search and inclusion criteria are presented in Fig. 1. The reference lists of the 15 articles were manually searched, but no additional relevant articles were found. The characteristics of the included studies are presented in Tables 1–3. The 15 articles were published between 1984 and 2008.

Studies of normal individuals

Three prospective studies conducted to determine bone uptake values in the condyles of individuals without any TMJ disorders were identified. The planar bone scanning technique was used in 2 of the 3 studies, and both planar and SPECT scanning were used in the third study performed by . In one study, condylar activity versus bone activity in the lumbar vertebra (L4) was used as a quantification method. All these 3 studies used the percentage difference of the activity in the right condyle versus the left condyle for quantification. In the two studies using planar bone scanning, the normal percentual difference between the right and left condyle was less than 10%.
Table 2. Quantification methods and diagnostic accuracy of the 7 studies showing detailed diagnostic data.

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</thead>
<tbody>
<tr>
<td>HAMP9</td>
<td>35 (11)</td>
<td>23</td>
<td>14 (8)</td>
<td>Planar</td>
<td>+</td>
<td>–</td>
<td>–</td>
<td>50%</td>
<td>100%</td>
<td>0.7</td>
<td>–</td>
<td>visual</td>
</tr>
<tr>
<td>ROBINSON25</td>
<td>10 (2)</td>
<td>10</td>
<td>6 (NR)</td>
<td>Planar</td>
<td>–</td>
<td>+</td>
<td>L/R ratio</td>
<td>100%</td>
<td>67%</td>
<td>0.8</td>
<td>+1 (10)</td>
<td>88%–112% (1.12)</td>
</tr>
<tr>
<td>HENDERSON11</td>
<td>14 (7)</td>
<td>14</td>
<td>4 (NR)</td>
<td>Planar</td>
<td>–</td>
<td>+</td>
<td>L/R ratio</td>
<td>100%</td>
<td>100%</td>
<td>1.0</td>
<td>–</td>
<td>NR</td>
</tr>
<tr>
<td>BOUSHLAVIZKI1</td>
<td>27 (11)</td>
<td>27</td>
<td>4 (NR)</td>
<td>Planar</td>
<td>–</td>
<td>+</td>
<td>Visual</td>
<td>–100%</td>
<td>–50%</td>
<td>–0.91</td>
<td>+1 (11)</td>
<td>&lt;1.10</td>
</tr>
<tr>
<td>HENDERSON11</td>
<td>14 (7)</td>
<td>14</td>
<td>4 (NR)</td>
<td>Planar</td>
<td>–</td>
<td>+</td>
<td>L/R ratio</td>
<td>100%</td>
<td>100%</td>
<td>1.0</td>
<td>–</td>
<td>&lt;1.10</td>
</tr>
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<td>BOUSHLAVIZKI1</td>
<td>27 (11)</td>
<td>27</td>
<td>4 (NR)</td>
<td>Planar</td>
<td>–</td>
<td>+</td>
<td>L/R ratio</td>
<td>100%</td>
<td>100%</td>
<td>1.0</td>
<td>–</td>
<td>&lt;1.10</td>
</tr>
<tr>
<td>HODDER12</td>
<td>18 (4)</td>
<td>11</td>
<td>NR</td>
<td>Planar/SPECT</td>
<td>–</td>
<td>+</td>
<td>Visual</td>
<td>–100%</td>
<td>–50%</td>
<td>–0.91</td>
<td>+1 (11)</td>
<td>&lt;1.10</td>
</tr>
<tr>
<td>PRIPATNANONT22</td>
<td>21 (7)</td>
<td>21</td>
<td>NR</td>
<td>SPECT</td>
<td>+</td>
<td>+</td>
<td>Δ% R/L</td>
<td>75%</td>
<td>100%</td>
<td>0.85</td>
<td>+ (5)</td>
<td>Δ% &lt;10%</td>
</tr>
<tr>
<td>SARIDIN29</td>
<td>56</td>
<td>56</td>
<td>29 (NR)</td>
<td>Planar/SPECT</td>
<td>++</td>
<td>++</td>
<td>Δ% R/L</td>
<td>67%</td>
<td>85%</td>
<td>0.77</td>
<td>–</td>
<td>Δ% &lt;10%</td>
</tr>
</tbody>
</table>


Table 3. Control studies.

<table>
<thead>
<tr>
<th>Study</th>
<th>Year of publ.</th>
<th>Origin</th>
<th>Design</th>
<th>Patients no. (male)</th>
<th>Time period</th>
<th>Age/range (yrs)</th>
<th>Quantit. Method</th>
<th>Normal value</th>
</tr>
</thead>
<tbody>
<tr>
<td>KABAN14</td>
<td>1982</td>
<td>U.S.</td>
<td>Prospective</td>
<td>34 (NR)</td>
<td>NR</td>
<td>NR/14–22.0</td>
<td>Planar 99mTc-MDP/22 μCi/kg</td>
<td>≤5% +Δ% R/L Cond/L4</td>
</tr>
<tr>
<td>POGREL20</td>
<td>1985</td>
<td>U.S.</td>
<td>Prospective</td>
<td>30 (18)</td>
<td>NR</td>
<td>&lt;45/NR</td>
<td>Planar 99mTc-PP1/NR</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>KAAN15</td>
<td>2006</td>
<td>Iran</td>
<td>Prospective</td>
<td>38 (19)</td>
<td>NR</td>
<td>13–34</td>
<td>Planar/SPECT 99mTc-MDP/25mCi</td>
<td>≤6.2% +Δ% R/L Cond/L4</td>
</tr>
</tbody>
</table>

between normal and abnormal condylar activity. These results support the concept of evaluation of condylar activity with bone scintigraphy in patients with potential asymmetric growth. Since only one of the control studies used the SPECT technique, the performance of more control studies may result in a more precise range of normal differences between the left and right condylar regions.

The pooled sensitivity of the bone SPECT technique for the detection of UCH (0.90) was significantly higher than that of the planar bone scan technique with a pooled sensitivity of 0.71, without differences regarding the specificity. The SPECT technique identifies an additional 19% of the UCH patients when compared with a standard planar bone scan. The pooled sensitivity of the SPECT scan was significantly different from that of the planar scan; this finding is consistent with the results of earlier studies\textsuperscript{12,21,29}, which reported that SPECT bone scanning is more reliable than planar scanning. SPECT bone scanning is more sensitive than planar scanning, and the condyles can be better isolated without superimposition of the contralateral condyle. A pooled sensitivity of 0.90 in the SPECT scan indicates the risk of performing corrective osteotomies in 10% of patients with active UCH. Increasing the sensitivity by using a lower cut-off value reduces this risk but this will result in a lower specificity and additional unnecessary condylectomies.

A review of the literature investigating the use of bone seeking radiopharmaceuticals in the diagnosis of UCH indicated that there is no uniform method for diagnosing a patient with UCH. No uniform method for quantification of bone activity was used in any of the planar and SPECT scan-based studies. Two studies used the ratio of activity in the right and left condyle, while the other study used the SPECT technique. The pooled sensitivity of 0.90 in the SPECT scan indicates the risk of performing corrective osteotomies in 10% of patients with active UCH. Increasing the sensitivity by using a lower cut-off value reduces this risk but this will result in a lower specificity and additional unnecessary condylectomies.
Another new diagnostic technique is the use of positron emission tomography (PET) for the measurement of bone activity. PET allows true quantitative in vivo measurements of bone activity in the condylar region. Quantitative uptake of labeled fluoride (18F) in bone, which is measured using PET, is directly correlated with histomorphometric parameters of bone formation and might improve the identification of asymmetric condylar activity.

In conclusion, on the basis of the present review and meta-analysis of recent literature on the use of bone scintigraphy in diagnosing UCH, it can be recommended that future studies be performed in a more uniform fashion, including standardization of bone scan technique and quantification methods. Future studies should include a diagnostic analysis of the reported data, including two by two contingency tables, to evaluate the accuracy of the diagnostic test. It can be concluded that a bone scan can best be performed using the SPECT scanning technique, and assessed by conducting a quantitative analysis by calculating the percentile differences of bone activity of the left and right condylar regions.

Competing interests
None declared.

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None.

Ethical approval
Not required.

References


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