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Martin Jurado, O; Clauss, M; Hatt, J M
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Abstract

Tooth wear is often suggested as an important factor limiting the lifespan of free-ranging wildlife. Given the frequent occurrence of poor dental health in captive animals reported in the literature, one would expect tooth health to be a limiting factor in captivity as well. Additionally, it could be assumed that brachydont (browsing) animals are more susceptible to dental health problems than hypsodont (grazing) animals, given current indications for systematic increased tooth wear in some browsing species. A pilot survey of necropsy reports of adult captive wild ruminants (n=294, 12 species) in one facility was performed in order to test these hypotheses and to calculate the incidence of irregular tooth wear. The overall incidence of irregular tooth wear was 20%, with a very high proportion of reports that did not mention the teeth at all. In contrast to the expectations, animals with irregular tooth were older than animals that died from other causes, indicating that reaching above-average age was a prerequisite for the development of reported abnormalities in this data set. A grazing species (blackbuck, Antilope cervicapra) was most affected, whereas two browsing species were not. Affected species had been regularly fed on sandy soil, whereas browsers had received feeds from racks, suggesting that husbandry practices are most important for dental health. There was a high proportion of reported serous fat atrophy in animals with irregular tooth wear, suggesting a clinical relevance of the problem. On average, adult individuals of the species investigated reached 41% of the maximum reported lifespan. Although this number appears low, the lack of comparative data from other facilities does not allow to draw conclusions on the adequacy of the husbandry practices used.
IRREGULAR TOOTH WEAR AND LONGEVITY IN CAPTIVE WILD RUMINANTS: A PILOT SURVEY OF NECROPSY REPORTS

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Abstract: Tooth wear is often suggested as an important factor limiting the life span of free-ranging wildlife. Given the frequent occurrence of poor dental health in captive animals reported in the literature, one would expect tooth health to be a limiting factor in captivity as well. Additionally, it could be assumed that brachydont (browsing) animals are more susceptible to dental health problems than are hypsodont (grazing) animals, given current indications for systematic increased tooth wear in some browsing species. A pilot survey of necropsy reports of adult captive wild ruminants (n = 294, 12 species) in one facility was performed in order to test these hypotheses and to calculate the incidence of irregular tooth wear. The overall incidence of irregular tooth wear was 20%, with a very high proportion of reports that did not mention the teeth at all. In contrast to this study’s hypotheses, animals with irregular tooth wear were older than animals that died from other causes, indicating that reaching above-average age was a prerequisite for the development of reported abnormalities in this data set. A grazing species (blackbuck, Antilope cervicapra) was most affected, whereas two browsing species were not affected. Affected species had been regularly fed on sandy soil, whereas browsers had received feeds from racks, indicating that husbandry practices are most important for dental health. There was a high proportion of reported serous fat atrophy in animals with irregular tooth wear, indicating the clinical relevance of the problem. On average, adult individuals of the species investigated reached 41% of the maximum reported life span. Although this number appears low, the lack of comparative data from other facilities does not allow for conclusions on the adequacy of the husbandry practices used.

Key words: Tooth wear, nutrition, husbandry, longevity, serous fat atrophy, artiodactyla, ruminants, feeding.

INTRODUCTION

It is generally believed that tooth wear and dental abnormalities are important factors limiting the life span, the reproductive success, and the body condition of free-ranging wild animals, although actual studies documenting this are still rare. Given several reports documenting that the condition of teeth is generally worse in captive animals when compared to free-ranging wild animals, it could be postulated that dental health could also be an important limitation for the longevity of captive wildlife. To date, retrospective studies to corroborate this hypothesis are lacking.

There are few studies investigating the incidence of tooth problems in captive wild ruminants. In giraffe (Giraffa camelopardalis), a comparison of skulls from six captive and 15 free-ranging individuals consistently showed moderate to severe dental wear in the captive specimens in contrast to mostly absent or mild tooth wear in the free-ranging specimens. Using a paleobiologic method (‘mesowear’) in the same species, it was demonstrated quantitatively that the dental wear pattern differed significantly between captive and free-ranging animals. A further investigation on additional ruminant species revealed that this pattern was evident for other browsing species as well. It should be noted that the mesowear method does not evaluate “pathologic” tooth wear, as animals with pathologic changes are excluded from mesowear scoring. The impacts on clinical relevance could only be speculated in these studies.

In order to gain insight into the frequency and relevance of dental health problems in captive wild ruminants, we performed a retrospective survey of necropsy reports from the Zurich Zoo, Switzerland, for the last 60 yr. The goal of this study was aimed at linking the findings with indicators of the body condition of the animals (serous fat atrophy), in order to evaluate the clinical relevance of the observed dental pathology, and with the life span of the animals. In order to compare the impact of dental problems on the life span of different species, the age at death was expressed as a percentage of the maximum life span reported for the species. Based on the consideration that browsers, with their low-crowned (brachydont) teeth, should be particularly susceptible to increased tooth wear in captiv-
Table 1. Results of the evaluation of 294 necropsy reports on adult individuals of 12 ruminant species at Zurich Zoo. Feeding type (FT) indicated as grazer (GR), intermediate feeder (IM), or browser (BR), and the typical winter diet fed at Zurich Zoo is indicated.

<table>
<thead>
<tr>
<th>Common name</th>
<th>FT</th>
<th>Diet*</th>
<th>No. of reports evaluated</th>
<th>Teeth not mentioned in reports</th>
<th>No excessive wear/deformation</th>
<th>Excessive wear/deformation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blackbuck</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antilope cervicapra</td>
<td>GR</td>
<td>GH 70, P 20, FV 10 (gr)*b</td>
<td>50</td>
<td>23</td>
<td>4</td>
<td>23</td>
</tr>
<tr>
<td>Axis axis</td>
<td>IM</td>
<td>GH, CE, FV (gr)</td>
<td>23</td>
<td>19</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>American bison</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bison bison</td>
<td>GR</td>
<td>GH 85, CE 15 (gr)</td>
<td>5</td>
<td>4</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Nilgai</td>
<td>IM</td>
<td>GH 70, P 5, CE 20, FV 5 (gr)*b</td>
<td>10</td>
<td>5</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Domestic goat</td>
<td>IM</td>
<td>GH, P, CE, FV (gr)</td>
<td>18</td>
<td>12</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Capra hircus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eld’s deer</td>
<td>IM</td>
<td>GH 70, P 20, FV 10 (gr)*b</td>
<td>18</td>
<td>5</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Cervus eldi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black wildebeest</td>
<td>GR</td>
<td>GH, CE, FV (gr)</td>
<td>13</td>
<td>10</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Connochaetes gnou</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goitered gazelle</td>
<td>IM</td>
<td>GH 35, P 40, CE 1, FV 24 (gr)*b</td>
<td>44</td>
<td>29</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Gazella subgutturosa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oryx</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oryx leucoryx</td>
<td>GR</td>
<td>GH 80, P 10, FV 10 (−)</td>
<td>14</td>
<td>11</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Reindeer</td>
<td>IM</td>
<td>GH 50, P 50 (gr)</td>
<td>31</td>
<td>22</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Rangifer tarandus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greater kudu</td>
<td>BR</td>
<td>LH 85, P 5, CE 5, FV 5 (gr)</td>
<td>24</td>
<td>17</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Lesser mouse deer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tragulus javanicus</td>
<td>BR</td>
<td>P, CE, FV (−)</td>
<td>44</td>
<td>37</td>
<td>7</td>
<td>0</td>
</tr>
</tbody>
</table>

*Diets fed are given as ingredient classes: GR = grass hay; LH = lucerne (alfalfa) hay; P = pelleted food; CE = cereals and bread;
V = fruits and vegetables. Numbers indicate the proportion of the respective ingredient in the total dry matter intake, if available from
nake studies.†*Diets are winter diets; additional diet items during summer months are indicated in brackets as gr = fresh grass.
*Animals received parts of their diet directly on sandy soil.

ity and, thus, should be predisposed to dental pathology; it was hypothesized that the browsing species in the data collection should have a higher incidence of dental abnormalities than the grazing species.

MATERIALS AND METHODS

The necropsy reports of ruminants that died between 1950 and 2005 at the Zurich Zoo were analyzed. Only species for which at least five necropsy reports were available and only individuals aged 1 yr and older were considered for this pilot investigation.

The species involved were blackbuck (*Antilope cervicapra*), axis deer (*Axis axis*), American bison (*Bison bison*), nilgai (*Boselaphus tragelaphus*), domestic goat (*Capra hircus*), Eld's deer (*Cervus eldi*), black wildebeest (*Connochaetes gnou*), goitered gazelle (*Gazella subgutturosa*), oryx (*Oryx leucoryx*), reindeer (*Rangifer tarandus*), greater kudu (*Tragelaphus strepsiceros*), and lesser mouse deer (*Tragulus javanicus*). These species were classified into feeding types (Table 1).

In Table 1, the ingredients of the diets fed to the animals are presented summarized by food categories. In species in which intake studies had been performed, the proportion of a diet category of the total dietary dry matter intake is listed. However, these measurements represent the diet at a single time point during the long period for which necropsy reports were evaluated and therefore must be used only as a general indication of the diets fed.

From the necropsy reports, the following parameters were included: species, age, sex, body weight, macroscopic findings of the oral cavity, heart, kidney, and diagnosis.

In order to cope with the heterogeneity of the data in the necropsy reports, only two dental states were distinguished: excessive/irregular tooth wear/deformation, as opposed to no excessive/irregular tooth wear/deformation. Individuals in whom the dentition was described as "wave-like," "staircase-
like,” or with pointed hooks were included in the group of animals with excessive/irregular tooth wear/deformation. Animals for whom the absence of tooth wear or deformation was reported or animals for whom only tooth loss, caries, oral abscesses, or gum inflammation in the absence of excessive/irregular wear was reported were included in the group of no excessive/irregular tooth wear/deformation. It was assumed that if one abnormality was noted in the oral cavity, then the oral cavity was examined completely. If there was no statement regarding the oral cavity in the necropsy report, the individual was assumed to have shown no observable teeth abnormalities. For the statistical calculations, these individuals were assigned to the no excessive/irregular tooth wear/deformation group.

Additionally, reported pathologic observations of the kidney and heart fat stores were considered, particularly among the animals with excessive tooth wear. The proportion of individuals with a reported serous atrophy of fat in the coronary heart groove and/or around the kidneys was calculated.

For individuals of known age at death, the relative life span was expressed in relation to the maximum life span recorded for the species.

The average life span achieved was compared between species by the Kruskal–Wallis test. A $\chi^2$-test served to test for differences between the species with regard to the relative proportion of individuals affected by irregular tooth wear. In order to identify species that had a particularly high or low incidence of irregular tooth wear in this data set, adjusted standardized residuals (ASR) were calculated in the (tooth wear) by (species) cross table. Residuals beyond $\pm 1.96$ were considered to indicate a significant deviation from the expectation. Within each species, differences in life span between animals with and without irregular tooth wear were tested by the $U$-test. To determine if serous fat atrophy was particularly prevalent in animals with irregular tooth wear, a Fisher’s exact test was used within species. All analyses were performed using SPSS 12.0 (SPSS, Inc., Chicago, Illinois 60606, USA). The significance level was set to 0.05.

**RESULTS**

Data from the necropsy reports of the 12 ruminant species involved in the survey over the last five decades are summarized in Table 1.

Of all 294 reports, teeth were not mentioned in 194 reports (66%); in 40 reports (14%) the oral cavity was explicitly described as normal or without particular changes, and teeth abnormalities were indicated in 60 reports (20%). Within this latter group, excessive/irregular tooth wear/deformation was considered as the cause of death in 42 reports (70%). Numerically, the species most affected by the condition were blackbuck (46% of all individuals investigated), followed by nilgai (40%), Eld’s deer (28%), and the goitered gazelle (21%). In contrast, the browser group, including the greater kudu, was not particularly affected (Table 1). The incidence differed significantly between the species ($\chi^2$-test, $P < 0.001$), a result that was due to blackbuck (ASR = 4.9), in whom the incidence of irregular tooth wear was significantly higher than expected from the pattern within the whole data set. The axis deer (ASR = −2.5) and mouse deer (ASR = −3.6) had a significantly lower incidence when compared to the other study animals.

Within the group of excessive/irregular tooth wear/deformation, 37 necropsy reports (62%) recorded serous atrophy in the coronary heart groove and/or around the kidneys. In contrast, only 23% (53 of 234) of cases of animals without reports of irregular tooth wear had serous fat atrophy, indicating that serous fat atrophy was associated with irregular tooth wear. The higher incidence of serous fat atrophy in animals with irregular tooth wear was, however, only significant in the blackbuck (Fisher’s exact test, $P = 0.001$).

The age was known in 204 individuals (all other were noted to be ‘adult’ or ‘senior’). The average life span achieved by all species was 41% of the maximum reported life span. There were no differences noted between the species’ life spans (Kruskal–Wallis test, $P = 0.108$) (Table 2). When the proportion of the maximum life span was calculated separately for individuals affected and not affected by irregular tooth wear, there was a difference between these groups in most species. Averaging these values for all species, 55% of the maximum life span was achieved by individuals affected by irregular tooth wear, as compared to 36% in individuals with no or nonreported dental disease. In other words, animals in whom irregular tooth wear was noted were relatively older. The age difference between animals with reported excessive tooth wear and the rest of the animals was significant within blackbuck ($U$-test, $P = 0.008$) and reindeer ($P = 0.004$).

If ordered by decades, nonreporting of tooth condition in necropsy reports was 88% in the 1950s, in contrast to 72% and 24% in the 1980s and the first decade of the new century, respectively. On the other hand, teeth abnormalities were reported in 4% of the cases in the 1950s, in 20% of cases in
Table 2. The species investigated in this study, including the reported maximum age, the absolute age in years (mean, ± standard deviation [SD]), and the percentage of the maximum age achieved by all studies' animals and those with and without irregular tooth wear (mean, ±SD).

<table>
<thead>
<tr>
<th>Animal</th>
<th>n</th>
<th>Maximum age (yr)</th>
<th>Age</th>
<th>% of maximum age</th>
<th>Without irregular tooth wear % of maximum age</th>
<th>With irregular tooth wear % of maximum age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antilope cervicapra</td>
<td>36</td>
<td>15</td>
<td>6.3 ± 4.5</td>
<td>42.0 ± 29.9</td>
<td>57.9 ± 33.5</td>
<td>29.3 ± 19.6</td>
</tr>
<tr>
<td>Axis axis</td>
<td>8</td>
<td>15</td>
<td>6.4 ± 4.7</td>
<td>42.9 ± 31.1</td>
<td>—</td>
<td>42.9 ± 31.1</td>
</tr>
<tr>
<td>Bison bison</td>
<td>4</td>
<td>25</td>
<td>13.0 ± 2.9</td>
<td>52.0 ± 11.8</td>
<td>—</td>
<td>48.0 ± 10.6</td>
</tr>
<tr>
<td>Busephalus tragocamelus</td>
<td>5</td>
<td>22</td>
<td>10.6 ± 4.9</td>
<td>48.2 ± 22.2</td>
<td>50.8 ± 24.3</td>
<td>44.3 ± 27.3</td>
</tr>
<tr>
<td>Capra hircus</td>
<td>12</td>
<td>20</td>
<td>8.6 ± 3.9</td>
<td>43.1 ± 19.6</td>
<td>52.5 ± 3.5</td>
<td>41.3 ± 21.1</td>
</tr>
<tr>
<td>Cervus eldi</td>
<td>13</td>
<td>19</td>
<td>6.0 ± 3.4</td>
<td>31.8 ± 17.9</td>
<td>45.6 ± 15.2</td>
<td>27.6 ± 17.2</td>
</tr>
<tr>
<td>Connochaetes gnou</td>
<td>7</td>
<td>20</td>
<td>9.6 ± 4.0</td>
<td>47.9 ± 20.2</td>
<td>52.5 ± 3.5</td>
<td>46.0 ± 24.3</td>
</tr>
<tr>
<td>Gazella subgutturosa</td>
<td>31</td>
<td>12</td>
<td>6.0 ± 3.7</td>
<td>50.1 ± 30.7</td>
<td>76.0 ± 34.4</td>
<td>46.3 ± 28.8</td>
</tr>
<tr>
<td>Oryx leucoryx</td>
<td>12</td>
<td>20</td>
<td>7.5 ± 6.7</td>
<td>37.7 ± 33.4</td>
<td>67.5 ± 17.7</td>
<td>31.8 ± 33.1</td>
</tr>
<tr>
<td>Rangifer tarandus</td>
<td>17</td>
<td>20</td>
<td>5.7 ± 4.4</td>
<td>28.6 ± 22.0</td>
<td>54.0 ± 12.9</td>
<td>18.0 ± 15.0</td>
</tr>
<tr>
<td>Tragelaphus strepsiceros</td>
<td>21</td>
<td>23</td>
<td>8.3 ± 5.6</td>
<td>36.3 ± 24.3</td>
<td>41.3 ± 9.2</td>
<td>35.8 ± 25.4</td>
</tr>
<tr>
<td>Tragulus javanicus</td>
<td>38</td>
<td>12</td>
<td>3.8 ± 3.1</td>
<td>31.9 ± 25.5</td>
<td>—</td>
<td>31.9 ± 25.5</td>
</tr>
</tbody>
</table>

the 1980s, and in 31% of cases in the last decade (Table 3).

DISCUSSION

The aim of this pilot study was to assess the frequency and, if possible, the relevance of irregular tooth wear in captive wild ruminants. Such a study is, in its contribution to evidence-based medicine, limited in the relevance of its conclusions by the small sample size and the resulting lack of significant correlations. In this study, significant findings were generally limited to those species in which the largest number of individuals had been investigated (blackbuck, goitered gazelle, mouse deer, and reindeer; Table 1). Therefore, this pilot study indicates that for more conclusive findings, larger sample sizes involving several zoologic institutions might be warranted; such a study would then, however, be influenced by variation due to differences in husbandry practices, including food presentation practice and specific feeds consumed.

For the population at the Zurich Zoo, irregular tooth wear was an important finding. The estimated minimum incidence of the problem of irregular tooth wear was 20% (60 out of a total of 294 necropsy reports), with a theoretical maximum estimated of 60% (60 of a total of 100 necropsy reports in which results of an oral examination were actually noted). This maximum incidence estimate is unlikely, as it can be assumed that in several cases in which the teeth were deemed 'normal' by the pathologist, they were not explicitly mentioned. In the last two decades investigated, the minimum incidence estimated did not change (about 30%), even though recently oral examinations were performed much more often (Table 3), which indicates that this number was representative for the population under study.

The potential consequences of irregular tooth wear are suggested by the high incidence of depleted fat reserves in the affected animals. As in another study, irregular tooth wear was also often cited as the direct cause of death. In free-ranging goats, a difference in diet selection was demonstrated between animals with different dental health, with animals with worn incisors avoiding grass forage. Thus, tooth wear can influence diet choice and, if no choice is available in a captive setting, probably also the food intake level.

Unexpectedly, irregular tooth wear did not seem to be an important limitation to the life span of the animals in this data set. At first this had been suspected because animals with irregular tooth wear only achieved an average 55% of their maximum life span. However, animals of this data set that
died without reported irregular tooth wear achieved
an even lower proportion of their maximum life
span. In theory, a calculation of risk factors in re-
lation to life expectancy would, in this data set, lead
to the paradox conclusion that irregular tooth wear
was a protective factor for the achievement of older
age. In this respect, tooth wear resembles other ge-
riatric diseases, such as cancer, which is more prev-
alent in older specimens. Undoubtedly, irregular
tooth wear will compromise the survival of captive
animals, but it seems that in the population under
study, animals had to live long enough for tooth
abnormalities to develop the degree of severity that
was noted at necropsy. When evaluating the age-
limiting effect of dental disease, other influencing
factors have to be considered. In a comparison of
two free-ranging raccoon (Procyon lotor) popula-
tions, the population with the higher incidence of
dental disease nevertheless lived longer on average,
most probably because of a supply of food from
human leftovers. In wild adult bears (Ursus amer-
icanus), no relationship between periodontal dis-
ease and age was found. But regardless of these sta-
tistical considerations, one might suggest that
there is a high probability that many of the animals
in the zoo population of this study would have sur-
vived even longer had they not died of the conse-
quences of irregular tooth wear. In other words, it
is suspected that with a management that would
have reduced irregular tooth wear, many individuals
would have lived even longer. Evidently such a hy-
pothesis should be confirmed by further studies.

It had been expected that irregular tooth wear
was more drastic in browsing ruminants compared to
grazing ruminants. It was assumed that the abra-
siveness of captive diets would predispose the low-
crowned (brachydont) teeth of browsers to develop
pathologic wear patterns, when compared to the
high-crowned (hypsodont) teeth of grazers. In gen-
eral, grass hay, as was offered to most species in
this survey, contains siliceous phytoliths that are
assumed to wear down tooth enamel. Legumes,
such as alfalfa/leucerne (Medicago sativa), which
was fed to the kudu, and browse contain no or much
fewer phytoliths and have, consequently, much lower contents of acid-insoluble ash. Given
the respective adaptations to the abrasive potential
gain and browse in terms of hypsodonty in graz-
ers, one would expect a similar degree of tooth
wear in grazers fed grass and browsers fed legume
forage. However, since additional zoo diet items,
such as pelleted feeds, are also likely to contain
more acid-insoluble ash than browse or legumes, a
disproportionately higher abrasive wear pattern in
the browser could be expected, and has been shown
in captive giraffes and other browsing species, as
compared to captive grazing ruminants, including
greater kudus. With respect to this investigation,
it was hypothesized that it is this increased abrasive
wear pattern in the browsers that will predispose
these animals to pathologic tooth wear. It is impor-
tant to note that tooth wear, as quantified by a 'mes-
owell score,' cannot be equated with 'excessive
tooth wear,' as noted by a pathologist; by method
definition, cases of pathologic wear, such as 'ex-
cessive' wear or drastic irregularities, are excluded
from the 'mesowell' analysis. In contrast to that
description, the species most affected was a grazer
(blackbuck) with a high hypsodonty index, whereas
the browser kudu was not particularly affected.

More recently, a study on the minor abrasive po-
tential of phytoliths has raised doubts about the
theory that hypsodonty had evolved in response to
grass phytoliths. In contrast, the theory that hyp-
sodonty is the response to increased grit load on
the natural forages consumed by hypsodont spe-
cies is emphasized. As feeding practices in zoos
usually prevent high contaminations of grit in the
diets fed, many captive grazers actually might show
a wear pattern less dominated by abrasion than that
observed in their free-ranging conspecifics, a hy-
pothesis confirmed by quantitative investigations.
However, while it appears impossible to challenge
the hypsodont teeth of grazers with diets of extreme
intrinsically abrasive phytoliths, the proportion
of external grit adhering to and ingested in tan-
dem with a diet can vary with feeding practices and
might very well exceed a level even hypsodont spe-
cies can endure without detrimental effects. Further
inquiries about husbandry practices at the Zurich
Zoo revealed that the most affected species of this
study were regularly given forage on the sandy soil
of their enclosure; in contrast, a browsing species
like the greater kudu was offered forage from hay
racks—to achieve a more natural foraging posture.
In horses it has been shown that feeding directly
on the ground increases the risk of sand ingestion,
and in sheep it has been shown that the amount of
soil ingested is directly correlated to the degree of
tooth wear. Thus, feeding practices, not the diet
itself, appear to be the most likely explanation
for the pattern in dental pathology observed across
species in this study.

The most evident result of this survey was the
high rate of nonreported findings of the investiga-
tion of tooth status at necropsy. This problem often
occurs in the retrospective evaluation of necropsy
reports and has already been explicitly stated in a
survey of dental health. The results also indicate
that the quality of necropsy reports has increased
over the years; nevertheless, the routine description of both pathologic findings and their absence remains a major aim in zoo animal pathology.

Another surprising finding was the low proportion of the maximum life span that was, on average, attained by the animals in this sample population. To the authors’ knowledge, comparative data are lacking in this respect, and it is not possible to know whether the average life span of this population is particularly low or is on a comparable level to that of other zoo ruminant collections. Comparative evaluations in this respect could help to increase the awareness of both particularly susceptible species and particularly favorable or unfavorable husbandry techniques.

CONCLUSION

This study confirmed that dental disease was an important health issue in the sample population, even if a particular life span limitation due to irregular tooth wear could not be demonstrated as a result of the high mortality of animals of low age.

Preventive measures for improved oral and/or dental health (e.g., feeding in such a way that sand adhesion to forage is avoided) should be part of standard husbandry practices; in addition, an oral examination should be performed at every opportunity to handle an animal. Dental health in captive animals could be considered an indicator of the oologic care status, reflecting housing, enrichment, diet, and correct species management, and should receive appropriate attention.

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