EVALUATION OF ORAL PATHOLOGIES IN *Pan paniscus* USING CT.

A Thesis

by

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ABSTRACT

Periodontitis and odontogenic abscesses are common dental ailments that affect the ability to obtain sufficient nutrition. Thus, they are important indicators of oral health and quality of life. In this study, oral health status was evaluated in *Pan paniscus* (bonobo) as they are genetically and cognitively similar to humans and deserve protection. In CT images of 140 bonobo skulls housed in the Royal Museum for Central Africa, Belgium, odontogenic abscesses, and periodontitis were investigated. For this study diagnostic criteria for periodontitis were loss of alveolar bone which includes loss of interdental bone and exposure of root furcation in multi-rooted teeth, Bone defect scores are calculated by the average of distance from Cemento Enamel Junction to deepest alveolar bone depth on mesiobuccal and distobuccal aspects of all premolars and permanent 1st and 2nd molars. Male (M) and female (F) specimens, as well as specimens of unknown sex (U), were categorized as juvenile/subadult (J), young adult (Y), and adult (A) depending on the dentition stage and root canal apices closure. Results indicated that 7 specimens (5%) had signs of odontogenic abscesses (3 M, 2F, 2 U; 6 A, and 1Y). In addition, there was a high prevalence of signs of periodontitis. The prevalence of periodontitis was 92.3% (M 90%, F 91%, U 95%), and 45.5% (M 40%, F 44.4%, U 50%) in adults and young adults, respectively. In juveniles 46.2% M, 50.0 % F and 51.3% U specimens showed signs of incipient periodontitis. Mean Bone defect score in adults was significantly greater than other age groups but was similar in different sex groups. Signs of other oral pathology or anomaly were rare. These findings suggest that bonobos generally had good dentition and oral health, while periodontitis was common and increased with age. The knowledge of oral health in bonobos, which along with chimpanzees are the closest extant relatives of humans, can thus provide valuable insights into the epidemiology of the disease from an evolutionary perspective.

CONTRIBUTORS AND FUNDING SOURCES

Contributors

This work was supervised by a thesis committee consisting of Dr. Qian Wang [Chair] of Department of Biomedical Sciences, Dr. Faizan A. Kabani of the Caruth school of Dental Hygiene, Dr. Sid Poorya Jalali of the Department of Endodontics and Dr. Sang Jin Suh of Department of Biomedical Sciences.

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1. INTRODUCTION

Non-human primates (NHP) such as the chimpanzees (*Pan troglodytes*), bonobos (*Pan paniscus*) and gorillas (*Gorilla*), orangutans (*Pongo*), gibbons (Hylobatidae) etc. are protected from experimentation because they are cognitively similar to humans. Many of the great apes are protected in colonies. Although bonobos share 98.7% of the genome with humans and are the closest extant relatives (Prüfer et al., 2012), there are no protective measures for the preservation of the species. As a result, they are targeted by poachers and are critically endangered. Therefore, there is a need to care for the health of this species. In recent years it has become clear that oral health has a significant impact on the systemic health and vice versa. Oral health is known to contribute to various diseases and conditions, including endocarditis, cardiovascular diseases, pneumonia as recently reviewed by Kane (Kane, 2017). Certain systemic diseases such as diabetes, osteoporosis etc. are also known to affect oral health. Most common oral pathologies in NHP include odontogenic abscesses, periodontitis, & caries. (Crovella & Ardito, 1994). Odontogenic abscesses, periodontitis and their associated tooth loss affect the individual's ability to maintain the dental structures necessary to obtain adequate nutrition for survival, growth, maturation, and reproduction (Li et al., 2018). NHP demonstrate clinical, microbiological, and immunologic similarities to the diseases in humans, including the transmission of bacterial pathogens *Porphyromonas gingivalis* and *Aggregatibacter actinomycetemcomitans* from mothers with gingivitis/periodontitis to infants. (Ebersole et al., 2014). Periodontitis and its subsequent effect on bone health in bonobos has not been studied in detail. In order to improve the overall health and survivability of this endangered species that is the closest extant relative of humans, it is necessary to evaluate the oral health of bonobos in detail as bonobos are endangered (IUCN, -2016). In this study oral health of bonobos is evaluated using Computed Tomography (CT) scans.

2. MATERIALS AND METHODS

2.1. Computed tomography scans of skeletal collections:

Computed tomography (CT) scans of 140 skulls of bonobos (*Pan paniscus*) from the bonobo skull collection at the Royal Museum for Central Africa at Tervuren, Belgium were used in the study. The CT scans were obtained by using the following parameters:120 kV, 135 mA, 1 mm-thick slices, reconstruction interval of 0.5 mm, 15 cm field of view, 0.29296875 mm pixel size, 512*512-pixel matrix (Balzeau et al., 2008)

2.2. Evaluation of CT scans:

The CT scans were evaluated using the software RadiAnt DICOM viewer (Medixant, Version 2020.2. https://www.radiantviewer.com**)** in

a.) Slice interval view: Views the specimen in progressive radiographic slices. (Figs. 1, & 3).

b.) 3D volume rendering: Reconstructs all the radiographic slices of the specimen into 3-D images which can enhance visualization of anomalies/pathologies. (Figs. 2, & 4).

The specimens were divided into the following three age groups on examination of their CT scans.

1.) **Juveniles:** specimen with primary dentition or mixed dentition.

2.) **Young adults:** specimen with dentition with open root canal apices/unerupted 3^{rd} molar.

3.) **Adults:** specimen with completely erupted teeth with closed apices.

Information about the sex of the specimens was provided by the Royal Museum for Central Africa and specimens without information on sex were denoted as specimens of

Unknown sex. Distribution of specimens among different age and sex demographics are listed in Table 1.

Sex / Age	Male	Female	Unknown Sex	SUM
Juveniles	**14**	**15**	**37**	**66**
Young Adults	**5**	**9**	**8**	**22**
Adults	**10**	**21**	**21**	**52**
TOTAL	**29**	**45**	**66**	**140**

Table 1: Distribution of specimens among different sex and age demographics.

2.3. Diagnostic criteria:

2.3.1. Periodontitis.

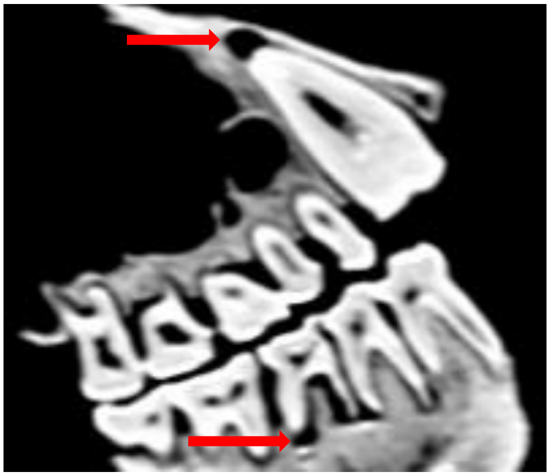
The criteria for diagnosis of periodontitis (Hirshmann, 1987). The details are as follows.

a.) Horizontal/Vertical/interdental bone loss (loss of crestal bone height) as seen in Figs. 3, & 4.

b.) Furcation exposure due to loss of cortical bone in multirooted teeth as seen in Fig. 4.

2.3.2. Odontogenic abscesses.

a.) Radiolucency of the bone at the periapical region or along the surface of the root that may or may not be associated with the fenestration of the cortical plate (Figs. 1, & 2)



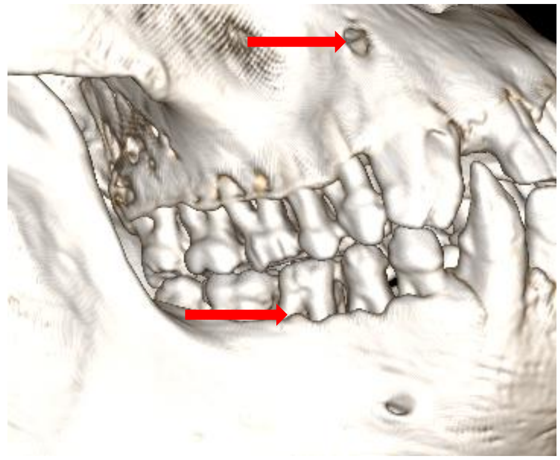
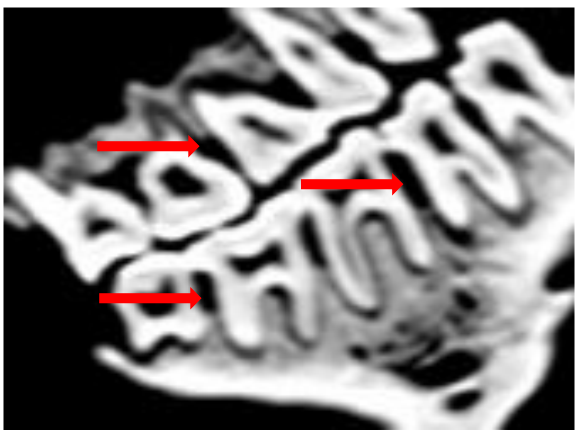


Figure 1: Slice interval showing periapical abscess in adult male irt #6 and #30.

Figure 2: 3D VR view of a specimen showing fenestration irt #6, but no fenestration irt #30.



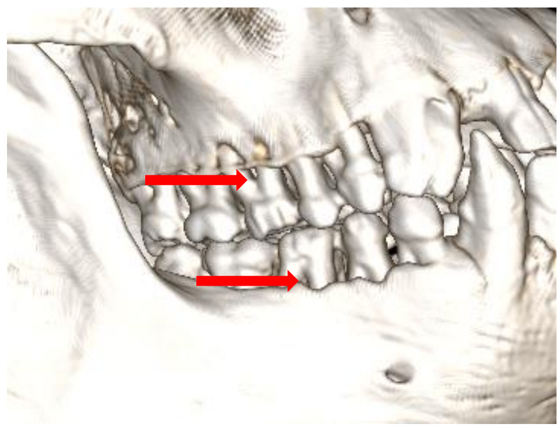


Figure 3: Slice interval view of an adult specimen showing multiple bone defects.

Figure 4: 3D VR of a specimen showing periodontitis related bone loss and furcation exposure in multiple affected teeth.

2.4. Periodontal disease measures:

Bone defect score is evaluated determining the distance from the deepest extent of the vertical bone defect to the C.E.J. on mesiobuccal and distobuccal sites of premolars and molars and averaged (Ebersole et al., 2016) (Fig. 5). The distance was measured using an inbuilt tool in RADIANT DICOM viewer software. Teeth missing ante mortem were assigned a value of 10. The antemortem and postmortem nature of the loss of teeth was determined by evaluating the sockets of missing teeth. Regions of missing teeth with shallow sockets were considered antemortem and regions with deep sockets were considered postmortem. Juvenile specimens with at least one permanent molar are only considered for the measures as these are done only on permanent teeth.

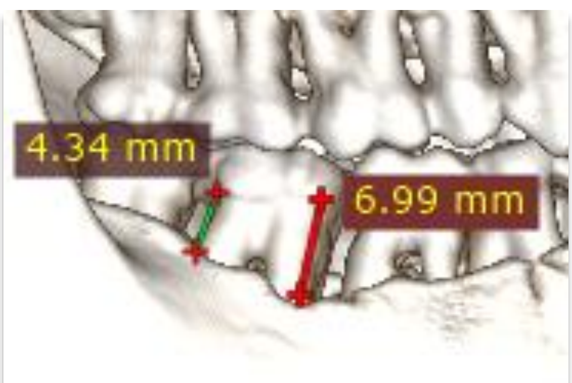


Figure 5: Measurements from C.E.J. to deepest extent of vertical bone defect on both mesiobuccal and distobuccal sites of #31.

2.5. Data Analysis:

Z tests were used to determine the statistical significance of differences in prevalence. **Z score of 1.96 was set for $\alpha = 0.05$.** Statistical significance of difference in mean bone defect scores was determined using Welch's ANOVA. The preset α value is also 0.05.

3. RESULTS

3.1. Prevalence of Odontogenic abscesses:

Out of 22 specimens of the young adult population, only 1 specimen had odontogenic abscesses (4.5% prevalence). In 56 adults, 6 were affected with odontogenic abscesses (11.5% prevalence). No juveniles were affected. Among the 7 specimens affected with odontogenic abscesses, 3 were male, 2 were female and 2 were of unknown sex. The difference in prevalence among different sex groups and age groups is not statistically significant **(Z score =1.061, p > 0.05).**

3.2. Prevalence of periodontitis:

3.2.1. In Juveniles:

Of the 66 specimens, 32 (48.5% prevalence) were affected with periodontitis. The prevalence in males is 43% (*i.e.,* 6 were affected out of 14 specimens). In females, 7 of 15 specimens were affected indicating 47% prevalence. 19 out of 37 specimens of unknown sex were affected indicating 51% prevalence. The prevalence is similar among different sex groups in juveniles.

3.2.2. In Young Adults:

10 in 22 young adults were affected with periodontitis (45.5% prevalence). Prevalence in males was 40% (*i.e.,* 2 of 5 young adult males were affected). In females 4 out of 9 specimens were affected indicating 45% prevalence. 4 out of 8 unknown sex specimens were affected indicating 50% prevalence. The differences in prevalence in different groups of sex are not statistically significant **(Z score = 0.54, p > 0.05).**

3.2.3. In Adults:

48 of 52 adults were affected with periodontitis (92% prevalence). Prevalence in males was 90% (*i.e.,* 9 of 10 adult males were affected). In females, 19 out of 21 were affected indicating 90% prevalence. In 21 adults of unknown sex, 20 were affected with periodontitis indicating 95% prevalence. The differences in prevalence among different sex groups in adults are not statistically significant **(Z score = 1.23, $p > 0.05$).**

Differences in prevalence among different groups of sex are statistically insignificant, but the difference in prevalence between adults and young adults is statistically significant **(Z score = 3.63, $p < 0.05$).** Similarly, the difference in prevalence between adults' and juveniles is also statistically significant **(Z score = 4, $p < 0.05$).**

3.3. Periodontal disease measures:

3.3.1. In Juveniles:

Only 36 juveniles were included in the study of periodontal disease measures because the remaining specimens did not have any permanent molars. Out of these 36 juveniles, only 1 had a Bone defect score of 3.5 mm, and the other 35 juveniles Bone defect scores were between 1-3 mm indicating no or only mild periodontitis.

3.3.2. In Young Adults:

Out of 22 young adults, only 1 specimen had Bone defect score between 3.6 mm indicating periodontitis. The other young adults scores ranged between 1-3 mm indicating no or moderate periodontitis.

3.3.3. In Adults:

Out of 52 adults, 17 had Bone defect scores of 1-3 mm indicating no or mild periodontitis, 22 had Bone defect scores of 3-6 mm indicating moderate periodontitis and 13 had Bone defect score of 6-10 mm indicating severe periodontitis.

3.3.4. Comparison of mean Bone defect scores:

The mean bone defect score of different sexes are as follows, Males = 3.2, Females = 3.2, Unknown sex = 2.5 (Fig. 6). The mean Bone defect score of different age groups is as follows. Juveniles =1.6, Young Adults =1.8, Adults = 4.5 (Fig. 7). The differences in mean of different sexes are not statistically significant **(Welch's ANOVA: F = 1.502, p = 0.230)**. The difference in the mean of Bone defect scores between adults and young adults, adults and Juveniles are statistically significant **(Welch's ANOVA: F=35.864, p < 0.001).** The difference between mean bone defect scores of juveniles and young adults is not statistically significant **(Post hoc Bonferroni: p = 1**).

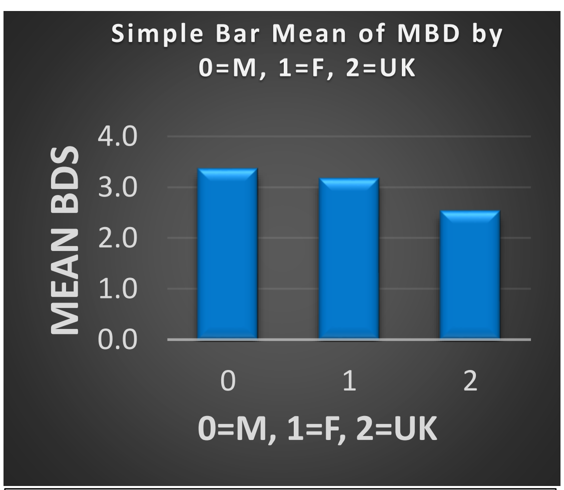


Figure 6: Comparison of Mean Bone defect scores among sex groups

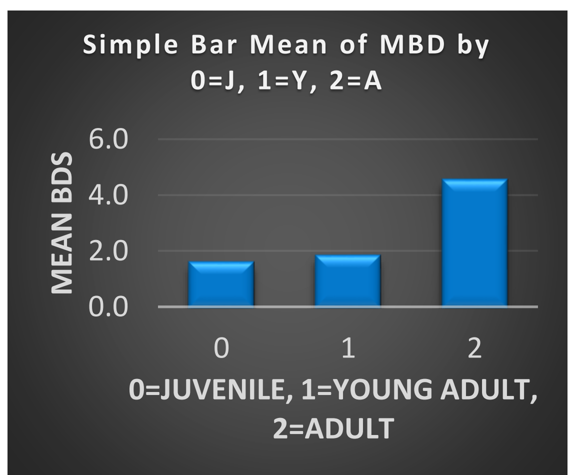


Figure 7: Comparison of Mean Bone defect scores among age groups.

4.DISCUSSION

Periodontitis and odontogenic abscesses are two of the most common oral pathologies causing maxillofacial skeletal lesions (Crovella & Ardito, 1994). The maintenance of dental structures is necessary to obtain adequate nutrition for growth, development, and reproduction (Li et al., 2018). In this study, the prevalence and pattern of odontogenic abscesses and periodontitis were systematically investigated. The prevalence of odontogenic abscesses in young adults and adults is 9.5% and not significantly different when compared to other animals such as *Macaca mullata:* 9.57% (Li et al., 2018) or *Chimpanzees*: M:14.6%, F:15.7% (Table 2), (Legge, 2012). The findings indicate a high prevalence of periodontitis among specimens that increased with age. The prevalence of periodontitis in adult bonobos is 92.3% and is significantly greater when compared to other species such as Humans: 49% (Eke et al., 2015) and Gorillas:70.6% Table 3 (Lowenstine et al., 2016). The differences in prevalence of periodontitis among different sex groups are insignificant but among the age groups are significant. Similarly, the difference between Bone defect scores is significant among the age groups but is not significant among the sex groups. Approximately 80% of specimen with periodontitis were associated with ante mortem tooth loss.

Species	Prevalence of odontogenic abscess in adults
Bonobos	9.5%
Macaques	9.7%
Chimpanzees	M: 14.6%, F: 15.7%

Table 2: Prevalence of Odontogenic abscesses among different species

Species	Prevalence of periodontitis in adults
Bonobos	92.3%
Humans	49%
Gorillas	70.6%

Table 3: Comparison of prevalence of Periodontitis among different species.

5.CONCLUSIONS

Even though affected with other minor oral pathologies such as fenestration, dehiscence and oroantral communication (6, 3 & 2 affected specimen respectively), periodontitis is highly prevalent among the bonobos with varying severity. The prevalence of periodontitis, and bone defects in bonobos are dependent on age but not on the sex of the animal. Bonobos have relatively poor oral health when compared to humans (Prevalence of periodontitis 92% vs 49%). The reason for this disparity can be due to differences in oral pathogens, lack of dental care, genetics, systemic health, etc. As CT is not optimal for diagnosing/evaluating caries other methods such as Visual inspection, Intraoral radiographs, Cone Beam Computed Tomography scans, etc., should be used to evaluate caries. The findings from this study warrant further investigation of the interwoven roles played by different factors on oral health in bonobos, especially in live animals, and such studies can provide an evolutionary perspective on oral health in humans. As their numbers are endangered this species requires protection similar to other apes.

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