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ORTHODONTIC CORRECTION IN RODENTS AND HARE-LIKE ANIMALS: PRINCIPLES AND METHODS OF TREATMENT

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The aim: *Our particular interest in this study is not only the ability to extrapolate the experience of orthodontics of humane medicine for effective orthodontic correction in representatives of the animal world, but also the possibility of using teleroentgenometry and craniometry to study the skull of rodents and hare-like animals for the early preclinical diagnosis of dental disease.*

Materials and methods. *The data of teleroentgenography (TRG), cranio- and gnatometry, biochemistry of connective tissue (GAG, GP, HST), fluoroscopy, densitometric parameters for early subclinical detection of dental disease in chinchillas (Chinchilla lanigera (n=20)), guinea pigs (Cavia porcellus (n=48)) and rabbits (Oryctolagus cuniculus(n=52)) are presented. All stages of the effective correction of mesial occlusion of incisors in rabbits (N=5) and dystropia of premolars in guinea pigs (N=5) are described. The camputation of efforts and points of their application that are necessary to move the tooth of the ellodont type is carried out. There are given the sequential stages of creating a dental imprint or 3D models, as well as the manufacture of fixed orthodontic structures, including an elastophore, orthodontic buttons with an Enlight Ormco fixation for incisors; and individual extraoral devices with expanding screws for premolars are presented.*

Results. *Namely, among animals with dental disease, the following anatomical characteristics reliably took place. The basal angle of inclination of the base of the jaws to each other characterizing the vertical position of the jaws increased by 11 %; the body of the lower jaw shortened by 18 %; the height of the branches of the jaw increased by 17.5, and the mandibular angle, which is measured between the tangents to the lower edge of the lower jaw and the back surface of its branches, increased by 6 %. These data must be considered together with a reliable densitometric decrease in bone density and changes of biochemical components of the connective tissue in the blood serum. An analysis of bone strength of rabbits and guinea pigs is given in Tab. 2, which shows that the bone marrow of animals with dental history is statistically significantly different from the strength of animal bones without such among patients of rabbits and guinea pigs (p = 0.012 and p = 0.024, respectively). Thus, the method of program densitometry can be used to quantify the severity of metabolic disorders in the bone tissue to predict the further course of the reparative process, to appoint adequate pharmacological correction and to control the evaluation of therapeutic measures.*

Conclusions. *The study of dental pathology of rodents and hare-like animals using densitometric, craniometric and biochemical methods allows detection of disorders in the early preclinical stage. And the extrapolation of the experience of humane orthodontics solves the issue of correcting the occlusion of these types of animals to restore the possibility of self-feeding*

Keywords: *rodents, hare-like animals, rabbit, densitometry, craniometry, orthodontic, dental, diagnosis*

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1. Introduction

Rodents and hare-like animals requiring dental care most often present with progressive syndrome of acquired dental disease (PSADD) at the stages of severe clinical symptoms requiring multi-stage, long-term, and sometimes lifelong treatment. Dental disease occurs in 39 % of our patients, hare-like animals older than 2 years, which is consistent with data from other authors [1, 2]. The small size and natural behavior of rodents make safe restraint and effective oral examination much more difficult in nonanesthetized rodent species than in rabbits. Complete oral inspection of rat-like and squirrel-like rodent species is not feasible without sedation. Complete inspection and proper diagnosis of dental disease in rodent species should be performed while the patient is under general anesthesia [3, 4]. Based on dentition, rodents can be divided into two groups. The larger group consists of animals who have elodont incisors and brachyodont (short crowns and anatomically-formed roots) premolars and molars. The smaller group is made up of animals whose teeth are all elodont [5]. The first group eats diets that are fairly high in caloric energy; they are not particularly abrasive, and, consequently, these rodents possess low crowned, well-rooted premolars and molars. Guinea pigs, chinchillas, capybaras, Patagonian cavies, and springhaas are in the latter group and are described as herbivorous rodents [6]. Their teeth have adapted to a more voluminous abrasive diet and have large chewing surfaces. Their cheek teeth continue to grow to compensate for the wear that occurs during prolonged chewing. Voles are an intermediate group that shows variation in crown length between species. Tooth roots either form, but not until skeletal maturity, or do not form; the species who have entirely elodont dentition are able to live in a harsher environment where the vegetation is tougher [7].

In most cases, treatment consists in permanent corrections or tooth extraction. Therefore, the question arises of the earliest possible subclinical detection of dental anomalies, as well as predisposition to them, for timely and noninvasive correction. Orthodontic treatment is based on the transfering force to the teeth, dentitions, jaw bones and the facial skeleton as a whole [8, 9]. We used torsion movement to simultaneously move the crown and root of the tooth in the same direction, that is, the crown and root of the tooth moved to the same distance [10].

The aim of the research Of particular interest in this study is not only the ability to extrapolate the experience of orthodontics of humane medicine for effective orthodontic correction in representatives of the animal world, but also the possibility of using teleroentgenometry and craniometry to study the skull of rodents and hare-like animals for the early preclinical diagnosis of dental disease.

2. Materials and methods

The research was conducted on the basis of the "EcoCenter" veterinary clinic, Kharkiv, Ukraine during 2020 - 2022. The data of teleroentgenography (TRG), cranio- and gnatometry, biochemistry of connective tissue (GAG, GP, HST), fluoroscopy, densitometric parameters for early subclinical detection of dental disease in chinchillas (Chinchilla lanigera (n=20)), guinea pigs (Cavia porcellus (n=48)) and rabbits (Oryctolagus cuniculus(n=52)) are presented. All stages of the effective correction of mesial occlusion of incisors in rabbits (N=5) and dystropia of premolars in guinea pigs (N=5) are described. The camputation of efforts and points of their application that are necessary to move the tooth of the ellodont type is carried out. The sequential stages of creating a dental imprint or 3D models, as well as the manufacture of fixed orthodontic structures, including an elastophore, orthodontic buttons with an Enlight Ormco fixation for incisors, are given; and individual extraoral devices with expanding screws for premolars are presented.

The experiments were carried out in accordance with the «General ethical principles of animal experiments» (Kyiv, 2001), which are consistent with the provisions of the European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes (Strasbourg, 1986), comply with the Law of Ukraine № 3447-IV from 21.02.2006 «On the Protection of Animals from Brutal Treatment» and Directive 2010/63/EU «On the protection of animals used for scientific purposes».

The materials of the article were reviewed and approved at the meeting of the bioethics committee of the State Biotechnological University, protocol No. 2 dated March 20, 2023.

3. Research results

To characterize the size and shape of the brain skull, measurements are taken of its three main diameters: longitudinal, transverse and height - and their ratios (pointers). For this, craniology (the study of the skull) and anthropology (the study of human) use craniometric points. Glabella (glabella) – the most protruding point in the region of the over the bridge of the nose, where the frontal bone forms a more or less pronounced bulge (this bulge is absent on children's skulls). Gnathion is a point on the lower edge of the lower jaw along the midline. Metopion – a point lying at the intersection of the line connecting the tops of the frontal tubercles with the sagittal plane (the line of the sagittal suture). Bregma – a point at the convergence of the sagittal and coronal sutures. Lambda is a point, located at the intersection of the lambdoid suture with the sagittal suture. Basion – a point in the middle of the front edge of the large (occipital) foramen. Nasion – the point of intersection of the nasolabial suture with the sagittal plane. Inion – external occipital protrusion.

Currently, there are more than 130 methods for the analysis of lateral TRG. Various methods differ from each other in the types of measurements (angular, linear, or a combination thereof); points, selected by the authors for analysis. The main types of analysis of side TRGs by measurements are as follows:

1. Determination of linear dimensions between certain points of their relationship (De Coster, Korkhaus, etc.) [11]

2. Measurement of angular dimensions (Bjork, Downs, Graber, etc.) [12]

3. Determination of the proportionality of the sizes of the bones of the facial skeleton and their individual plots. Combined methods of analysis are more widely used, which allow taking into account both linear and angular dimensions, as well as the proportionality of the structure of the facial skeleton.

For the analysis of TRG (tele-roentgenometry) the points of the plane jaw are used, location options are determined by the front, inclinational angle and horizontal angle:

1) the front angle F is formed when the N – Se and N – A lines intersect (inner lower corner). Its value characterizes the location of the upper jaw in relation to the base of the skull in the sagittal direction. An angle less than normal is characteristic of retrognathy, more than normal – for prognathy; if it is within normal limits, we speak of normognathia;

2) the horizontal angle H is formed at the intersection of the line H (horizontal line) and Pn (inner upper corner) and determines the position of the articular head of the lower jaw relative to the base of the skull, which affects the shape of the face profile;

3) the inclination angle J is formed at the intersection of the lines Pn and SpP (inner upper corner). If the angle J is greater than the average, then the jaws are tilted forward, which Schwartz called the antineclination. If the angle is less than average, then the jaw is tilted back. This position of the jaw is called retroinclination.

The most important parameters of gnatometry according to Schwartz:

1) basal angle B is the angle of inclination of the base of the jaws to each other (SpP – MR), characterizing the vertical position of the jaws;

2) the length of the body of the lower jaw MT is measured along the plane of the MR from the projection of the point Pg onto the MR to the point of intersection with the tangent to the branch of the lower jaw;

3) the height of the MT branches is measured tangentially to the trailing edge of the branch from the point of intersection with the MP plane to the projection of point C on the tangent (Table 1).

Table 1

Classification of dentofacial anomalies and their combinations (N=120)

Dentofacial anomaly	**Animal species**		
	Chinchilla lanigera (n=20)	*Oryctolagus cuniculus (n=52)*	*Cavia porcellus (n=48)*
I. Anomalies in the size of the jaws			
Macrognathia (upper, lower, combined)		2	2
Micrognathia (upper, lower, combined)	2		
Asymmetry		1	
II. Anomalies of the position of the jaws in the skull			
Prognathia (upper, lower)		1	
Retrognathia (upper, lower)	1		
Asymmetry	1		4
Jaw slopes		1	
III. Anomalies in the ratio of dental arches			
Distal bite (Fig 2)	6	6	6
Mesial bite (Fig 1)		18	6
Excessive cutting overlap (horizontal, vertical)		1	2
Deep bite	1		
Open bite (front, side)		2	
Cross bite (unilateral - two types; bilateral - two types)			3
IV. Anomalies in the shape and size of dental arches			
Narrowed dental arch (symmetric V-shaped)			2
Flattened anterior (trapezoidal) dental arch size anomalies			
Enlarged arc/Reduced arc	1	2	1
V. Anomalies of individual teeth			
Violation of the number of teeth (adentia, hypodentia, hyperodentia)	2	1	
Anomalies in the size and shape of teeth (macrodentia)			4
Violations of the formation of teeth and their structure (hypoplasia enamel)	8	9	12
Teething disorders (retained teeth)		1	
Dystopia or inclinations of individual teeth (Fig 3)	6	32	16

Fig. 1. Mesial occlusion is characterized by the advancement of the lower dentition in relation to the upper when the jaws are closed (n=24)

Fig. 2. Distal or sagittal occlusion is characterized by the noticeable advancement of the teeth of the upper row in relation to the teeth of the lower row (n=18)

Fig. 3. Dystopia is the inclination of the tooth in one direction or another and/ or being outside the tooth arcade (n=54)

Densitometry was performed with a test object, which had the role of a reference, to ensure the identity of measurements from different x-ray parameters using the X-Rays software package, developed by the Department of Biotechnical Medical Automated Systems of Kharkiv National University of Radio Electronics. The X-Rays software package is an effective diagnostic tool for osteoporosis in humans, which allows measurements of bone optical density using an x-ray without using a densitometry machine. The optical resolution of 256 shades of gray makes it possible to determine the difference in optical density in the part of the test object that is invisible to the eye. The evaluation of the state of the bone tissue was carried out by changing the optical density of the image of the bone on an x-ray. Radiographs were entered into a computer using a UMAX ASTRA-1220P scanner with a slide module. The scanning was carried out with an optical resolution of 600 dpi in BMP format [13].

The analysis of bone strength of rabbits and guinea pigs is given in Tab. 2, which shows that the bone marrow of animals with dental history is statistically significantly different from the strength of animal bones without such among patients of rabbits and guinea pigs ($p = 0.012$ and $p = 0.024$, respectively). Thus, the method of program densitometry can be used to quantify the severity of metabolic disorders in the bone tissue to predict the further course of the reparative process, to appoint adequate pharmacological correction and to control the evaluation of therapeutic measures (Table 2).

Table 2

Analysis of bone strength of rabbits and guinea pigs with dental disease

Animal species	Bones	The presence of dental disease	n	Statistical indicators in groups		
				M	m	P
Oryctolagus cuniculus	*Maxilla*	–	38	1.45	0.058	0.012
		+	38	1.07	0.057	
	Os femoris	–	38	0.88	0.050	
		+	38	0.72	0.057	
	Os ilium	–	38	0.90	0.069	
		+	38	0.78	0.061	
Cavia porcellus	*Maxilla*	–	32	1.37	0.027	0.024
		+	30	1.15	0.000	
	Os femoris	–	32	1.18	0.048	
		+	30	1.00	0.000	
	Os ilium	–	32	1.18	0.055	
		+	30	1.21	0.000	

Orthodontic treatment is based on the transfering force to the teeth, dentitions, jaw bones and the facial skeleton as a whole. We used torsion movement to simultaneously move the crown and root of the tooth in the same direction, that is, the crown and root of the tooth moved to the same distance.

Primary intraoral rubber traction was used as the acting force in case of mesial occlusion. The orthodontic hyperdynamic chain Elastofors was used. The point of application of the acting force on the incisors and the supports on the premolars were formed using the orthodontic button with the Enlight Ormco fixation kit (Fig. 4).

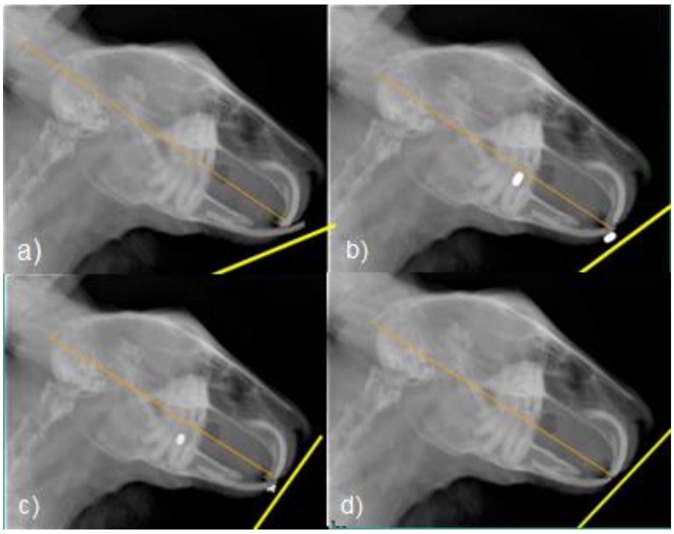

Fig. 4. Stages of incisors mesial occlusion treatment in a rabbit: *a* – before treatment; *b* – after installation of orthodontic hyperdynamic chain (Elastofors); *c* – occlusion after 3 weeks; *d* – occlusion after 6 weeks

For the treatment of dystopia of premolars in guinea pigs, we used an external individual functional action orthodontic plate with expanding orthodontic screws in a plate from Villacryl Ortho (Fig. 5).

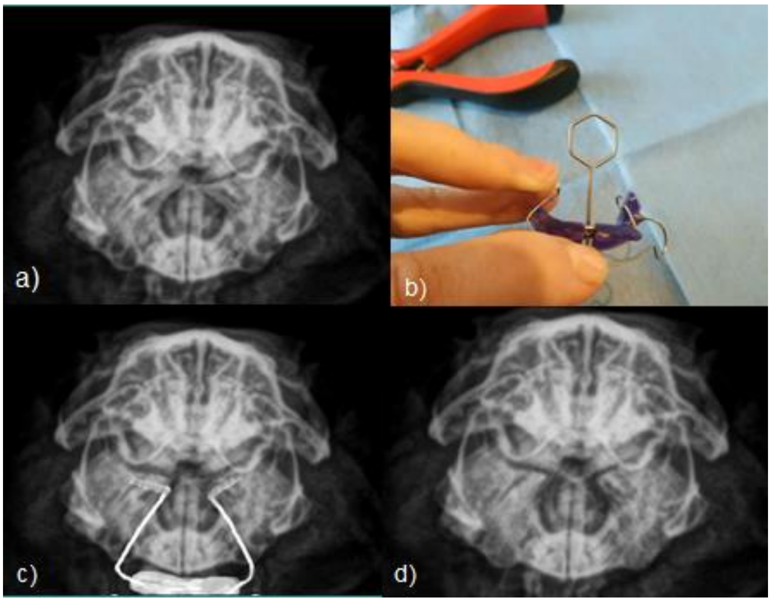

Fig. 5. Stages of orthodontic treatment of dystopia in a guinea pig: *a* – before treatment; *b* – external individual functional action orthodontic plate with expanding orthodontic screws in a plate from Villacryl Ortho; *c* – occlusion after 3 weeks; *d* – occlusion after 6 weeks

No relapse during 53 weeks of observation. In 40 minutes before the installation of orthodontic plates, patients were placed in the neonatal box with additional oxygenation and temperature control, where they were administered maropitant at a dose of 1 mg/kg subcutaneously and meloxicam at a dose of 1 mg/kg orally. The premedication was performed 20 minutes before the planned emplacement with a combination of butorphanol (0.4 mg/kg for guinea pigs and 0.4 mg/kg for rabbits) and dexmedetomidine (0.05 mg/kg for guinea pigs and 0.2 mg/kg for rabbits) subcutaneously. The induction was performed by inhalation in a box with isoflurane 5 vol %. Maintenance at 1.5-3 vol % is also with isoflurane. After the emplacement for another 10 days, patients received oral meloxicam at home at a dose of 0.5 mg/kg every 12 hours until the expansion plate microscrew was corrected [14–16].

Namely, among animals with dental disease, the following anatomical characteristics reliably took place:

- the basal angle of inclination of the base of the jaws to each other characterizing the vertical position of the jaws increased by 11 %;
- the body of the lower jaw shortened by 18 %;
- the height of the branches of the jaw increased by 17.5 %,
- the mandibular angle, which is measured between the tangents to the lower edge of the lower jaw and the back surface of its branches, increased by 6 %.

The measurement of serum parameters of connective tissue metabolism in 27 guinea pigs showed that

● the first fraction of glycosaminoglycans (GAG) increased by 8 %;

● the second – decreased by 11.1 %,

● the third – increased by 3.1 %, which correlated with the total amount of chondroitin sulfates, increased by 13.6 %.

The level of glycoproteins increased by 13.6 %. These data indicate a systemic pathological process and catabolism of GAG in bone-cartilage structures of the body.

The conducted fluoroscopic studies of chewing rodents and hare-like animals showed that if the length of the feed fibers is less than 3.4 millimeters, then the length of time, required for chewing for every 10 grams of feed, is reduced by 3.7 times in rabbits, 3.3 times in chinchillas and 2.7 times in guinea pigs. So, the length of the feed fibers provides the duration of chewing movements, which is necessary for the natural grinding of teeth (Fig. 6).

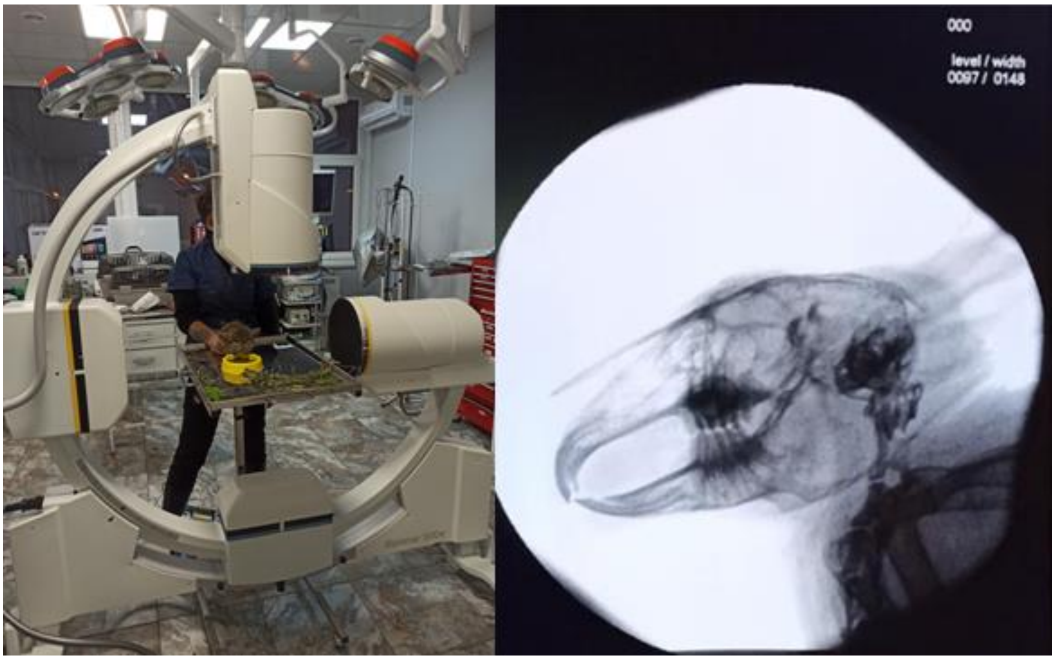

Fig. 6. Conducting fluoroscopy in a chinchilla and a fluoroscopic picture of a rabbit head

This means that this provides the basis for further research in this direction to elucidate the species-specific norms of these measurements for the early preclinical diagnosis of dental disease of rodents and hare-like animals.

4. Discussion

Dental disease occurs in 39 % of our patients hare-like animals older than 2 years, which is consistent with data from other authors [1,2]. Complete inspection and proper diagnosis of dental disease in rodent species should be performed while the patient is under general anesthesia [3,4]. In most cases, treatment consists in permanent corrections or tooth extraction. Therefore, the question arises of the earliest possible subclinical detection of dental anomalies, as well as predisposition to them, for timely and non-invasive correction. Orthodontic treatment is based on the transfering force to the teeth, dentitions, jaw bones and the facial skeleton as a whole [8,9]. We used torsion movement to simultaneously move the crown and root of the tooth in the same direction, that is, the crown and root of the tooth moved to the same distance [10].This method of orthodontic treatment was implemented for the first time for rodents and lagomorphs. Which corresponds to the latest trends in organ-preserving non-invasive therapy to restore the possibility of self-feeding.

Research limitations. As part of our study, it was not possible to perform magnetic resonance tomography, which did not allow us to assess part of the volumetric structural changes in the bone tissue.

Prospects for further research. The **c**onducted fluoroscopic studies of chewing rodents and lagomorphs showed that if the length of the feed fibers is less than 3.4 millimeters, then the length of time, required for chewing for every 10 grams of feed, is reduced by 3.7 times in rabbits, 3.3 times in chinchillas and 2.7 times in guinea pigs. So, the length of the feed fibers provides the duration of chewing movements, which is necessary for the natural grinding of teeth.

This means that this provides the basis for further research in this direction to elucidate the species-specific norms of these measurements for the early preclinical diagnosis of dental disease of rodents and hare-like animals.

5. Conclusions

The study of dental pathology of rodents and hare-like animals using densitometric, craniometric and biochemical methods allows detection of disorders in the early preclinical stage. And the extrapolation of the experience of humane orthodontics solves the issue of correcting the occlusion of these types of animals to restore the possibility of self-feeding. The basal angle of inclination of the base of the jaws to each other characterizing the vertical position of the jaws increased by 11 %; the body of the lower jaw shortened by 18 %; the height of the branches of the jaw increased by 17.5, and the mandibular angle, which is measured between the tangents to the lower edge of the lower jaw and the back surface of its branches, increased by 6 %. These data must be considered together with a reliable densitometric decrease in bone density and changes of biochemical components of the connective tissue in the blood serum. The analysis of bone strength of rabbits and guinea pigs is given in Tab. 2, which shows that the bone marrow of animals with dental history is statistically significantly different from the strength of animal bones without such among patients of rabbits and guinea pigs (p=0.012 and p=0.024, respectively). Thus, the method of program densitometry can be used to quantify the severity of metabolic disorders in the bone tissue to predict the further course of the reparative process, to appoint adequate pharmacological correction and to control the evaluation of therapeutic measures.

Conflict of interests

The authors declare that they have no conflict of interest in relation to this study, including financial, personal, authorship, or any other, that could affect the study and its results, presented in this article.

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Data availability

Data will be provided upon reasonable request.

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