Data Article

Datasets describing the morphometric evaluation of the adult rat mandible following growth stimulation of the condyle using ultrasound

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A B S T R A C T

Evaluating morphological changes of the mandible due to the unique role of the condyle in mandibular special growth and remodeling pattern is challenging. This data describes a comprehensive evaluation using new techniques to detect morphological changes of the young adult rat mandibles treated by low intensity pulsed ultrasound (LIPUS) comparing to matching controls. Two-dimensional (2D) analysis was performed on digital photographs of the hemi-mandibles using AutoCAD software with high accuracy. The anatomical points which were more determinative and prone to visual illusion were defined with particularity. Selective combination of measurements was done to allow for a thorough morphometric evaluation of the mandible focusing on the condyle and the main direction of condylar and mandibular growth. The procedure was simulated for three-dimensional analysis of virtual models of the hemi-mandibles via Geomagic-Qualify software. In the whole procedures, conditions were strictly standardized to ensure reliability and repeatability.

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Specifications Table

| Subject                              | Dentistry, Oral Surgery and Medicine |
|--------------------------------------|--------------------------------------|
| Specific subject area                | Orthodontics and Craniofacial Orthopedics; Morphometric Analysis of the Mandible |
| Type of data                         | Table                                 |
|                                      | Figure                                |
| How the data were acquired           | Digital pictures of the medial view of the right and left hemi-mandibles were obtained using a digital camera (Canon T2i, lens: Canon EF 50mm f/5.6 Macro, program: aperture priority set to f/5.6) with standardized configuration settings (aperture f/5.6, shutter speed 1/30 s, and magnification of 2.6), fixed on a steady mount, and imported to Autodesk® AutoCAD® (2014, SR, CA, USA) software (accuracy 0.0001 mm – measurements were calibrated by having a caliper in each photograph). These procedures were done to perform linear and angular measurements with high precision. The condylar length and width were also measured directly on the dissected half-mandibles using a digital caliper with an accuracy up to 0.01 mm. Micro-computed tomographic (μCT) reconstructed images of the hemi-mandibles, were used to create 3D virtual models via the medical software package Materialize Mimics (Version 2013.6.0, Plymouth, MI, USA) in a form of triangular mesh called standard tessellation language (STL). The STL files were imported into Geomagic Studio/Qualify software (Version 2014.1.0, Research Triangle Park, NC, USA). Geomagic Qualify used to provide us with optimal facilities to standardize the condition for linear measurements on 3D virtual models of the hemi-mandibles. |
| Data format                          | Raw                                    |
|                                      | Analyzed                               |
| Description of data collection       | Morphological evaluations were performed for 8 control and 10 LIPUS treated mandibles. To gather the data, overall 16 linear and 1 angular morphometric parameter were quantified on dissected half mandibles, their 2D digital photographs, and 3D virtual models. Detailed descriptions can be found in subsequent sections. |
| Data source location                 | • University of Alberta                |
|                                      | • Edmonton, Alberta                    |
|                                      | • Canada                               |
| Data accessibility                   | Repository name: Mendeley Data          |
|                                      | Data identification number: doi: 10.17632/k38ntfyxyh.1 |
|                                      | Direct URL to data:                    |
|                                      | https://data.mendeley.com/datasets/k38ntfyxyh/1 |
| Related research article            | Y. Hadaegh, H. Uludag, D. N. Dederich, T. H. El-Bialy. The effect of low intensity pulsed ultrasound on mandibular condylar growth in young adult rats, J. Bone Rep. 15 (2021) 101122. https://doi.org/10.1016/j.jbonr.2021.101122 |

Value of the Data

- This data describes a thorough, reliable, and repeatable morphometric evaluation of the mandible focusing on the condyle and the main direction of condylar and mandibular growth using standardized conditions and precise methods.
- These datasets are of particular interest to researchers who are working on growth modification of the mandible. In addition, they can be beneficial for those who are evaluating the mandibular development or attempting for regeneration or tissue engineering of the mandible.
• The methods can help evaluating anatomical changes of the mandible due to application of therapeutic or growth promoting drugs/techniques, particularly in rat animal models.
• The shared data can be used for comparison in similar experiments which evaluate the effect of an altering factor on the results. Thus, the time and resources can be saved and the animal loss would be less.

1. Data Description

Herein detailed 2D and 3D morphometric analysis of the control and LIPUS treated adult rat mandibles are provided as a supplementary data related to the associated article “the effect of low intensity pulsed ultrasound on mandibular condylar growth in young adult rats” [1].

16 linear and 1 angular morphometric parameter were determined (Table 1) and quantified. Figs. 1, 2, 4, and 5 demonstrate how these evaluations have been performed.

Dahlberg's formula [2] was used to calculate the error of measurement. Intra rater reliability for 6 randomly selected animals for each measured variable was tested using an intra-class correlation coefficient (ICC) test. This data and the results for each measured variable is shared in the corresponding dataset [3], excel files (1and 2) sheet one.

All the evaluations were done twice with an interval of two weeks. There was no significant difference between the two registrations (using paired t-test) (for all p>0.05); thus, the mean value representing each hemi-mandible for all the evaluated parameters was used for statistical

| Landmarks | Linear & angular parameters |
|-----------|----------------------------|
| 1         | The most anterior point of the lingual alveolar bone |
| 2         | The midpoint of the mandibular foramen |
| 3         | The most anterior-superior point of the condyle (determined as a tangent of 45° line and anterosuperior border of the condyle) |
| 4         | The most superior point of the condyle (determined as a tangent of parallel line to mandibular plane (MP: the line that passes through points 9 and10) and superior border of the condyle) |
| 5         | The most posteroinferior point of the condyle (determined as a tangent of 45° line and posteroinferior border of the condyle) |
| 6         | The most posterior-inferior point of the condyle (determined as a tangent of 45° line and anteroinferior border of the condyle) |
| 7         | The middle point of 3 and 6 |
| 8         | Intersection point of 2-7 extension line and outer contour of the condyle |
| 9         | The most inferior point of the lower border of the angular process |
| 10        | The posterior-inferior point of attachment of the digastric muscle |
| i         | (1-2) The length of mandibular base |
| ii        | (2-8) The length of condylar process 1(condylar process axis) |
| iia       | (2-5) The length of condylar process 2 |
| iii       | (1-8)The mandibular length 1 |
| iv        | (5-10) The mandibular length 2 |
| v(via)    | (3-6) The length of the condyle |
| vi        | Ramus height (The distance from point 4 to MP) |
| vii       | The distance from point 3 to MP |
| viii      | The distance from point 8 to MP |
| viiia     | The distance from point 5 to MP |
| ix        | The distance from point 6 to MP |
| x         | The distance from point 3 to perpendicular line from point 2 on MP |
| xi        | The distance from point 8 to perpendicular line from point 2 on MP |
| xia       | The distance from point 5 to perpendicular line from point 2 on MP |
| xii       | The distance from point 6 to perpendicular line from point 2 on MP |
| α         | Angle of condylar process axis to MP |
| w         | The width of the condyle |
Fig. 1. Identifying the constant regions (arrows) on the lateral side of the mandible that each hemi-mandible sits on; this has been determined by locating hemi-mandibles on a paper tape colored with fresh paint.

Fig. 2. Illustration of the anatomical landmarks and morphometric parameters determined on digital photographs using AutoCAD software.

analysis described below. This data is shared in the corresponding dataset [3], excel files (1 and 2) sheet two.

In morphometric evaluation on 2D photographs and dissected half mandibles, to compare the LIPUS and control groups when compensating for correlation between the outcomes, considering laterality (left and right hemi-mandibles) generalized estimating equation (GEE) was used to analyze the data. To perform two-by-two comparison when considering the multiple comparisons,
Bonferroni method was employed. All statistical analysis was performed by SPSS (version 21.0, IBM Co., Chicago, IL, USA) and P-value less than 0.05 was considered statistically significant.

Following the experimental period, no statistically significant difference was observed between the groups for the 16 linear measurement parameters; nevertheless, the degree of alpha was significantly more in the LIPUS group in comparison to the control group (Table 2). In addition, it was noteworthy that in the experimental group the most top area of the condylar head in almost all samples, also the posterior and anterior end of the cartilaginous cap in some condyles were thick and translucent. Since Alpha is the angle of condylar process axis to the mandibular plane (MP) and both MP and point 2 (the midpoint of mandibular foramen) are anatomical reference and assumed to be invariant, thus point 7 is the key point for changes in the degree of alpha which per se is dependent on the position of the most anterior superior (3) and posterior inferior (6) points of the condyle. The distance of these points, especially point 6, to MP (vii, ix) and particularly to the perpendicular line from point 2 on MP (x, xii), were less in the LIPUS group compared to the control group. Therefore, the statistically significant increment in the degree of alpha geometrically can be attributed to more of an anterior inferior location of the most anterior superior and especially posterior inferior points of the condyle, which may depict a potential progression of the cartilaginous cap in the perichondrial-periosteal junction consequent to LIPUS treatment (Fig. 3).

On the other side, point 8 was located even more posteriorly superior in the experimental group (increment in the viii and xii distances), and the mean difference for condylar process length 1(ii) and mandibular length 1(iii), remained positive in favor of the LIPUS group. It should be noted that these parameters are still dependent on the degree of alpha. More importantly, in the LIPUS group the most posterosuperior point of the condyle (or point 5) was also in a more posterosuperior location (increment in the viiiia and xia distances), and condylar process length 2 (iia) and mandibular length 2 (iv), which are at the main direction of condylar and mandibular growth (upward, backward), showed higher values; however, not to a significant degree. The above-mentioned observations may suggest a slight growth of the condylar cartilage and/or bone in the top (middle) area of the condylar head, which it’s apex was determined as the most posterosuperior point of the condyle in measurements, following LIPUS therapy (Fig. 3).

All the statistical analysis described for 2D morphometric evaluation was performed for the two linear measurements on 3D virtual hemi-mandibles. Condylar process and mandibular
Table 2
Values of Linear (mm) and Angular (°) Measurements (Mean ± SD) in experimental and control groups.

| Response Variable | Laterality | Control mean±SD | LIPUS | Mean difference | P  | Response variable | Laterality mean±SD | LIPUS difference | Mean | P  |
|-------------------|------------|-----------------|-------|-----------------|----|-------------------|-------------------|-------------------|------|----|
| i                 | L          | 20.91 ± 0.51    | 21.29 ± 0.63 | 0.471* | α  | L                | 32.88 ± 2.66 | 36.05 ± 1.55 | 0.118 |    |
|                   | R          | 21.52 ± 0.35    | 21.46 ± 0.55 |       |    | R                | 32.5 ± 1.34   | 34.4 ± 2.51 |      |    |
|                  | Total      | 21.21 ± 0.53    | 21.37 ± 0.58 | 0.16 | 0.834 | Total            | 32.69 ± 2.04 | 35.23 ± 2.2 | 0.001 | >0.25 |
| ii                | L          | 8.14 ± 0.40     | 8.15 ± 0.26  | 0.893 | vii | L                | 12.25 ± 0.3   | 12.16 ± 0.44 | 0.744 |      |
|                   | R          | 8.13 ± 0.44     | 8.19 ± 0.33  |       |    | R                | 12.17 ± 0.46 | 12.13 ± 0.6 |      |    |
|                  | Total      | 8.14 ± 0.40     | 8.17 ± 0.29  | 0.03 | 0.803 | Total            | 12.21 ± 0.38 | 12.14 ± 0.51 | -0.07 | 0.62 |
| iia               | L          | 8.22 ± 0.18     | 8.23 ± 0.28  | 0.24  | viii | L                | 11.84 ± 0.34 | 11.91 ± 0.26 | 0.549 |      |
|                   | R          | 8.01 ± 0.38     | 8.25 ± 0.36  |       |    | R                | 11.77 ± 0.5  | 11.84 ± 0.43 |      |    |
|                  | Total      | 8.12 ± 0.31     | 8.24 ± 0.31  | 0.12 | 0.295 | Total            | 11.8 ± 0.42  | 11.88 ± 0.35 | 0.08  | 0.586 |
| iii               | L          | 28.15 ± 0.56    | 28.24 ± 0.70 | 0.796 | viiia| L               | 11.62 ± 0.36 | 11.78 ± 0.43 | 0.324 |      |
|                   | R          | 28.59±0.40      | 28.64 ± 0.56 |       |    | R                | 11.56 ± 0.5  | 11.58 ± 0.37 |      |    |
|                  | Total      | 28.37±0.52      | 28.44 ± 0.65 | 0.07 | 0.442 | Total            | 11.59 ± 0.42 | 11.68±0.40 | 0.09  | 0.499 |
| iv                | L          | 24.10 ± 1.29    | 24.33 ± 0.62 | 0.034 | ix  | L                | 9.54 ± 0.48  | 9.36 ± 0.38 | 0.532 |      |
|                   | R          | 24.05 ± 1.03    | 24.23 ± 0.81 |       |    | R                | 9.5 ± 0.45   | 9.26 ± 0.44 |      |    |
|                  | Total      | 24.08 ± 1.13    | 24.28 ± 0.71 | 0.20 | 0.347 | Total            | 9.52 ± 0.45  | 9.31 ± 0.4 | -0.21 | 0.198 |
| v                 | L          | 4.57 ± 0.15     | 4.53 ± 0.32  | 0.033  | x  | L                | 3.63 ± 0.16  | 3.22 ± 0.41 | 0.916 |      |
|                   | R          | 4.45 ± 0.27     | 4.53 ± 0.32  |       |    | R                | 3.8 ± 0.35   | 3.42 ± 0.42 |      |    |
|                  | Total      | 4.51 ± 0.22     | 4.53 ± 0.31  | 0.02 | 0.729 | Total            | 3.52 ± 0.29  | 3.32 ± 0.42 | -0.2  | 0.121 |
| va                | L          | 4.26 ± 0.14     | 4.23 ± 0.28  | 0.896  | xi | L                | 6.8 ± 0.28   | 6.85 ± 0.26 | 0.022 |      |
|                   | R          | 4.21 ± 0.19     | 4.29 ± 0.28  |       |    | R                | 6.64 ± 0.33  | 6.72 ± 0.2 |      |    |
|                  | Total      | 4.24 ± 0.16     | 4.26 ± 0.27  | 0.02 | .740  | Total            | 6.72 ± 0.31  | 6.79 ± 0.24 | 0.07  | 0.532 |
| w                 | L          | 1.84 ± 0.10     | 1.82 ± 0.09  | 0.796  | xia | L                | 6.83 ± 0.37  | 6.96 ± 0.34 | 0.336 |      |
|                   | R          | 1.79 ± 0.15     | 1.88 ± 0.12  |       |    | R                | 6.91 ± 0.27  | 7.04 ± 0.45 |      |    |
|                  | Total      | 1.81 ± 0.13     | 1.85 ± 0.11  | 0.03 | 0.442 | Total            | 6.87 ± 0.31  | 6.97 ± 0.40 | 0.1   | 0.417 |
| vi                | L          | 12.49 ± 0.3     | 12.47 ± 0.4  | 0.826  | xii | L                | 7.27 ± 0.35  | 6.76 ± 0.41 | 0.795*|      |
|                   | R          | 12.48 ± 0.49    | 12.42 ± 0.49 |       |    | R                | 6.98 ± 0.39  | 6.94 ± 0.45 |      |    |
|                  | Total      | 12.48 ± 0.39    | 12.45 ± 0.43 | 0.02 | 0.778 | Total            | 7.13 ± 0.38  | 6.85 ± 0.43 | -0.28 | 0.05 |

The results of ICC test showed excellent absolute agreement (for all r >0.9).

† Based on GEE, considering the correlation between responses. L: Left, R: Right.

* Based on GEE, comparison of left and right laterality considering the correlation between responses. SD: Standard Deviation.
length, even though statistically non-significant, were again more in the LIPUS group in comparison to the control group (Table 3).

2. Experimental Design, Materials and Methods

2.1. Gross morphological evaluation of the rats’ mandibles

Hemi-mandibles were dissected from young adult (≈120-day old) female rats following 28 days of the experiment, during which using a custom-built ultrasound device (Smile Sonica Inc., Edmonton, AB, Canada), LIPUS applied to the temporomandibular joints (TMJs) of the experimental animals bilaterally for 20 minutes daily [1]. Morphological evaluations were performed for 8 control and 10 LIPUS treated mandibles.

2.2. Morphometric measurements on 2D photographs

Rat hemi-mandibles were located on their lateral side as the outer surface was determined to be a reproducible and stable position for this anatomical structure (Fig. 1). A digital camera (Canon T2i, lens: Canon EF 50mm f/25 Macro, program: aperture priority set to f/5.6) with standardized configuration settings (aperture f/5.6, shutter speed 1/30 s, and magnification of 2.6) was fixed on a steady mount. Digital pictures of the medial view of the right and left hemi-mandibles were obtained and imported to Autodesk® AutoCAD® (2014, SR, CA, USA) software (accuracy 0.0001 mm – measurements were calibrated by having a caliper in each photograph). This was used to perform linear and angular measurements with high precision. The condylar length and width were also measured directly on the dissected half-mandibles using a digital caliper with an accuracy up to 0.01 mm. The anatomical landmarks and morphometric parameters were determined according to a modified methodology that has been previously reported [3,4] (Table 1; Fig. 2). The anatomical points which were more determinative and also prone to visual illusion were defined with more particularity. For instance, the most posterosuperior point of the condyle was determined as a tangent of 45° line and posterosuperior border of the condyle. To quantify the condylar and mandibular growth in their main direction, upward backward, condylar process length and mandibular length, were measured in two ways. The first method is developed from the technique has been described by Xiong et al. [4] and the second one is derived from the mandibular length determination in Taira et al. [5] study.

| Table 3 | Values of linear measurements (mm) on 3-D virtual models in experimental and control groups. |
|---------|-------------------------------------------------|
| Response variable | Laterality | Control | LIPUS |
| | | Mean ± SD | Median (IQR) | Mean ± SD | Median (IQR) | P* |
| Condylar process length (2) | R | 8.22 ± 0.26 | 8.24 (8.01 to 8.35) | 8.33 ± 0.39 | 8.41 (8.23 to 8.62) | 0.448 |
| | L | 8.41 ± 0.3 | 8.35 (8.19 to 8.61) | 8.41 ± 0.19 | 8.39 (8.28 to 8.55) | 0.981 |
| | Total | 8.31 ± 0.29 | 8.26 (8.1 to 8.52) | 8.37 ± 0.3 | 8.41 (8.25 to 8.56) | <0.590* |
| Mandibular Length (2) | R | 24.85 ± 0.85 | 24.87 (24.15 to 25.53) | 25.06 ± 0.54 | 25.1 (24.73 to 25.27) | 0.520 |
| | L | 24.75 ± 0.8 | 24.71 (24.19 to 25.33) | 25.05 ± 0.46 | 25.03 (24.74 to 25.52) | 0.311 |
| | Total | 24.8 ± 0.8 | 24.8 (24.15 to 25.53) | 25.06 ± 0.49 | 25.06 (24.73 to 25.35) | 0.391* |

The results of ICC test showed excellent absolute agreement (r >0.9).

* Based on ICC considering the correlation in the responses;
§ Comparison of right and left;
* adjusted for the effect of laterality; IQR: Inter-quartile range; SD: standard deviation; L: Left; R: Right.
3. Morphometric Measurements on 3D Virtual Models

Micro-computed tomographic (μCT, SkyScan 1072, Aartselaar, Antwerp, BE) reconstructed images of the hemi-mandibles [6], were used to create 3D virtual models via the medical software package Materialize Mimics (Version 2013.16.0, Plymouth, MI, USA) in a form of triangular mesh called standard tessellation language (STL). The STL files were imported into Geomagic Studio/Qualify software (Version 2014.1.0, Research Triangle Park, NC, USA) which has been built for optimizing and comparing 3D objects to a reference object [7]. Here, Geomagic Qualify provided us with optimal facilities to standardize the condition for linear measurements on 3D virtual models of the hemi-mandibles.

To achieve this aim, following alignment techniques (A and B) were performed to align the hemi-mandibles to the environment of the program and to each other (clearly these procedures were performed for right and left hemi-mandibles separately).

A. Aligning an object (hemi-mandible) to the global coordinate system: Initially, the deepest point of coronoid notch (1), the most inferior point of the lower border of the angular process (2), and the posterior-inferior point of attachment of digastric muscle (3) were determined. Then, a plate was made by these 3 points and a vector was created from point 2 to 3. Finally, using the “align to world” option in Geomagic Qualify, the plate was matched with x z plane, the vector paired with x vector and point 2 was used as origin (Fig. 4).

B. Aligning the objects (all hemi-mandibles) together: Using the built-in algorithm for best fit (iterative closest point algorithm (ICP)), hemi-mandibles (Test objects) from both groups were aligned to the one (Reference) which was previously aligned to the world coordinate system. The algorithm works in two stages: the first stage fitting uses 300 points from similar locations on each object. The second stage uses 1500 points to make fine adjustments to best fit the models

![Fig. 4. Aligning one hemi-mandible to the world coordinate system in Geomagic Qualify software.](image-url)
Fig. 5. Determining the most posterosuperior point of the condyle on 3D virtual models to perform the linear measurements.

(analogous to a least square best fit algorithm). In this way, all the mandibles were aligned to each other and to the world coordinate system.

Prior to linear measurements, the most posterosuperior point of the condyles was precisely determined (Fig. 5- A to D). For this purpose, a 45° plane (using section through object), was moved up to the last possible location of the condyle (Fig. 5-A), the area was selected (Fig. 5-B) and the center was determined using a default option (Fig. 5-C). If the point was not at the outer contour (green arrow), the identical point at the outer contour (orange arrow) was determined as the most posterosuperior point of the condyle (Fig. 5-D). The condylar process length 2 and the mandibular length 2 (Table 1) on the medial side of the 3D virtual hemi-mandibles were measured (Fig. 5-E).

**Ethics Statements**

This experiment was approved by the Animal Care and Use Committee for Health Sciences, University of Alberta, Canada (AUP: 000000381-REN1).

**Declaration of Competing Interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.
Data Availability

Datasets describing the morphometric evaluation of the adult rat mandible following growth stimulation of the condyle using ultrasound (Original data) (Mendeley Data).

CRediT Author Statement

Yasamin Hadaegh: Methodology, Visualization, Investigation, Data curation, Writing – original draft; Tarek H. El-Bialy: Supervision, Conceptualization, Validation, Writing – reviewing & editing.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi: 10.1016/j.dib.2022.108664.

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