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Three - dimensional assessment of musculoskeletal features in Class II and Class III patients

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SUMMARY

Objective: To evaluate and compare dimensional morphology of masseter and medial pterygoid muscles and mandibular skeletal parameters between subjects with skeletal Class II and Class III

Materials and Methods: The sample consisted of 13 patients with skeletal Class II and 10 patients with skeletal Class III prior to the start of combined orthodontic treatment and orthognathic surgery with correspondence to definite inclusion and exclusion criteria. Magnetic resonance imaging was performed for mandibular muscles and following 2D and 3D measurements were done: cross-sectional area (CSA), thickness, width, longitudinal dimension and volume. 3D multi-slice computed tomography investigation was performed for the assessment of skeletal mandibular parametres and following measurements were done: height of mandibular ramus, length af mandibular corpus, overall mandibular length, intergonial width. All the measurements were done bilaterally. Data were analyzed using descriptive statistics, t-test, and correlation coefficients.

Results: it was found that values of all mandibular and medial pterygoid measurements were higher in Class III subjects with statistical significance ($p<0.05$). There was a tendency of all masseter variables to be higher in Class III patients. Positive correlations were found between muscles' volume and CSA in both groups, muscles' volume and all mandibular parameters in Class II group, CSAs and all mandibular variables except intergonial width in Class II group.

Overall symmetry was observed between left and right sides in all muscular and mandibular measurements in both groups.

Conclusions: The data were acquired using two different imaging techniques – MRI and MSCT that can be mentioned as a novelty in this field of research. Remarkable differences were observed between study groups for both skeletal and muscular measurements.

Key words: masseter, medial pterygoid muscle, mandible, magnetic resonance, multi-slice computed tomography.

INTRODUCTION

The performance of masticatory muscles can be associated with several significant aspects from orthodontic view. As being a part of biomechanical environment creators in craniofacial area, they can affect growth and development of dentofacial complex and thus influence aetiology process of dentofacial deformities [1,2,3,4,5]. The role of muscles in response to treatment is critical. Successful treatment outcome and stability of treatment results require reorganization and adaptation of muscle fibres [6]. From all mandibular muscles a particular importance is allocated to masseter and medial pterygoid muscles on the subject of their anatomical location and function [6]. The creation of tendinous sling between them allows the medial pterygoid and masseter to be powerful elevators of the jaw.

Relation between mandibular muscles and craniofacial morphology has been studied widely with different methods and from several aspects. Most of studies have been directed to facial growth pattern assess-

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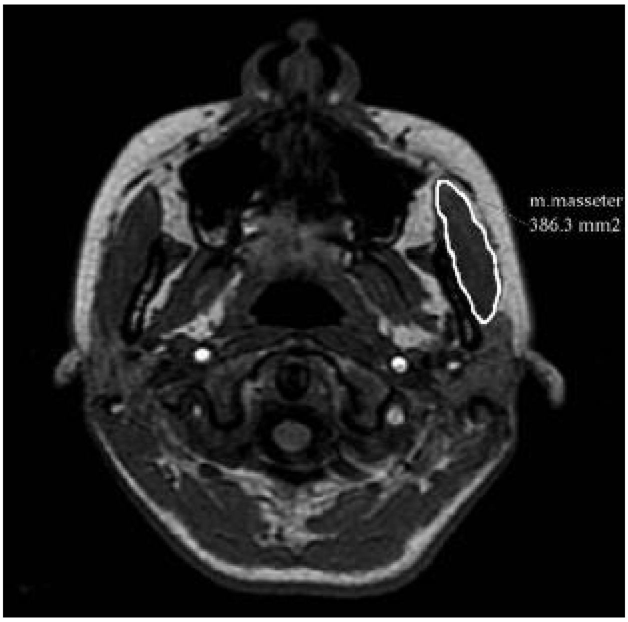

Fig. 1. Cross-cectional area of Masseter muscle

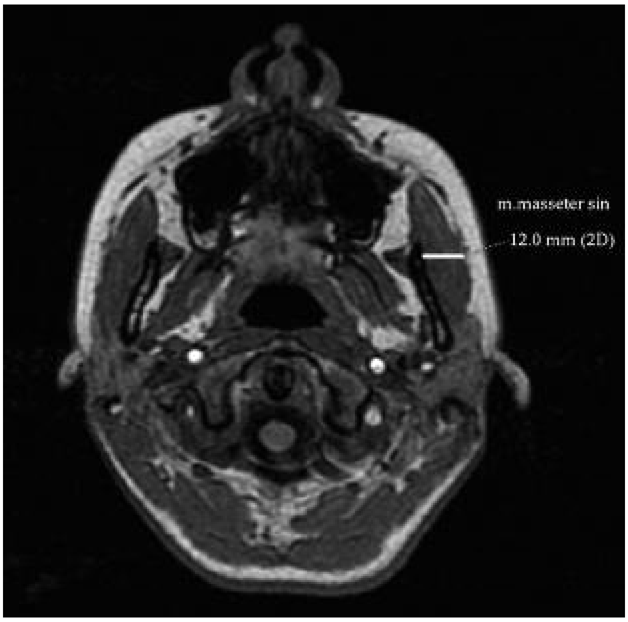

Fig. 2. Thickness of Masseter muscle

ment with the main conclusion that subjects with strong mandibular muscles have wider and shorter facial dimensions [7,8,9,14,15]. The recent advent of modern imaging techniques enables more precise assessment of different muscular size parameters.

Mandibular muscles can be investigated using different imagining techniques: ultrasonography [7,8], computed tomography (CT) [14-19] and magnetic resonance (MRI) [9-13].

MRI as a non-invasive imaging technique has high resolution quality in superficial and in profound soft tissues as well. It allows 2D and 3D image acquisition that enable accurate assessment of masticatory muscle dimensional morphology.

Acquiring of multiplanar images, high resolution in hard tissues and a full size truly volumetric 3D description in real anatomical (1:1) size are the advantages of CT imaging method [21], thus this could be a method of choice for the assessment of skeletal structures.

There are no studies in literature with the aim of particular and integrated investigation of dimensional morphology of skeletal and muscular parameters in such severe deformities as skeletal Class II and Class III.

The aim of the present study was to evaluate and compare dimensional morphology of masseter and medial pterygoid muscles and mandibular skeletal parameters between subjects with skeletal Class II and Class III.

MATERIAL AND METHODS

The sample consisted of 13 patients with skeletal Class II (mean age 18.4) and 10 patients with skeletal Class III (mean age 19.2) prior to the start of combined orthodontic treatment and orthognathic surgery with correspondence to subsequent inclusion and exclusion criteria. The inclusion criteria for Class II patients were: overjet ≥6 mm, angle ANB ≥4 degrees, Wits appraisal ≥4 mm; for Class III patients: overjet ≤0 mm, angle ANB ≤0 degrees, Wits appraisal ≤-4 mm. The exclusion criteria were: clinically evident facial asymmetry, functional mandibular deviations, symptoms of temporomandibular disorders, previous orthodontic treatment. All patients had indication for combined orthodontic treatment and orthognathic surgery.

Magnetic resonance imaging (MRI)

Before starting preorthognathic orthodontic treatment MRI was performed in all patients using GE “Signa Advantage” 1.0 MR System. The position of patients was standardized: supine position with Frankfurt horizontal plane oriented vertically and in habitual occlusion. Scan protocol included: T1 SE in saggital plane, T2 FSE in axial plane, STIR T2 sequence images in coronal plane and 3D SPGR T1 with following 2 D and 3 D image reconstructions for the assessment of muscular size parametres.

Following measurements of masseter muscle were performed: 2D cross-sectional area (CSA) at the midpoint of mandibular ramus (mm^2) (Picture 1), thickness (mm) in anterio-posterior dimension (Picture 2), width (mm) in medio-lateral dimension (Picture 3), longitudinal dimension or length (mm) (Picture 4), and 3D volume (cm^3). For medial pterygoid muscle: 2D cross-sectional area (mm^2) (Picture 5), thickness (mm) at the level of *tuberositas pterygoidea mandibulae* and 3D volume (cm^3). All the measurements were done bilaterally.

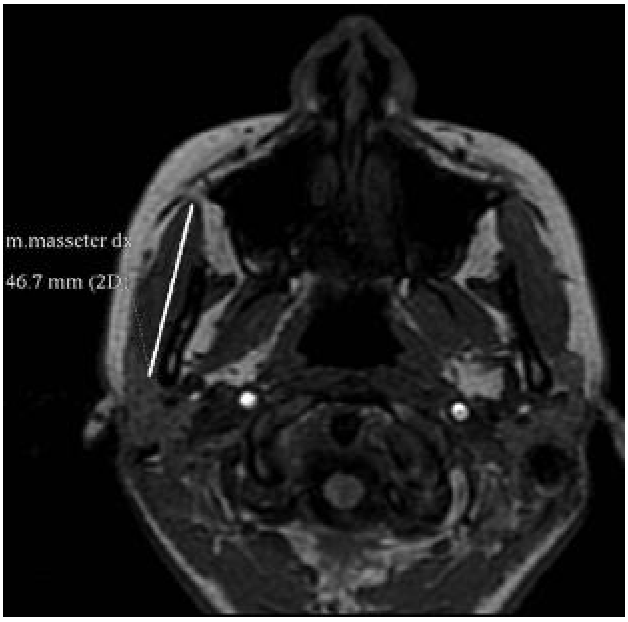

Fig. 3. Width of masseter muscle

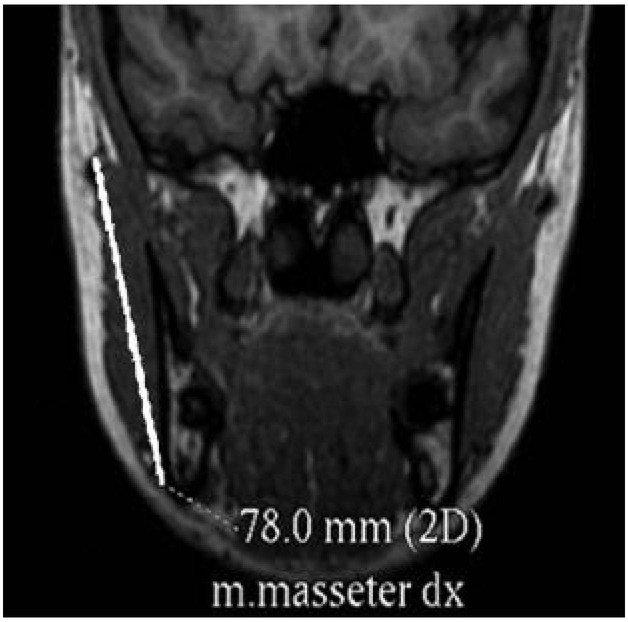

Fig. 4. Length of masseter muscle

Multi slice computed tomography (MSCT) examination

Before starting preorthognathic orthodontic treatment, a 3D MSCT investigation was performed using GE Medical Systems Light Speed Pro 16CT99_Oc0 system. The position of the patient was lying on the back, head positioned in the middle of orbitomeatal plane, closed mouth position – direct touch of molar teeth in habitual occlusion. Axial scanning was done from soft tissue point *Glabella* down to upper margin of C6. CT scan protocol – helical full 1.0 s, slice thickness 0.625 mm, pitch 0.625 mm, reconstruction – bone and soft tissue using *IAC Review* and *Transparent bone* programs.

Following measurements were done: height of *mandibular ramus* – linear distance between *condylus* and *gonion*, length af mandibular corpus – linear distance between *gonion* and *gnathion*, overall mandibular length – linear distance between *condylus* and *gnathion*, intergonial width – linear distance between left and right *gonion*. All the measurements were done bilaterally.

All the measurements were done by one operator three times with a time interval 2 weeks.

Statistical analyses

Descriptive statistics were calculated for all the measurements of muscular and mandibular structures and the difference of mean values were tested using t-test. The differences were considered significant at $P<0.05$.

For evaluation of relation between muscular and mandibular skeletal variables, correlation coefficients were calculated.

Study was approved by Riga Stradins University Ethical committee.

RESULTS

The means, standard deviations and differences between Class II and Class III study groups of masseter variables are listed in Table 1. Calculation was performed separately for the left and right sides, but there were no statistically significant differences in volume, thickness, length, width and cross-sections between both sides neither in Class II nor Class III study group. Although there was a tendency of all the measurement values to be higher in Class III study group, the differences were not with the statistical significance.

The means, standard deviations and differences between Class II and Class III study groups of medial pterygoid variables are listed in Table 2. Calculation was performed bilaterally, but there were no statistically significant difference in volume, thickness and cross-sections between the left and right muscles neither in Class II nor Class III study group.

There were significant differences between study groups in volumetric measurements ($p=0.001$) and thickness ($p=0.004$) between Class II and Class III study groups. Cross-sectional areas values tend to be higher in patients with Class III deformity, but with no statistical significance.

The means, standard deviations and differences between Class II and Class III study groups of mandibular skeletal variables are listed in Table 3. Calculation was performed bilaterally, but there were no statistically significant differences between left and right sides in neither Class II nor Class III study group.

Fig. 5. Cross-sectional area of ptreygoid medial muscle

As showed in Table 3, patients with Class III deformity have larger mandibles comparing with Class II patients. There were observed significant differences in mandibular length (p<0.0001), mandibular ramus height (p=0.04) and mandibular body length (p<0.001) between both groups.

Relationship between muscular and skeletal variables in Class II patients are shown in Table 4. and Table 5. There were several significantly positive correlations between: masseter volume and mandibular length, masseter volume and mandibular body length, masseter volume and ramus height of mandible, masseter CSA and all the mandibular parameters except intergonial width. Positive weaker correlations were observed between other masseter and mandibular variables.

Medial pterygoid muscles' volume and CSA showed positive correlations with mandibular length, body length and ramus height.

Relationship between muscular and skeletal variables in Class III patients are shown in Table 6. and Table 7. Mainly no significantly positive correlations between muscular and skeletal parameters were found in this study group except mandibular body length and muscles' volume and CSA.

Table 1. Descriptive statistics for masseters' variable

Variables	Class II patients		Class III patients		P
	Mean	SD	Mean	SD	value
Volume					
Left side	21.5	4.7	24.2	6.2	NS
Right side	22.7	4.5	25	5.4	NS
CSA					
Left side	450.3	91	495.7	110	NS
Right side	446.3	106	490.8	103	NS
Thickness					
Left side	14	1.7	14	2.1	NS
Right side	14.5	1.8	14.7	2.7	NS
Length					
Left side	70.24	6.8	73.1	5.4	NS
Right side	71.5	5.8	72.2	4.7	NS
Width					
Left side	42	4.3	43.2	4.8	NS
Right side	41.4	4	43.1	3.7	NS

NS – statistically not significant (P>0.05); * P<0.05; CSA – cross-sectional area

Table 2. Descriptive statistics for medial pterygoids' variables

Variables	Class II patients		Class III patients		P
	Mean	SD	Mean	SD	value
Volume					
Left side	9.7	3.9	16.7	5.3	*
Right side	9.7	3.8	16.6	5.3	*
CSA					
Left side	311.9	65	348	62	NS
Right side	306.2	54	345.2	61	NS
Thickness					
Left side	17.8	2	19.9	1.5	*
Right side	16.9	1.7	19.9	1.9	*

NS – statistically not significant (P>0.05); * P<0.05; CSA – cross-sectional area

Table 3. Descriptive statistics for mandibular variables

Variables	Class II patients		Class III patients		P
	Mean	SD	Mean	SD	value
Md length					
Left side	109.7	7	131.6	6.2	*
Right side	110.8	6.7	132.6	7.4	*
Md ramus					
height	57.5	6.7	66.6	13	*
Left side	59.5	6.5	68.1	12.3	*
Right side					
Md body	70.8	6.7	84.1	6.2	*
length					
Left side	72	8.2	85.1	6	*
Right side	109.7	7	131.6	6.2	*

NS – statistically not significant (P>0.05); * P<0.05; Md – mandibular

DISCUSSION

The data were acquired using two different imaging techniques – 3D MRI and MSCT that can be mentioned as a novelty in this field of orthodontic research.

This report documents: (1) the association of dimensional morphology of masseter and medial pterygoid muscles with mandibular skeletal parameters separately in skeletal Class II and Class III patients; (2) the comparison of masseter and medial pterygoid muscles between Class II and Class III study groups.

Some authors have found no difference in measurements on both sides of the face [10,11,17,18] and similarly overall symmetry was observed between left

Table 4. Correlation coefficients (r) of masseter and mandibular variables in Class II patients

Variables	Md length	Md ramus height	Md body length	Go-Go distance
Mas volume	0.7	0.7	0.8	0.3
Mas CSA	0.6	0.6	0.7	- 0.4
Mas thickness	0.7	0.4	0.8	0.1
Mas length	0.4	0.2	0.3	0.7
Mas width	0.6	0.1	0.5	-0.4

Mas – masseter muscle; CSA – cross-sectional area; Md – mandibular; Go- gonion

Table 5. Correlation coefficients of medial pterygoid muscles' and mandibular variables in Class II patients

Variables	Md length	Md ramus height	Md body length	Go-Go distance
Pt volume	0.8	0.8	0.9	0.1
Pt CSA	0.6	0.6	0.5	0.2
Pt thickness	0.3	0.3	0.01	-0.1

Pt – medial pterygoid muscle; CSA – cross-sectional area; Md – mandibular; Go – gonion

Table 6. Correlation coefficients of masseter muscles' and mandibular variables in Class III patients

Variables	Md length	Md ramus height	Md body length	Go-Go distance
Mas volume	0.4	-0.3	0.6	0.1
Mas CSA	0.4	-0.3	0.6	0.3
Mas thickness	0.4	-0.6	0.7	0.3
Mas length	0.3	0.02	0.4	0.05
Mas width	0.3	0.1	0.4	0.04

Mas – masseter muscle; CSA – cross-sectional area; Md – mandibular; Go- gonion

Table 7. Correlation coefficients of medial pterygoid muscles' and mandibular variables in Class III patient

Variables	Md length	Md ramus height	Md body length	Go-Go distance
Pt volume	0.2	0.02	0.6	0.01
Pt CSA	0.4	-0.4	0.5	0.01
Pt thickness	0.1	-0.1	0.2	-0.02

Pt – medial pterygoid muscle; CSA – cross-sectional area; Md – mandibular; Go – gonion

and right sides in all muscular and mandibular measurements in both groups in our study.

Class III patient group had larger mandibles in all dimensions that is explicable with subjacent aetiopathology of definite deformity. There was a tendency of all the muscular variables to be higher in Class III patient group as well but with different statistical significance. In present study masseter volume in Class II patients was 22.1 and in Class III it was 24.6 and the comparison of data with that of other MRI reports of different and mixed study groups shows: 29.2 in individuals with no malocclusion [20], 31.4 in Class I individuals [19], 23.8 in individuals with varying vertical craniofacial morphology [13], 26.16 in retrognathic patients [12] and CT Class III report: 24.7 [15]. Similarly CSA of masseter in this study was 4.4 and 4.9 and comparison with that of other reports shows: 5.5 [20], 6.3 [19], 4.9 [13], 6.64 [12]. Medial pterygoid muscles' volume in present study were 9.7 in Class II and 16.7 in Class III group and data in other reports are: 10.4 [20], 11.0 [19], 10.4 [13], 11.27 [12]. Similarly CSAs of medial pterygoid muscle in our study were 3.08 and 3.46 respectively and comparative data shows: 3.4 [20], 3.4 [19], 3.2 [13], 4.09 [12]. It is not easy and correct to make direct comparisons between studies because of variations in study groups in accordance to specific deformity or malocclusions, ethnicity, age and protocol of investigation.

Positive strong correlations were found between the muscles' volume and CSA that coincide with other reports [9, 17].

We found mandibular ramus height to be correlated with muscles' parameters only in Class II group comparing with Class III group.

It was previously reported that subjects with stronger, larger mandibular muscles have a tendency toward wider transverse facial dimensions [9, 10], but it was not observed in our study. No correlations were found between intergonial width and any of muscular measurements.

CONCLUSIONS

1. Remarkable differences were observed between skeletal Class II and Class III study groups for both skeletal and muscular measurements.
2. More significant association between skeletal and muscular structures were observed in subjects with skeletal Class II malocclusion.
3. Profound examination (MRI and MSCT) of craniofacial structures in severe skeletal malocclusions might be relevant in planning orthodontic treatment and orthognatic surgery.

REFERENCES

1. Roberts WE, Hartsfield JK. Bone development and function:genetic and environmental mechanisms. *Semin Orthod* 2004;10:100-22.
2. Alaqeel SM, Hinton RJ, Opperman LA. Cellular response to force application at craniofacial sutures. *Orthod Craniofacial Re*, 2006;9:111-22.
3. Van Limborgh J. The role of genetic and local environmental factors in the control of postnatal craniofacial morphogenesis. *Acta Morphol Neerl Scand* 1972;10:37-47.
4. Enlow DH, Hans MG. Essentials of facial growth. Philadelphia: Saunders; 1996.
5. Kiliaridis S. The Importance of Masticatory Muscle Function in Dentofacial Growth. *Semin Orthod* 2006;12:110-9.
6. Hunt NP, Shah R, Sinanan A, Lewis M. Muscling in on malocclusions: Current concepts on the role of muscles in the aetology and treatment of malocclusion. *J Orthod*

2006;33:187-97.
7. Benington CM, Gardener JE, Hunt NP. Masseter muscle volume measured usinh ultrasonography and its relationship with facial morphology. *Eur J Orthod* 1999;21:659-70.
8. Kubota M, Nakano H, Sanjo I, Satoh K, Sanjo T, Kamegai T, et al. Maxillofacial morphology and masseter muscle thickness in adults. *Eur J Orthod* 1998;20:535-42.
9. Hannam AG, Wood WW. Relationships between the size and spatial morphology of human masseter and medial pterygoid muscles, the craniofacial skeleton, and jaw biomechanics. *Am J Phys Anthropol* 1989;80:429-45.
10. Van Spronsen PH, Weijs WA, Valk J, Prahl-Andersen B, van Ginkel FC. Relationships between jaw muscle cross-sections and craniofacial morphology in normal adults, studied with magnetic resonance imaging. *Eur J Orthod* 1991;13:351-61.
11. Van Spronsen, Weijs W, Valk J, Prahl-Andersen B, van Ginkel F. A comparison of jaw muscle cross-sections of long face and normal adults. *J Dent Res* 1992;71:1279-85.
12. Dicker G, van Spronsen P, van Schijndel R, van Ginkel F, Manoliu R, Boom H. Adaptation of jaw closing muscles after surgical mandibular advancement procedures in different vertical craniofacial types: a magnetic resonance imaging study. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2007; 103:475-82.
13. Boom HPW, van Spronsen PH, van Ginkel FC, van Schijndel RA, Castelijns JA, Tuinzing DB. A comparison of human jaw muscle cross-sectional area and volume in long- and short-face subjects, using MRI. *Arch Oral Biol* 2008; 53:273-81.
14. Chan HJ, Woods M, Stella D. Mandibular muscle morphology in children with different vertical facial patterns: a 3-dimensional computed tomography study. *Am J Orthod Orthop* 2008;133:10.e1-13.
15. Kitai N, Fujii Y, Murakami S, Furakawa S, Kreiborg S, Takada K. Human Masticatory Muscle Volume and Zygomatico-mandibular Form in Adults with Mandibular Prognatism. *J Dent Res* 2002; 81: 752-756.
16. Weijs WA, Hillen B. Relationships between masticatory muscle cross-section and skull shape. *J Dent Res* 1984; 63:1154-7.
17. Gionhaku N, Lowe AA. Relationship between jaw muscle volume and craniofacial form. *J Dent Res* 1989;68:805-9.
18. Ariji Y, Kawamata A, Yoshida K, Sakuma S, Nawa H, Fujishita M, et al. Three-dimensional morphology of the masseter muscle in patients with mandibular prognathism. *Dentomaxillofac Radiol* 2000;29:113-8.
19. Hsu CW, Shiau YY, Chen CM, Chen CK, Liu HM. Measurements of the size and orientation of human masseter and medial pterygoid muscles. *Proc Natl Sci Counc Repub China* 2001;25:45-9.
20. Goto TK, Tokumori K, Nakamura Y, Yahagi M, Yuasa K, Okamura K. Volume changes in human masticatory muscles between jaw closing and opening. *J Dent Res* 2002;81:428-32.
21. Swennen RJ, Schutyser F. Three-dimensional cephalometry: Spiral multi-slice vs cone-beam computed tomography. *Am J Orthod Dentofacial Orthop* 2006;130:410-6.

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