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Original Article

Chewing efficiency and contact area discrepancies in Angle's class I and II malocclusion: A comparative study

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ABSTRACT

Objective: The study aimed to assess and compare both the chewing efficiency and the contact area between class I and class II of Angle's malocclusions.
Material and methods: A total of 120 individuals aged between 19 and 30 years were examined and were divided into two groups according to Angle's class (Class I and class II). The chewing efficiency was quantified using the ViewGum software and two-colored chewing gum. The contact area was quantified using modeling wax and MATLAB software. All data were collected, then, analyzed using SPSS software 21. Data normality was checked through kurtosis test. Descriptive results were calculated. Matched sample t-tests were used to compare chewing efficiency measurements between right and left sides. Independent t-tests were used to compare chewing efficiency and the contact area between class I and class II of Angle's malocclusions. Linear regression and Pearson correlation were used to assess the correlation between chewing efficiency and the contact area. The significance level was fixed at $p = 0.05$.
Results: For group 1, the mean hue value on both sides was 0.086 ± 0.058. For group 2, it was 0.095 ± 0.055. The difference between both groups was statistically significant ($p = 0.03$). For group 1, the mean contact area was 49.91 ± 21.47 mm^2. For group 2, it was 51.42 ± 19.76 mm^2. The difference was statistically not significant ($p = 0.4$). The correlation between the contact area and the chewing efficiency in both groups was statistically significant and it was negative (in class I $p = 0$ and $R = -0.616$; in class II $p = 0.01$ and $R = -0.408$).
Conclusion: The Chewing is better for patients with Angle's Class I malocclusion. The contact area is higher. Larger occlusal contact area leads to higher masticatory efficiency. Further studies should be conducted.

1. Introduction

Mastication represents the initial stage of the digestive process, facilitating food intake. This primary oral function significantly influences individuals' overall health and quality of life (van der Bilt, 2011). Evaluation methods such as masticatory ability, performance, and efficiency (Magalhães, Pereira et al. 2010) are used to assess it. Factors like tooth loss, decreased muscle strength, or malocclusion can potentially compromise mastication (Magalhães, Pereira et al. 2010). While the impact of malocclusion in the sagittal plane, as defined by Edward Angle, remains uncertain (Katz, 1992), orthodontic treatment for Angle Class III malocclusion is often recommended due to its significant aesthetic impact, especially in childhood. However, the necessity for orthodontic correction in Angle Class II malocclusion is not as automatic. Therefore, the existing literature lacks evidence confirming reduced masticatory efficiency for this type of malocclusion. On the other hand, it's clear that the mastication function primarily engages the occlusal surfaces of teeth. Their specific morphology and arrangement across different planes enable the establishment of a precise and repetitive pathway, known as the masticatory cycle (Sierpinska, Kropiwnicka et al. 2017). Consequently, the contact areas between the upper and lower teeth are vital for breaking down and blending food into a bolus suitable for swallowing. However, there have been very few studies that compare these specific zones according to Angle's classification.

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For all the reasons mentioned, this study aimed to achieve three objectives: Firstly, to assess chewing efficiency and compare it between Angle Class I and Class II. Secondly, to evaluate the contact area for both classes and make a comparative analysis. Finally, to establish the potential relationship between chewing efficiency and the contact area.

2. Materials and method

2.1. Study design

It was a cross sectional study set from December 2021 to February 2022 in the faculty of dental medicine Monastir Tunisia.The study was reviewed and approved (CER-SVS/ISBM04/2022). Taking into consideration a previous study (Bae, Son et al. 2017), the sample size was multiplied to obtain more accurate results.

2.2. Inclusion and exclusion criteria

All participants were divided into two groups according to Angle's classification of malocclusion (Group 1 and 2 for respectively class I and II of Angle's classification).

According to angle classification (Weinberger T 1993), in the Class I, the mesiobuccal cusp of the upper first molar occludes with the mesiobuccal groove of the antagonist first molar, while the mesial slope of maxillary canine coincides with the distal slope of mandibular canine. The Class II is characterized by a mesial situation of both maxillary first molar and canine. They were clearly informed before participation, as well as, verbal and written consent was obtained.

Only healthy students with class I and II of Angle's classification were included in the study that are aged between 18 and 30. Those with Class II half unit classification was excluded.

It excluded students who underwent previous orthodontic treatment, suffered from temporomandibular disorders, presented craniofacial deformity like a cleft lip and palate, had severe periodontal disease, severe tooth wear or malposition and missing teeth (excepted third molar). Those aged more than 30 years were excluded, as well.

2.3. Study protocol

A detailed clinical file was filled including the gender, the age, the overbite, the overjet, propulsion and laterality types through a detailed clinical examination. The mastication type was subjectively reported by the participant.

2.3.1. Assessment of the chewing efficiency

Two customized pink-green chewing gum (dimensions of 30*18*3 mm) (Schimmel, Christou et al. 2015) were given to participants to chew on both left and right sides for 20 mastication cycle (Halazonetis, Schimmel et al. 2013). Once the experiment ended, the boluses were received back from the oral cavity. They were rinsed in tap water and dried, then preserved in a special transparent plastic bag. It was then flattened into 1 mm thick wafers (Prinz, 1999). A Canon Camera (EOS 5D Mark II) was used to photograph both sides of each specimen. The Chewing efficiency was quantitatively estimated through colorimetric analysis performed with the ViewGum software respecting the original protocol (Schimmel, Christou et al., 2015) (Fig. 1).

The ViewGum© software employs colorimetric analysis by converting loaded and segmented images from RGB to HSI color. It calculates pixel probabilities for foreground or background based on pixel values at stroke areas and their distances. The software uses the hue component for a more accurate representation of color mixing, considering that poorly mixed chewing gum colors exhibit higher hue variance among neighboring pixels. The variance of hue serves as a measure for the level of color mixture, indicating better color mixing and improved chewing efficiency when the hue variance is lower. (Milic, Rajkovic et al., 2021).

2.3.2. Assessment of the contact area

The participant was invited to bite a prepared modeling wax (Cavex Set Up Hard Modeling Wax) in order to get the imprints of the contact areas. A white card-board was placed under the specimens to ensure a white and light background. Then, it was photographed using a Canon Camera (EOS 5D Mark II).

After that, each image was converted to monochrome mode by Adobe Photoshop 2019 (Fig. 2). Once obtained, monochrome images were sent to MATLAB software that calculated the number of pixels

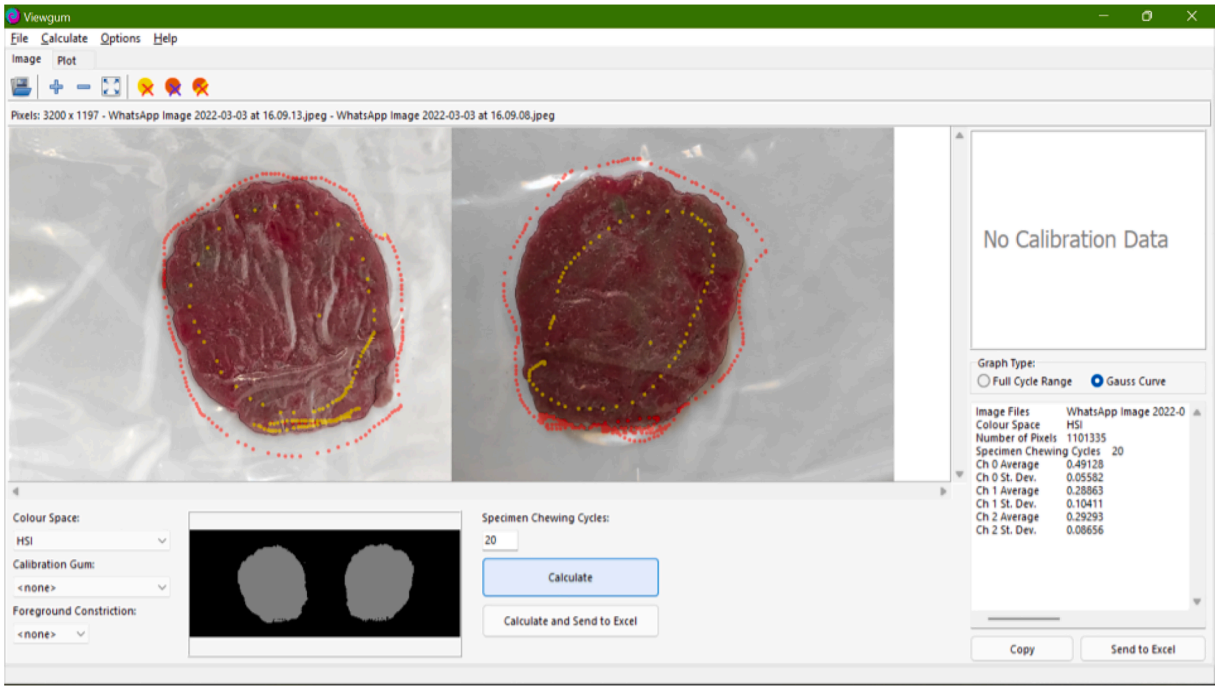

Fig. 1. Obtained specimen analyzed by ViewGum software.

Fig. 2. Monochrome image obtained from image of the bite wax.

(Bae, Son et al. 2017). The contact area was calculated using the following formula:

Contact area surface = 0.1024* Pixels of the contact Area obtained by MATLAB software.

2.3.3. Camera settings

A Canon Camera (EOS 5D Mark II) was used to photograph the specimens. A constant fixed distance of 12 cm was respected for all specimens in order to ensure the protocol reproducibility. To obtain a white and light background, a white card-board was placed under the specimens. Once images were obtained, they were saved in a tagged image file format (png) and labeled with identification codes for the subsequent analysis.

2.4. Data collection and analysis

Data normality was checked through Kolmogorov-Smirnov test. Descriptive results including the mean and standard deviation were calculated. Chi-squared test was used to verify the homogeneity of groups. Matched sample t-tests were used to compare the chewing efficiency between right and left sides. Independent sample t-tests were used to compare both the chewing efficiency and the contact area between I and II classes. The linear regression and Pearson correlation were used to assess the correlation between chewing efficiency and the contact area. The significance level was fixed at p = 0.05.

3. Results

A total of 120 dental students participated in the present study. The demographic data including the age, sex and mastication type were comparable (Table 1). Descriptive results of chewing efficiency and contact area are presented by Table 1. Their distribution according the gender, the protection type and the mastication type are shown in Table 2. The correlation between the chewing efficiency and the contact area was statistically significant for both groups (Group 1: P = 0.01, r = -0.408; Group2: P = 0, r = -0.616).

4. Discussion

The ability to grind food defines the masticatory efficiency. High masticatory efficiency implies that, with the least effort, the maximum number of particles are grinded. To date many tools have been used aiming to assess the masticatory efficiency. The sieves system was the first method created by Gaudenz et al (Gaudenz, 1901). This tool depends on variable factors such as the number of sieves, the orifice diameter, the type of aliment. (Goiato, Garcia et al., 2010) (Manly and Braley, 1950) (Toman, Toksavul et al., 2012). In 1984, Poyiadjis and Likeman were the first to use chewing gum (Poyiadjis and Likeman, 1984). In 1998, Hayakawa et al (Hayakawa, Watanabe et al., 1998) suggested the use of the colored chewing gum through two layers. Subjective methods have been used, also, through questionnaires (Slagter, Olthoff et al., 1992) (Demers, Bourdages et al., 1996). In 2013, the ViewGum Software was used by Halazonetis DJ et al (Halazonetis, Schimmel et al., 2013) for the first time aiming to test its validity and establishing a graphic representation of the masticatory ability of a healthy population. Later, it has been widely used by researchers in different fields. In the present study, the masticatory efficiency was assessed using colorimetric analysis through the ViewGum software which seems to be the most accurate and cost-effective tool as it is freely downloaded. The average hue value for group 1 on both sides was 0.086 ± 0.058. As for group 2, it was 0.095 ± 0.055. Using the Hubba-Bubba Tape chewing gum and by the ViewGum Software, Halazonetis et al. (Halazonetis, Schimmel et al., 2013) and Chawisa et al. (Chawisa Thangjittiporn, 2021) reported respectively 0.144 ± 0.082 and 0.051 ± 0.024. Lemić et al. (Milić Lemić, Rajković et al., 2021) reported, also, near values (0.063 ± 0.025) with Five Tape sugarless chewing gum.

In 2015, Schimmel et al (Schimmel, Christou et al., 2015) have established the characteristics of the suitable gum used for a mixing ability test.

A statistically significant difference was found between both groups (p = 0.03), suggesting that class I malocclusion exhibits better masticatory performance compared to Angle class II. This study marks the first exploration in this area. Previous research has not utilized the VOH and ViewGum software to compare chewing efficiency between Angle class I and II. Toro et al. (Toro, Buschang et al., 2006) reported, using the sieves method, that children with Angle class I displayed superior masticatory ability compared to those with class II and III. Owens et al. (Owens, Buschang et al., 2002) in 2002, using a similar method, concluded that subjects with class I malocclusion exhibited significantly better masticatory ability. Additionally, in 2006, English et al. (English, Buschang et al., 2002) combined the sieves system with a visual analog scale. Their findings indicated that subjects with class I had significantly smaller particle sizes (p = 0.01) and broader particle distributions (p < 0.01) compared to subjects with class II.

However, Jungin Baea et al. (Bae, Son et al., 2017) calculated, in 2017, the mixing ability index (MAI) according to Angle's class. The

Table 1
Demographic data and descriptive results for both groups.

	Group 1 (n = 64)	Group 2 (n = 56)	p
Demographic Data			
• **Age (Mean ± SD)**	23.00 ± 2.316	23.21 ± 2.556	0.63*
• **Gender (%)**			
Males	51.5	48.2	
Females	48.44	51.8	0.70*
• **Mastication type**			
Unilateral mastication	32.8	39.3	*
Bilateral mastication	67.2	60.7	0.57**
Descriptive results (Mean ± SD):			
• **Overjet**			
• **Overbite**	1.46 ± 0.956	1.5 ± 1.289	0.39*
• **VOH**	2.07 ± 1.054	2.6 ± 1.719	0.50*
Left side			
Right side	0.091 ± 0.069	0.099 ± 0.059	–
Both sides	0.084 ± 0.047	0.105 ± 0.072	–
• **Contact area:**	0.086 ± 0.058	0.095 ± 0.055	**0.03*-**
	49.41 ± 21.47	51.42 ± 19.76	**0.4***

Level of significance set a 5%.
* : Independent T-test.
** : Chi-squared test.

Table 2
Mean hue values and contact area distributions according to the gender, protection type and the mastication type for both groups.

	VOH						Contact Area					
	Group 1			Group 2			Group 1			Group 2		
	Mean	SD	P*	Mean	SD	p	Mean	SD	p	Mean	SD	p
Gender												
Male	0.099	0.047		0.082	0.053		51.59	20.9		57.45	19.61	
Female	0.105	0.073	0.2*	0.092	0.04	0.01*	46.9	22.63	0.7*	47.15	18	2*
Protection type												
Canine protected occlusion	0.116	0.068		0.088	0.032		47.11	22.16		50.56	18.23	
Group protected occlusion	0.08	0.04	0.6*	0.087	0.055	0.02*	54.05	20,02	0.2*	52.55	21.18	0.3*
Mastication type												
Unilateral mastication	0.101	0.055	0.9*	0.074	0.04		47.8	12.3	0.4*	56.55	19.51	
Bilateral mastication	0.0103	0.085		0.108	0.05	0.06*	52.21	19		45.26	19.5	**0.02***

Level of significance set a 5%.
* : Independent T-test

difference was statistically not significant between both groups (Angle class I and II) ($p > 0.05$).

The present investigation aimed, also, to quantify the occlusal contact area through the MATLAB software. These zones are defined by a thickness less than 50 μm. Different software's and complex protocols were used in the literature. Wilding et al. (Wilding, 1993) used a system for image analysis in order to quantify the thickness of wax interocclusal records. In 2002, Owen et al. (Lee, Kim et al., 2015) (Owens, Buschang et al., 2002) used UTHSCSA software. In 2015, Lee et al used a three-dimensional scanner and the RapidForm software. In 2017, Baea et al. (Bae, Son et al., 2017) used a silicone interocclusal recording material in maximum intercuspation to measure the occlusal contact area with a thickness less than 50 mm. The specimens were photographed. The obtained images were converted to monochrome images through PhotoScape software. The occlusal contact area was calculated with the MATLAB software.

For group 1, the mean contact area was 49.91 ± 21. 47 mm^2. For group 2, it was 51.42 ± 19.76 mm^2. Close results were reported by Bae et al. (Bae, Son et al., 2017): for class II with a mean value of 45.5 ± 29 mm^2. For class I, the values were higher (72.4 ± 37.2 mm^2). This difference could be attributed to the used material. The difference was statistically not significant between both groups ($p = 0.4$). No previous study with the same protocol was conducted. In this issue, the results available in the literature are controversial. Lee et al. (Lee, Kim et al., 2015) have reported that the contact area for class I showed a tendency to be larger while the difference was statistically not significant ($p = 0.078$). However, Bae et al. (Bae, Son et al., 2017) found the difference was statistically significant among the three angles groups ($p < 0.01$). This could be explained by different protocol used.

The correlation between chewing efficiency and the contact area surface was statistically significant for both groups. It was negative and median. These findings mean that the chewing efficiency are inversely proportional to the contact area. This deduction was consistent with Wilding et al (Wilding, 1993) who reported a correlation between chewing efficiency and occlusal contact area. After 15 chewing strokes, the difference between intermediate occlusal contact areas and the particle size was significant ($p < 0.001$). The Pearson correlation was negative ($R = -0.59$), as well. Also, Owen et al.'s study (Owens, Buschang et al., 2002) suggest a negative correlation between ACNC (areas of contact and near contact) and both the median particle size and the breadth of particle distribution.

However, Bae et al. (Bae, Son et al., 2017) found a weak positive correlation ($p < 0.01$, $R = 0.13$) between the MAI and occlusal contact area. Controversial results could be explained by the protocols used or the average age of the participants.

The present study exhibited some limitations that should be mentioned. First, the sample size would be greater. Secondly, during the sampling step, some factors which may affect both the masticatory efficiency or the contact area such as the body size or the bite force were not taken into consideration. Finally, in terms of the material, the use of the silicone would give better precision. The modeling wax was used as it takes less time for its manipulation. It is cheaper as well.

5. Conclusion

The present study aimed to compare the chewing efficiency between I and II Angle classification. Statistically significant difference was reported with $p = 0.03$. It could suggest that their occlusal relationship might be contributing positively to their chewing ability. It revealed that masticatory efficiency was higher among patients with Angle's Class I malocclusion. The study aimed, also, to assess the correlation between the chewing efficiency and the contact area. It was statistically significant. It was negative in both groups (in group 1: $p = 0$ and $R = -0.616$; in group 2: $p = 0.01$ and $R = -0.408$). This suggests that a larger occlusal contact area led to increased masticatory efficiency, as seen in the reversal of VOH (Variable Occlusal Thickness) concerning the contact area. Therefore, further studies are needed to explore this relation even better.

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.

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