

Evaluation of reproduction technique of bitemarks printed in chewing gum for human identification

Avaliação da técnica de reprodução de marcas de mordida impressas em gomas de mascar para identificação humana

Evaluación de la técnica de reproducción de marcas de mordeduras impresas en goma de mascar para identificación humana

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Abstract

Forensic Odontology is the science that correlates dental and legal principles, used for processes such as human identification. One of the possible acting fields for Forensic

Odontologists is the analysis and study of patterns and injuries created by human bite marks. This study aimed to show the applicability of dental marks printed in chewing gum for human identification in forensic investigations. A transversal observational study was carried out. The data was collected from 20 volunteers over 18 years old. Each subject had their upper and lower dental casts and was asked to chew a piece of gum for one minute. The pieces of chewing gum were refrigerated at -20°C for a week, and reproduced with addition and condensation silicones using an adapted reproduction technique. The analysis of the chewing gum was made by overlays. The ANOVA test showed no significant differences on width and length between the pieces of chewing gum and their reproductions (greatest width $p=0.918$, and the length $p=0.981$). The analysis of the reproductions with plaster mold showed that there was no difference when using addition silicone or condensation silicone. During the analysis, various suspects could be excluded from the investigation (up to 11, depending on the technique used), but it was not possible to confirm one of them as the main suspect. The study showed that the reproduction technique of chewing gum is efficient, viable and easily performed; and can be used in cases of human identification in forensic investigations. However, it is necessary to certify that the chewing gum effectively presents a bite mark and that it is correctly handled to avoid alterations. It also became evident that the process of refrigeration is essential for the analysis proposed in this study.

Keywords: Human identification; Bitemarks; Forensic dentistry.

Resumo

A odontologia forense é a ciência que correlaciona os princípios odontológicos e jurídicos, utilizados para processos como a identificação humana. Um dos possíveis campos de atuação do especialista em Odontologia Legal é a análise e estudo de padrões e lesões criadas por marcas de mordidas humanas. Este estudo teve como objetivo mostrar a aplicabilidade de marcas dentais impressas em gomas de mascar para identificação humana em investigações forenses. Foi realizado um estudo observacional transversal. Os dados foram obtidos de 20 voluntários maiores de 18 anos. Cada sujeito teve suas arcadas superior e inferior moldadas e foi solicitado a mascar um chiclete por um minuto. As gomas de mascar foram refrigeradas a -20°C por uma semana e reproduzidas com silicones de adição e de condensação por técnica adaptada. A análise da goma de mascar foi realizada usando sobreposições. Utilizando o teste estatístico de ANOVA, não houve diferenças significativas na largura e comprimento entre as gomas e suas reproduções (maior largura $p=0.918$ e maior comprimento $p=0.981$). A análise das reproduções das gomas de mascar mostrou que não houve diferença ao usar silicone de

adição ou silicone de condensação, conforme o teste qui-quadrado de Pearson. Durante a análise, vários suspeitos puderam ser excluídos da investigação (até 11, dependendo da técnica utilizada), mas não foi possível confirmar um deles como o principal suspeito. O estudo mostrou que a técnica de reprodução da goma de mascar é eficaz, viável e de fácil execução; e pode ser utilizada em casos de identificação humana em investigações forenses. No entanto, é necessário certificar-se de que a goma de mascar realmente apresenta marca de mordida e que foi manuseada de maneira adequada para evitar alterações. Também ficou claro que o processo de refrigeração é primordial para a análise proposta neste estudo.

Palavras-chave: Antropologia forense; Marcas de mordidas; Odontologia legal.

Resumen

La odontología forense es la ciencia que correlaciona los principios dentales y legales, utilizados para procesos como la identificación humana. Uno de los posibles campos de actuación de los odontólogos forenses es el análisis y estudio de patrones y lesiones creadas por las marcas de mordeduras humanas. Este estudio tuvo como objetivo mostrar la aplicabilidad de las marcas dentales impresas en chicle para la identificación humana en investigaciones forenses. Se realizó un estudio de observación transversal. Los datos se obtuvieron de 20 voluntarios mayores de 18 años. Cada sujeto tenía sus modelos dentales superior e inferior y se le pidió que masticara un chicle durante un minuto. Los trozos de chicle se refrigeraron a -20°C durante una semana y se reprodujeron con siliconas de adición y condensación mediante una técnica de reproducción adaptada. El análisis de la goma de mascar se realizó mediante superposiciones. El ensayo de análisis de varianza no mostró diferencias significativas en el ancho y el largo entre los trozos de chicle y sus reproducciones (mayor ancho $p=0.918$, y largo $p=0.981$). El análisis de las reproducciones con molde de yeso mostró que no hubo diferencia al utilizar silicona de adición o silicona de condensación. Durante el análisis, varios sospechosos pudieron ser excluidos de la investigación (hasta 11, dependiendo de la técnica utilizada), pero no fue posible confirmar a uno de ellos como el principal sospechoso. El estudio demostró que la técnica de reproducción del chicle es eficaz, viable y de fácil realización; y se puede utilizar en casos de identificación humana en investigaciones forenses. Sin embargo, es necesario certificar que el chicle presenta efectivamente una marca de mordedura y que está correctamente manipulado para evitar alteraciones. También se hizo evidente que el proceso de refrigeración es fundamental para el análisis propuesto en este estudio.

Palabras clave: Antropología forense; Marcas de mordeduras; Odontología forense.

1. Introduction

The study of recognition and interpretation of marks and injuries produced by human bites is increasing in Forensic Dentistry (Hinchliffe, 2010). Although some authors affirm that there cannot be two people with the same dental standards, there is still no concrete theory about the individuality of dentitions and the behavior of skin marks (Carvalho & Matoso, 2010; Daniel & Pazhani, 2015). In general, especially bites on human skin, the bitemark on substrate analysis will never be as unique as the dentition that created it, since the uniqueness is one of the key requirements for an identification method (Tuceryan, Li, Blitzer, Parks, & Platt, 2011; Osborne, Woods, Kieser & Zajac, 2014). This analysis has been criticized in Courts and among forensic researchers (Oliveira et al., 2010; Reesu & Brown, 2016). Despite this limitation, in some cases these are the only forensic evidences (Tuceryan et al., 2011; Verma, Kumar & Bhattacharya, 2013). In recent years, the use of bitemarks have been refuted (De Sainte Croix, Gauld, Forgie & Lowe, 2016). Many experts argue that the use of these marks as evidence depends on many factors such as well-positioned photographs, expert experience, type of bruise, among others (Verma et al., 2013; Chinni, Al-Ibrahim & Forgie, 2014; Reesu & Brown, 2016). This study aimed to show the applicability of a method to reproduce pieces of chewing gum for human identification purposes.

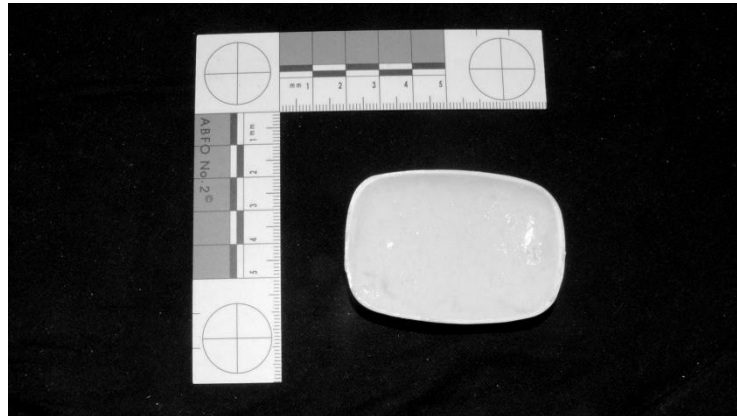
2. Material and Methods

This observational transversal study received approval from the Ethics and Research Committee of the Faculty of Dentistry of Ribeirao Preto, Sao Paulo University, through n. 0183212.7.0000.5419. Twenty volunteers, all of them over 18 years old, had their jaws reproduced using AvaGel[®] alginate (Dentsply[®], Pirassununga, SP, Brazil), by only one operator, using the measurement recommended by the company. The dental casts were made with Type III Dental Stone (Asfer[®], São Caetano do Sul, SP, Brazil), using 20ml of water for each 100g of plaster. After 40 minutes the models were removed and trimmed.

The volunteers received a piece of chewing gum - Trident[®] (Cadbury Adams[®], Louveira, SP, Brazil), which was chewed for one minute. These participants were not given guidance on how to chew and expel the piece of gum, for that reason, some of the pieces did not have visible bitemarks. The volunteers expelled the chewing gum in a piece of aluminum foil that was placed in a container numbered from 1 to 20 for storage, under refrigeration at -20°C to freeze them.

The technique for molding and reproduction of chewing gum was according to Silva, Flores and Lino Jr (2014). First, the alginate was manipulated using the manufacturer's recommended measurement, for each half of the cast recipient, a measure of alginate was used. After manipulation, the alginate was inserted into the half of the cast recipient (Figure 1) and the refrigerated piece of chewing gum was placed in the pink mass of the alginate.

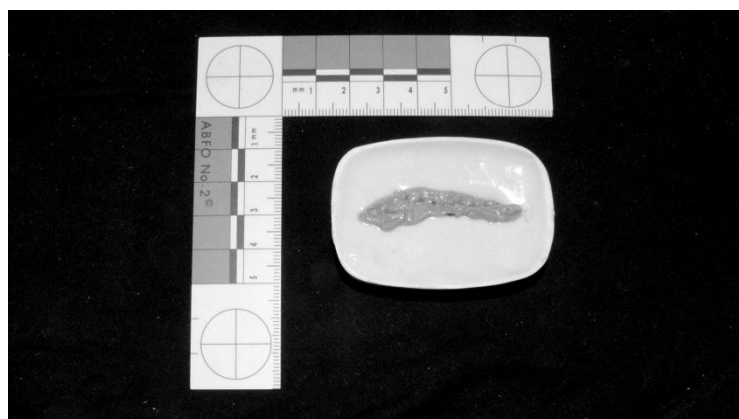
Figure 1 – Half of the plastic recipient filled with alginate.



Source: Authors (2020).

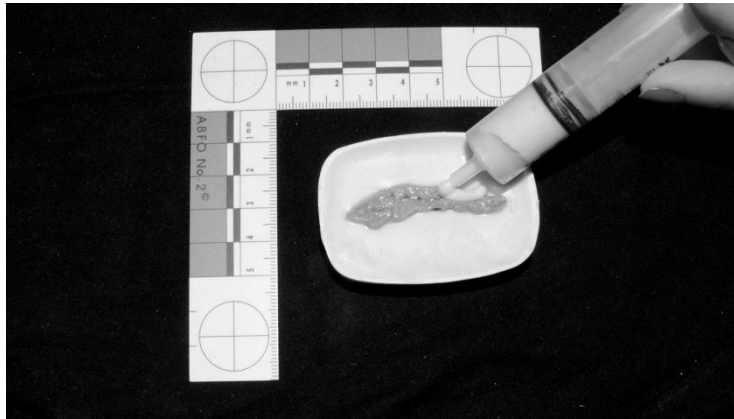
After 1 minute, when the alginate became white (Figure 2), another alginate measure was manipulated and it was placed in the disposable syringe, and then, using the syringe, the refrigerated piece of chewing gum was careful covered (Figure 3).

Figure 2 – Chewing gum included in the plastic recipient containing alginate.



Source: Authors (2020).

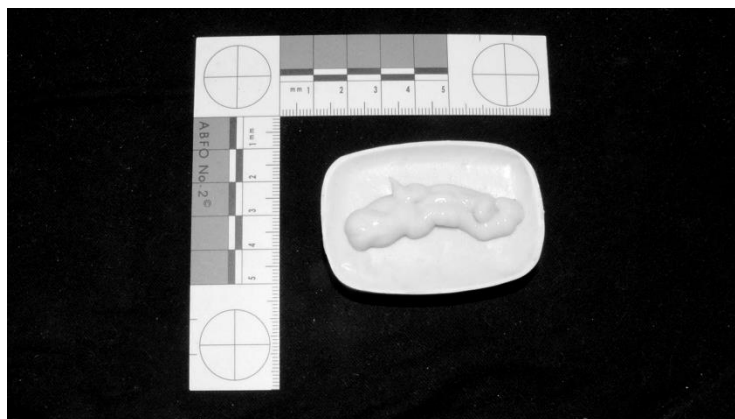
Figure 3 – Alginate application with disposable syringe on the chewing gum.



Source: Authors (2020).

The rest of the material was placed in the other half of the cast recipient, which was carefully closed (Figure 4).

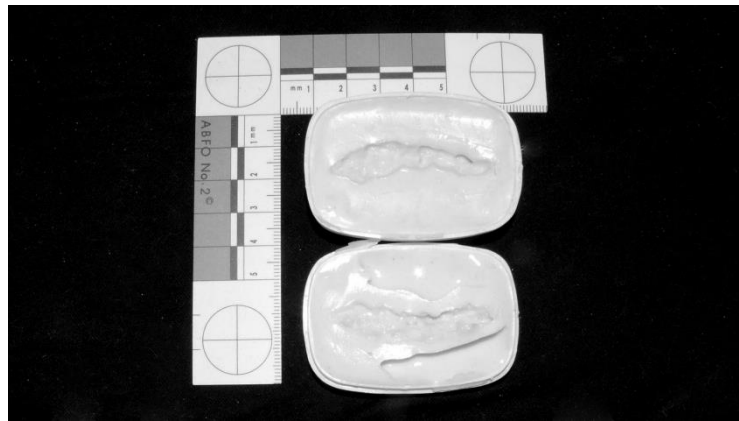
Figure 4 – Alginate application in the other part of the plastic recipient.



Source: Authors (2020).

After setting time of the material, the cast recipient was carefully opened and the piece of chewing gum removed and refrigerated again. After this process, we had a negative reproduction of the piece of chewing gum (Figure 5).

Figure 5 – Mold after material cure.



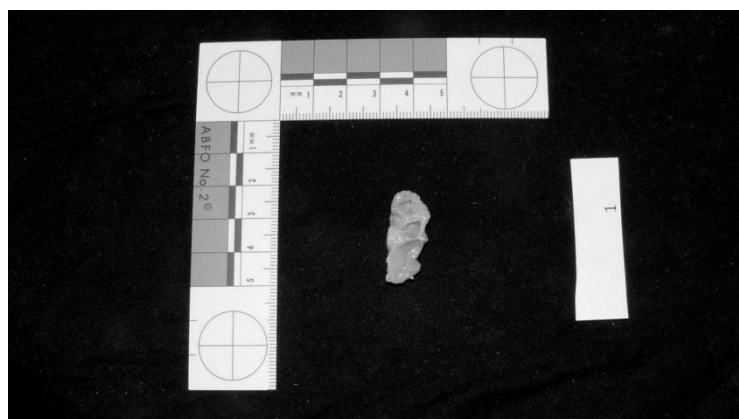
Source: Authors (2020).

This process was carried out with each type of material, using the measurements reported by each company. The elastomers addition silicone in the dispenser, the condensation silicone, the base paste, and the accelerator paste were placed in two strands of the same length on a glass plate and mixed with a spatula. Then it was spread regularly on top of one another.

Measurement of samples and reproduction of chewing gum.

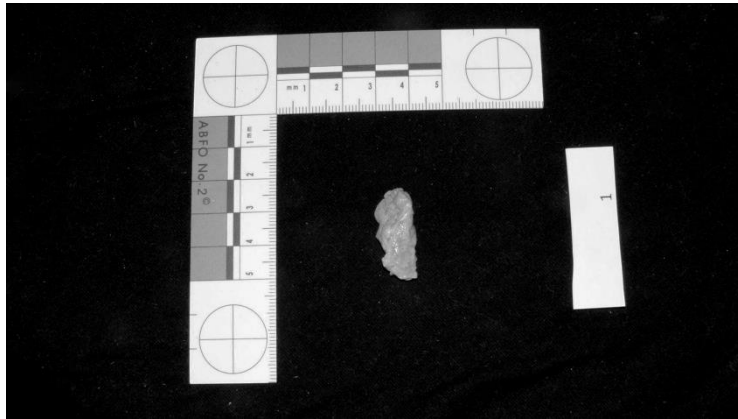
First, to assess the quality of the samples and the reproductions, they were measured with a digital caliper (UPM™, Austria), considering the greater length and height of the chewing gum and the reproductions (Figure 6 and 7).

Figure 6 – Height measurement of a sample of chewing gum.



Source: Authors (2020).

Figure 7 – Width measurement of a sample of chewing gum.



Source: Authors (2020).

The size of the bites was not measured. The total was 120 measurements: 20 refrigerated chewing gum; 20 reproductions with addition silicone; and 20 reproductions with condensation silicone, since 2 sets of measurements were taken for each piece of chewing gum and reproduction, as illustrated in Table 1.

Table 1 – Measurements of samples and reproductions of chewing gum (n=20).

	Addition silicone reproductions	Condensation silicone reproduction	Original samples
1	25,69 x 10,43mm	25,39 x 10,91mm	25,39 x 10,93mm
2	29,44 x 10,08mm	29,74 x 9,74mm	29,63 x 10,04mm
3	16,44 x 8,45mm	16,45 x 8,91mm	16,47 x 8,85mm
4	28,37 x 7,38mm	28,56 x 7,43mm	30,14 x 8,08mm
5	17,93 x 10,25mm	16,69 x 9,93mm	16,61 x 9,77mm
6	14,50 x 12,86mm	14,32 x 12,71mm	14,21 x 12,78mm
7	26,52 x 13,41mm	25,50 x 14,59mm	25,19 x 15,38mm
8	32,73 x 8,89mm	33,23 x 8,91mm	34,41 x 8,80mm
9	33,23 x 12,9mm	31,00 x 12,25mm	33,94 x 11,82mm
10	18,45 x 12,53mm	17,36 x 11,62mm	17,77 x 12,78mm
11	23,42 x 17,51mm	23,25 x 17,87mm	23,85 x 12,51mm
12	20,58 x 11,22mm	20,73 x 11,29mm	19,36 x 11,80mm
13	30,64 x 14,16mm	30,16 x 13,06mm	31,27 x 12,07mm
14	33,00 x 11,68mm	32,06 x 11,13mm	34,11 x 10,8mm
15	43,40 x 9,83mm	42,12 x 9,31mm	44,94 x 9,30mm
16	19,72 x 11,48mm	19,72 x 10,70mm	19,00 x 12,49mm
17	19,08 x 14,96mm	18,57 x 14,31mm	17,41 x 13,91mm
18	20,73 x 13,78mm	20,45 x 13,66mm	20,50 x 13,50mm
19	18,08 x 14,78mm	18,40 x 14,68mm	16,74 x 16,26mm
20	24,44 x 17,41mm	23,75 x 16,29mm	23,66 x 15,48mm

Source: Authors (2020).

The distribution of the sample was statistically evaluated by the parametric test Analysis of Variance (ANOVA) using one criterion. In addition, the complementary Tukey

test was used to determine which group had differences between itself. The estimated level of significance was 5%, as provided in Table 2.

Table 2 – Analysis of Variance (ANOVA) – greatest width and greatest length.

		Sum of squares	df	Mean squares	F	Sig
Greatest length	Between groups	2,238	2	1,119	0,02	0,981
	Within groups	57	57,168			
	Total	59				
Greatest width	Between groups	1,165	2	0,582	0,086	0,918
	Within groups	57	6,674			
	Total	59				

Source: Authors (2020).

Analysis of plaster models vs reproductions of chewing gum.

Identification methods used were overlay between the reproductions of chewing gum and plaster models; and overlay with transparency sheets.

1. Overlay between the reproductions of chewing gum and the plaster models

Each of the 40 reproductions of chewing gum were interposed between the plaster models, trying different ways to find some compatibility between the reproductions and the incisal / occlusal surfaces of plaster models. Thus, each piece of chewing gum made possible 40 interpositions with the plaster models. Considering that there were 20 suspects, 800 clashes performed. This analysis showed possible suspects and excluded other.

2. Manual overlay with transparency sheet

The 40 dental models, 20 upper and 20 lower, had their cusps painted with a marker. Later the models were placed in a multifunctional printer Epson Stylus TX430W (Epson®, Beijing, China) to perform copies. A sheet of transparency was placed on top of each copy and marks of the cusp of each model were transfixed to the sheet, reproducing the occlusal profile to be used for analysis.

For the photos of the reproductions, the following materials were used: Nikon D3000 camera (Nikon Corporation™, Thailand); Tamron 18-200mm lens XR Dill; tripod; remote trigger and ABFO number 2 scale. The pictures were taken by the same investigator, with the camera on a tripod with 85th tilt, fixed lens in 18mm, shutter f22 and trigger 1/200 with built-in flash. The camera was kept still for all the photos, and they were all taken with a remote trigger in order to maintain the quality and sharpness of the images.

The 80 photos of the reproductions of chewing gum were printed, being each one on one side of each reproduction, all in actual size. The transparency sheet was overlapped on the photographs, in order to find matching points, to obtain possible suspects or exclude suspects.

3. Results

The measurements of samples and reproductions of silicone are in Table I. When comparing the measurements of samples and reproductions of chewing gum, the statistical result using ANOVA, to the greatest width was $p=0.918$, and the length, $p=0.981$. For either length or width of the reproductions, the results were not significant, suggesting that the distortions between the pieces of chewing gum were similar to the reproductions. Therefore, these materials can be used for reproduction of chewing gum with confidence.

Overlay between the reproduction of chewing gum and plaster models.

Through overlay of the reproductions of chewing gum and the plaster models, some suspects could be excluded from investigation. However, correspondence could not be confirmed with any of the subjects.

Considering both reproductions (made with addition and condensation silicone), from the 20 pieces of gum chewed by the suspects, 7 led to exclusion in 70 clashes (which corresponds to 35 percent of the analyzed samples and 25 percent of the total of clashes). The other 13 pieces of gum did not allow the exclusion or the identification of the suspect, corresponding to 65 percent of the total sample. Of these, 32.5 percent represented the samples that did not have any bitemarks. These were considered possible for all suspects in the statistical analysis.

A single piece of chewing gum presented differences between the materials of reproduction. More suspects were discarded using the condensation silicone (10 suspects) compared to the addition silicone (4 suspects). This result is explained by the presence of bubbles often observed when using the addition silicone, preventing a better assessment of compatibility.

For the statistical analysis of the difference in the usage of silicone reproductions of condensation or addition, the Pearson's Chi-Squared Test was used. The results showed 100% compatibility in the analyses, suggesting no statistical differences between the usages of addition or condensation silicones and is illustrated in Table 3.

Table 3 – Pearson chi-square for manual interposition for overlay between the reproduction of chewing gum and plaster models.

		Addition		Total	
		Possible	Excluded		
Condensation	Possible	Count	71	0	71
		% within condensation	100%	0,00%	100,00%
	Excluded	Count	7	62	69
		% within condensation	10,10%	89,90%	100,00%
TOTAL		Count	78	62	140
		% within condensation	55,70%	44,30%	100,00%

Source: Authors (2020).

Manual overlay with transparency sheet.

From the overlap of transparency sheets and photographs of the reproductions of pieces of chewing gum, it was possible to exclude some suspects. However, just as in the analysis by interposing the models, there was no confirmation of any suspect.

From the total of reproductions, only 13 (32.5%) were used in this method. The results were divided according to the overlap between reproductions made with addition silicone and with condensation silicone.

A single piece of chewing gum presented exclusion differences between different reproduction materials. More suspects were discarded by using addition silicone (4 suspects) compared to condensation silicone (11 suspects).

Pearson's Chi-Squared Test showed that, when using the condensation silicone, there is a 98.7% chance of possible analysis by addition silicone. It suggests that there are no statistical differences between these materials. These are displayed in Table 4.

Table 4 – Pearson chi-square for manual overlay with transparency sheet.

		Addition		Total	
		Possible	Excluded		
Condensation	Possible	Count	74	1	75
		% within condensation	98,7%	1,3%	100,00%
	Excluded	Count	3	62	65
		% within condensation	4,6%	95,4%	100,00%
TOTAL		Count	77	63	140
		% within condensation	55%	63,45%	100,00%

Source: Authors (2020).

4. Discussion

Forensic Odontology has a key role to clarify investigations, including cases where bitemarks are found at the crime scene (Saks et al., 2016). These marks may be present on human skin or on various substrates, such as food. Among the bitten food commonly found at crime scenes, the most cited in literature are: cheese, chocolate, apple, orange, cucumber, cookie and chewing gum (Naether, Buck, Campana, Breitbeck & Thali, 2012; Corte-Real, Pedrosa, Saraiva, Caetano & Vieira, 2018). These analyses have contributed to arrest people involved in many crimes (Page, Taylor & Blenkin, 2012). However, it is still an unclear area in forensics, due to the difficulty of molding, analysis, and storage of these types of food (Barsley et al., 2018).

Some places in the United States and other countries already accept bitemarks as evidences (Kaur, Krishan, Chatterjee & Kanchan, 2013; Balachander, Babu, Priyadharsini & Masthan, 2015). In Brazil, where any evidence obtained lawfully and legitimately is admitted as expert evidence that may lead to the conviction of the suspect, bitemarks analysis is a growing research field and has been accepted by the Court to solve some crimes (Paranhos et al., 2019). The study of this area in Forensic Dentistry is very important because often these are the only existing elements of expert evidence (Pretty & Sweet, 2010; Golden, 2015; Barsley et al., 2018).

Franco, Willems, Souza, Coucke and Thevissen (2017) indicates that forensic investigations with bitemarks can be carried out in closed populations; and, in cases with specific dentition characteristics or individual dental differences, as this is the only way to

exclude or include suspects. According to the guidelines of the American Board of Forensic Odontology (2018), the analysis of bitemarks allows three conclusions: (a) exclusion; (b) cannot be excluded; and, (c) inconclusive due to insufficient information. In this way, perfect agreement cannot be affirmed, just the exclusion or a probable inclusion.

The physical nature of the support and the strength of the bite are factors that influence the interpretation of the bitemarks (Osborne et al., 2014; Corte-Real et al., 2018). The bite force, and the characteristics of the material, cause the primary distortions; and, secondary distortions are produced by the elapsed time and technical details involved in registering the bitemarks (Wright & Golden, 2010; Fournier et al., 2020).

Experts in forensic sciences doubted the use of bitemarks as evidence, due to different possibilities of identification among different specialists and because it is not possible to estimate the elapsed time (Araújo, Recalde, Jacometti, Costa & Silva, 2019). However, the stability of the bitemarks is directly related to the type of support and the time interval, so they should be used as an element to exclude possible suspects and not for identification (Wright & Golden, 2010; Lewis & Marroquin 2015). This article supports this statement.

The methods to analyze bitemarks are metric analysis, overlay with transparency sheet, superposition by computer program, and interposition of models (Tai, Chong, Asif, Rahmat, Nambiar, 2016; Ali, Sansare & Karjodkar, 2018). In this research, the techniques used were overlay with transparency sheet and interposition of models, because they are less complex and cheaper techniques.

Of the total pieces of gum obtained from suspects, 55% did not show any bitemarks. This characteristic influences directly in the amount of information available for analysis and, therefore, in the identification of an individual. Unlike Marques et al. (2007), in this study the volunteers were not told to "bite" the chewing gum prior from expelling it, reflecting in the pattern of the samples. This data corroborates with the assumption that the analysis of dental patterns is not always possible when these types of evidences are found at crime scenes. However, it is important to remember that, in addition to providing reproduction elements of the occlusal patterns, chewing gum can provide biological sample for DNA analysis. Therefore, it is important that the DNA material is collected before any procedure of analysis of the piece of chewing gum. In our research, we do not collect DNA sample because that was not our purpose.

The analyses performed in this study showed that overlay presented more errors. This fact is due to the inability to directly evaluate the occlusal or incisal surfaces and the malleability of the reproduction material for the interposition that promotes compatibility

between reproductions and models. Models with minor differences in the incisal patterns may also be compatible with different reproductions due to the elasticity of the addition and condensation silicones (Reinprecht, Van Staden, Jordaan & Bernitz, 2017).

The materials chosen for the reproductions of chewing gum were selected due to its elastic and compressible properties, its less chance to suffer deformities, dehydration and decomposition, and because they are considered reliable and effective in forensic studies (Reddy, Rakesh, Kaushik, Devaraju & Kumar, 2011). Greco et al. (2009) stated that addition silicones have the best elastic properties and less dimensional changes. That can be confirmed by this study, as reproductions of pieces of chewing gum in addition silicone had lower dimensional changes when compared to the reproductions in condensation silicone.

Anusavice affirms that there are five reasons for dimensional changes: polymerization shrinkage, loss of byproduct during the condensation reaction, thermal contraction due to temperature of the mouth and the environment, soaking when exposed to water or alcohol, and incomplete elastic recovery from deformation (Anusavice, Chiayi & Rawls, 2012). However, in this study, only three of these reasons may explain the dimensional changes of the silicones: the polymerization shrinkage, product loss during the condensation reaction or incomplete elastic recovery from deformation.

An important finding in this study was the dimensional change of the reproductions of the chewing gum. It ranged from 0.3mm to 5.06mm, in the case of reproduction in addition silicone, and 2.94mm to 5.36mm in the case of reproduction in condensation silicone. Note that the values of 5.06mm and 5.36mm were presented by reproductions of the same piece of chewing gum. However, the dimensional changes of the other reproductions were practically insignificant. The addition silicone can also be used for shaping the bitemarks as showed by Bush, Thorsrud, Miller, Dorion and Bush (2010).

The reproduction of the chewing gum has a great importance, since they are difficult to handle and may change over time. Through this study it became evident that, in the need for the evaluation of dental patterns in pieces of chewing gum, either of the silicones faithfully reproduce it. There are methods that can be used especially when there are no other methods available that produce more sophisticated impressions.

The findings also highlight the importance of disseminating the need to preserve evidences, such as chewing gum found at a crime scene. Often this evidence is present but neglected by authorities. Many are unaware of their potential value in identifying criminals and clarification of facts for justice.

5. Conclusion

According to the analyses performed, it was concluded that the molding technique of chewing gum and reproduction with both addition and condensation silicones is applicable in forensic routine. However, the expert conclusion will depend on the visible presence of bitemarks on chewing gum and its proper handling and storage, in order to prevent alterations.

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Conflict of Interests

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