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The Effective Tooth Brushing Parameter of Different Case Studies: A Literature Review

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Abstract: Tooth decay and non-carious cervical lesions (NCCLs) are common oral complications that deteriorates peoples' oral health, which without any proper understanding to mitigate the issues could eventually worsen the complications. The main objective in the journal review is to provide an overview on the effects of different configuration from both toothbrush and toothpaste as well as understanding the interaction between these tooth cleaning components', where the collection of selected journals are taken from ScienceDirect, ResearchGate and also Scopus Indexed Publications. In this review, the parameters that affect toothbrushes are; (the type of brushes head configuration, the diameter and stiffness), for toothpastes; (RDA- value, concentration, different abrasives) and for physical factors; (brushing loads, speed, temperature). Each of these parameters had effects onto the efficiency of tooth cleaning process. From this journal review, it is suggested to incorporate engineering-based journals regarding tooth cleaning efficiency to compare the findings from dentistry-based journals.

Keywords: Tooth Cleaning, Toothbrush, Toothpaste, Abrasion, Wear

1. Introduction

Tooth cleaning process is usually performed with the use of filament-based toothbrush and a toothpaste, constitutes of ingredients such as abrasives particle, binding agent, fluoride, flavoring agent and detergents. In removing the extrinsic stain from tooth surfaces, tooth cleaning component together with the physical factor plays a significant role that affects the plaque removal effectiveness.

In order to investigate the parameters that would affect the efficacy of tooth cleaning process that would lead to a better oral hygiene, it is crucial to understand how the components involved in tooth cleaning process interacts with each other and how each component along with its characteristics would affect the tooth cleaning process.

For instance, the characteristics of toothbrush itself may contribute to the effectiveness in tooth cleaning process such as the number of bristles in each tufts, number of tufts, stiffness and material of bristles and many more. Furthermore, toothpaste also plays an important role especially the abrasive particles present in it. There are different types of abrasive particles such as calcium carbonate, perlite,

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silica, sodium bicarbonate and many more. Each abrasive particles have their own unique properties. Physical factors such as the load applied, speed of tooth brushing, and the surrounding oral condition does contribute to the factor that could influence the tooth cleaning efficacy.

1.1 Oral Complications

Tooth decay is a global oral diseases that affects people who care less of their oral hygiene. The main factor that leads to dental caries is the accumulation of bacteria due to establishment of unremoved biofilm from teeth surface. The formation of dental biofilm begins with the Acquired Enamel Pellicle (AEP); its thickness ranges between 0.02μm and 1μm. It is a layer of protein that covers the tooth's enamel surface with proteins from the oral environment.

Studies have shown that AEP promotes the attachment of 1000 different bacteria species roughly 2 hours after being exposed to the oral surroundings [1]. The increase in biofilm thickness and its maturing towards dental plaque is due to the bacterial absorption on the AEP. Root cause of tooth degradation are because of continuous compositional changes of dental biofilm that also displays a complex structure. Therefore, eliminating the dental biofilm at early stage is crucial in oral care to prevent plaque formation and indirectly improves overall oral health [1].

Unrelated to caries, non-carious cervical lesions (NCCLs) is the loss of dental hard-tissue oral health complications at the cement-enamel junction, which could plagued up to 2/3 of the population [2]. It was first recorded in the literature in 1728. [3] Although remain unclear, the mechanism of NCCLs' formation appear to involve dental wear processes, such as abrasion, erosion and fatigue.

There has been a growing interest towards a better comprehension on the role of toothbrush, toothpaste and related tooth cleaning behaviors in dental wear as preventative oral care information becomes extensively available and numerous of at-home oral hygiene product due to toothbrushing abrasion and increasing number of patients retaining natural teeth into older ages. [2]

1.2 Anatomy of Tooth

Humans have twenty primary teeth. As time progressed, these teeth were substituted with 32 secondary teeth. The arrangement of mouth into two opposing arches of teeth enables the action of chewing. As shown in Figure 1, each arch has different type of tooth set that serves its own purpose. The incisor teeth are responsible for shearing; the canines are developed for holding prey and molars are utilized for chewing. The different surfaces of teeth are also explained in Figure 2. [4]

1.3 Tooth Cleaning Component

The toothbrush is a common oral hygiene device used to clean the teeth, gums and tongue. It comprises of a head with firmly grouped filament at the top of which toothpaste will be spread on it and also encourages the cleaning of the hard to reach zones in the mouth. There are three known type of toothbrush bristle hardness; which are soft, medium and hard with different bristle configurations which are the flat-trimmed-shaped bristles, rippled-, angled- and multilevel-bristled brush heads. In respect to the tip's shape, apart from the end-rounded tip, narrow and feathered bristles are also available. [2]

Toothpaste is a paste or gel based dentifrice to be used with a toothbrush to remove plaque or stain layer. It also enhances one's oral hygiene and aesthetics by improving the effect of mechanical scrubbing and delivers therapeutic agents to the oral cavity. [5] Toothpaste formula usually constitutes of both active and inactive components. The common ingredients of toothpaste are abrasive 10–40%, humectants 20–70%, water 5–30%, binder 1–2%, detergent 1–3%, flavor 1–2%, preservative 0.05–0.5%, and therapeutic agent 0.1–0.5%. [6] The active ingredients such as anti-caries, desensitizing and anti-microbial agent are responsible for the therapeutic benefits of toothpaste whereas the inactive ingredients such as abrasive material, humectant system, detergent and also flavorings are responsible for the mechanical action, preserving the slurries consistency and also giving the toothpaste either a natural or an artificial taste.

2. Materials and Methods

2.1 Methods

In establishing a comprehensive overview, selection of journal articles that focused on the parameter of both toothbrush and toothpaste that would affect the efficacy of tooth cleaning process were systematically analyzed. Data base search was performed on two well established data bases; ScienceDirect and ResearchGate. Keywords such as "tooth cleaning", "toothbrush*", "toothpaste", "abrasion" and "wear" were included in the search options and the scope was restricted to academic papers in English, including recent publications from year 2001 to 2019.

In the first step, the terms "tooth cleaning", "toothbrush*", "toothpaste*", "abrasion*", and "wear*" were being searched. In the second step, the title, abstract and keywords were manually checked and selections were refined by removing all non-related papers. In the third step, the related papers were searched through exploration of references and citations of already selected papers. In the fourth step, in covering all experiments regarding tooth cleaning process, the searched paper were included with terms such as "effects", "variables", and "configurations". Lastly, a final refinement was made predicated on full texts and sorting of all papers were also predicated on full texts.

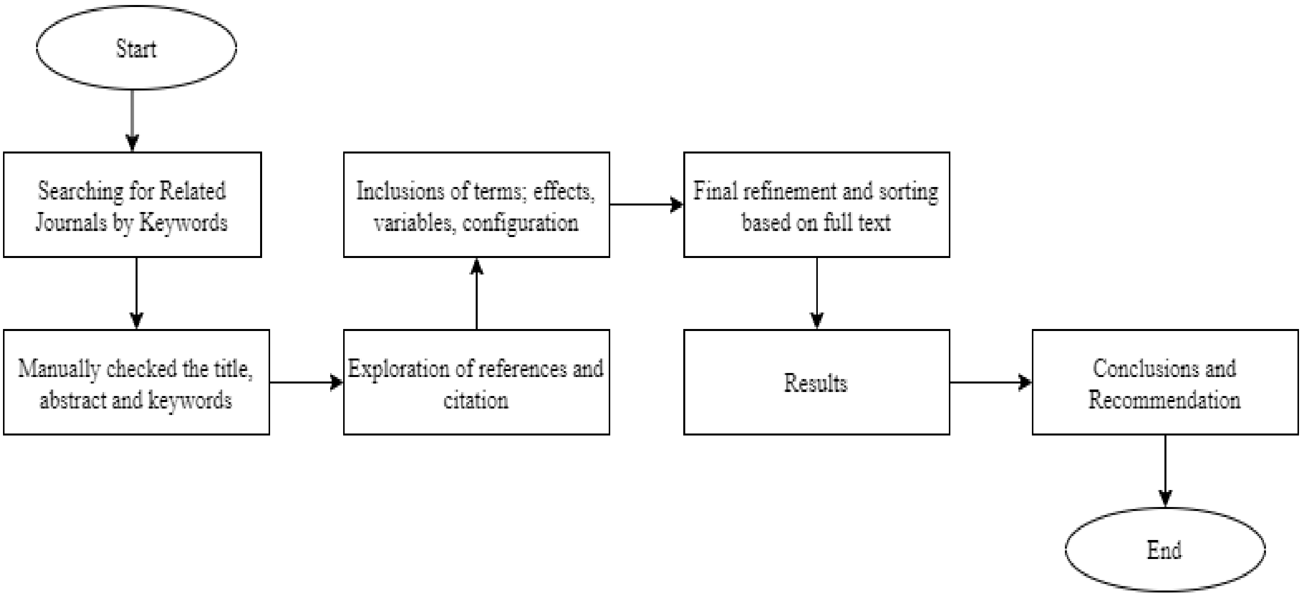

Figure 1: Flowchart of Project's Methodology

3. Results and Discussion

The significant parameter from the tooth cleaning components from selected journals were identified. The overall data and results collected from the searched and selected papers were being critically discussed.

3.1 Toothbrushes' Parameter

3.1.1 Types of Head

(Turssi C.P. et al., 2019) had conducted a study regarding the effects of toothbrush filament configuration on the development of simulated non-carious cervical lesions (NCCLs). In (Turssi C.P. et al., 2019) study, the ordinary/flat-trimmed toothbrush had produced most volume loss (3.81 mm^3) in comparison to rippled-, cross-angled- (rubbers), cross-angled- (flex-head) and feathered (2.56 – 2.92 mm^3). These findings may be partially elucidated by the nylon filaments' diameter in the ordinary toothbrush (0.35 mm) which was larger than the other toothbrushes filaments diameter (0.02mm to 0.12 mm). It was to be assumed that larger filament diameter may have transported a greater toothpaste's quantity even though there is no agreement on the function of filament diameter in entrainment of abrasive particle on dentin wear.

Based on (Turssi C.P. et al., 2019) findings, there is a significant relation between lesion shape and toothbrush configuration, with feathered toothbrush presenting the lowest prevalence of wedge-shaped lesions (3.1%) and the rippled toothbrush and that having rubber bristles displaying the highest frequency of wedge-shaped lesions. The ordinary and flex head toothbrush had resulted most in cup-shaped lesions. The least frequent lesions, regardless of the configuration of the bristles are the flat type lesions. One can expect that the use of feathered toothbrush may be a beneficial choice over the others, assuming an additive impact of occlusal load which in respect to the lesion shape where wedge-shaped lesions accumulate larger stress under occlusal loading in contrast to cup shaped lesions. However, the influence of filament arrangement on abrasion of exposed dentin and the development of NCCLs are still limited to studies which may not represent the behavior of the native root surface.

3.1.2 Filaments' Stiffness and Diameter

(Wiegand A. et al., 2009) found out that the filament diameter where the decrease in filament diameter leads to an increment in dentin loss as shown in Figure 4**.** Except for control group (RDA 10), toothbrushes with lower filament stiffness caused higher dentin wear in all toothpaste slurry groups (RDA 20, 50 and 100). In comparison to Harte and Manly results who revealed that the abrasion of dentin increased along with toothbrush stiffness, the results by (Wiegand A. et al., 2009) demonstrated the opposite for eroded dentin. The observation might be explained by the soft bristles' greater flexion causing an increment in duration and bristle contact area to the brushed surface which results in an increasing amount of abrasives moving over the surface. Furthermore, assumptions regarding the efficiency in capturing abrasives by brush might be affected by the amount of filaments per toothbrush as the diameter of filament increased with the reduction in filaments' quantity.

As for (Oliveria et al., 2014) studies in analyzing the effects of different toothpaste abrasives on the bristle end-rounding quality of toothbrushes, revealed that the deterioration of bristle tips through Kruskal-Wallis tests showed significance differences after the brushing cycles**.** Through Mann-Whitney test, it was showcased that the toothbrush in group Soft (S) exhibited a more rounded bristle tips morphology followed by with those in group Extra Soft (ES) and Hard (H). (Oliveria et al., 2014) revealed that all toothbrushes demonstrated less rounded bristle tips through Mann-Whitney test. It was found out that the soft filament brush produced the best filament tip morphology, exhibiting better quality control in comparison to other toothbrushes. As for hard filament toothbrush, it showed the worst tip morphology which may injure the hard and soft tissues. The various abrasive toothpastes did not affect the decline of filament tip in soft (S) and hard (H) toothbrushes, except for extra-soft (ES) toothbrush. The possible explanation is due to the less stiffness nature in extra-soft filaments compared to soft and hard filaments.

Nonetheless, conventionally, it has been taken into account that the relation between the toothbrush bristle diameter and abrasion was inferior to the relation between toothpaste abrasivity and abrasion. (Wiegand A. et al., 2009) has revealed that eroded dentin's abrasion is majorly influenced by the toothpaste abrasivity than by the toothbrush bristle diameter. In the case study of (Oliveria et al., 2014), the effect of different filament tip morphologies influenced by the abrasives depends most on the filament diameter for they revealed that the extra-soft filaments have a smaller diameter than the soft and hard filaments.

3.2 Toothpastes' Parameter

3.2.1 RDA Value

(Wiegand A. et al., 2009) performed a linear regression analysis to identify the impact of toothpaste slurries abrasivity and toothbrush filament diameter on abrasion of eroded dentin,. Data revealed that as the RDA-value of toothpaste slurries increases, the dentin loss also increases as depicted in Figure 5. The observation made by (Wiegand A. et al., 2009) that the increment in abrasion of eroded dentin along with the RDA-value validates Hooper et al. results where toothpaste with RDA 189 caused more wear on eroded dentin than abrasive toothpaste with RDA 85. The lower abrasivity toothpastes might be assumed only to abrade the outermost feature of the demineralized dentin and the unprotected collagen matrix. The deeper section of the erosively changed surface also seems might be affected by brushing with the use of high abrasives.

3.2.2 Concentration

From the studies of (Franzo D. et al., 2010) the average enamel and dentin wear values are presented in Table 1. The mean enamel wear ranged from 0.3 to 0.11 μm and there were no significant differences ($p > 0.05$) between concentrations within and between toothpaste treatments. The mean dentin wear ranged from 0.28 to 27.63 μm and there was in general significant differences between some concentrations particularly as the difference in concentration increased within each toothpaste treatment. There were significant differences for mean dentin wear between Toothpastes A and B at the concentrations 33.3, 50, 65 and 80% (w/w). By using simple linear regression, a straight line was fitted to the logarithm since

$$\log(c(t)) = \log(A) - \lambda t.$$

Considering other values of T enables dentin wear to be calculated at other time points and this is shown in Figure 6 for both toothpastes.

3.2.3 Different Abrasives

According to (Oliveria et al., 2014) studies on the effect of different toothpaste abrasives on the filament tips, toothpaste 3 (calcium bicarbonate, calcium carbonate and hydrated silica) demonstrated the highest decline in the filament tip morphology of ES, followed by toothpaste 5 (calcium carbonate) and 1 (silica). The wide range of abrasives in toothpaste 3 may elucidate the increment in bristle's tip morphology decline of extra-soft bristles for the interaction of different abrasives can enhance the RDA value of toothpaste 3. Determinant such as abrasive particles' type, size and shape significantly influence the friction force produced by the toothbrush. These determinants had affected the toothpastes' RDA values and could explain on the effects of the diversity of changes to the filament tip morphologies as observed in (Oliveria et al., 2014) study with the same abrasives.

3.3 Physical Factors

3.3.1 Brushing Load

As for the investigation of the effects of different brushing loading by (Parry J. et al., 2007) on abrasion of enamel and dentin tissue loss, the higher the value of brushing load, the value of mean abrasion depth also increases. Nonetheless, only the enamel samples brushed with $Ca_2O_7P_2$ and dentin samples brushed with $CaCO_3$ displayed consistent statistically notable difference. There is a tendency for the increment in brushing loads in conjunction with increment in wear, which confirms the studies on the effects of brushing force by Kon M. et al..

3.3.2 Speed

As for the investigation of brushing speed's effects by (Parry J. et al., 2007), it was revealed as demonstrated in Figure 4-9, there is a significant difference, though small, in average abrasion depths for enamel after brushing at 60 rpm with slurries based on $CaCO_3$ or $Ca_2O_7P_2$ when compared to 120 rpm or 180 rpm. At the higher speed of 120 rpm and 180 rpm, there was no distinguishable outcome though on abrasion depths.

3.3.3 Temperature

The increment in temperature leads to an increment in abrasivity when the enamel were brushed with slurries of Zeodent 113 Silica and Sturcal CaCO3 as shown in Figure 4-10. From the brushing temperature studies of (Parry J. et al., 2007), the increased in enamel abrasion is in conjunction with the rising temperature for silica and calcium carbonate abrasives. This may be due to the reduced viscosity of the abrasive slurry affecting particle distribution as temperature elevated.

Another significant finding from the (Oliveria et al., 2014) study was the difference in filament tips' deterioration caused by toothpaste 5 (calcium carbonate) for the substance produces less abrasive than silica and pyrophosphate in study by (Parry J. et al., 2007). Given that (Oliveria et al., 2014) had conducted their study in a tropical region with high temperature, the temperature possibly caused the highest decline in the filament tip morphology in the subgroup of extra-soft toothbrush brushed with toothpaste 5 (calcium carbonate) and the least decline in those brushed with toothpaste 4 (pyrophosphate and silica).

4. Conclusion

There is some gap which needs to be addressed in order to yield a better comprehension on the matter of subject. The recommendation consist of reviewing at least five or more related journals for each discussed parameters. This is to broaden the results of different researchers so that more input can be collected while comparing the different results from their experiments. This will definitely produce a more detailed and refined discussions. In addition, it is preferable to include journals from the engineering-based journals rather than dentistry-based journals so that a comparison of results can be made between these two unrelated fields.

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Appendices

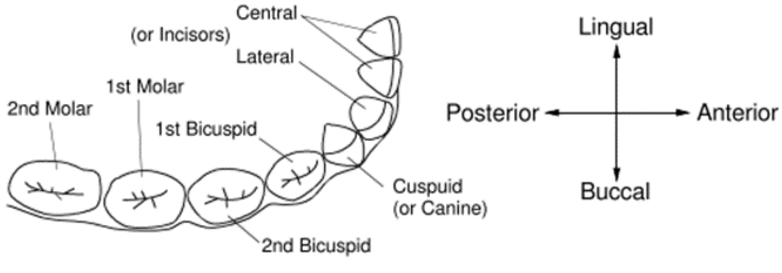

Figure 2: The different types and surfaces of teeth [4]

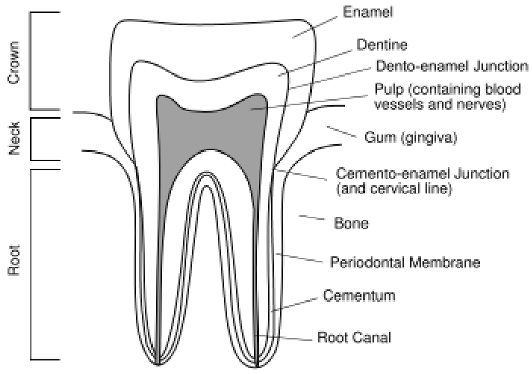

Figure 3: The schematic section of a tooth [4]

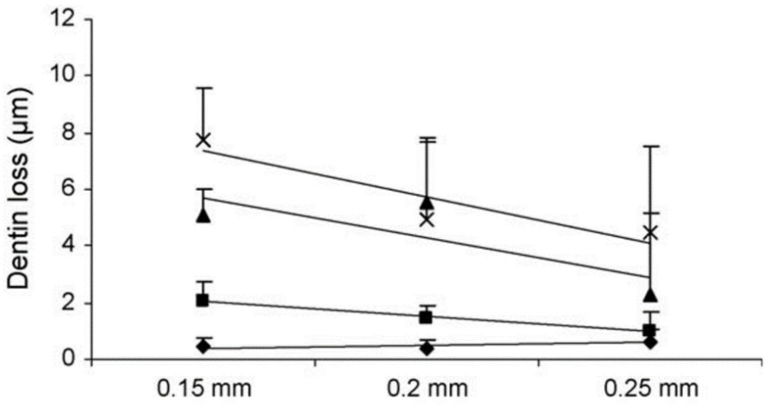

Figure 4: Dentin loss (average ± S.D.) and regression lines for dentin loss with respect to filament diameter for four diameter RDA-values: ♦= RDA 10 ($r^2 = 0.05$, $p = 0.3$), ■ = RDA 20 ($r^2 = 0.38$, $p = 0.0014$), ▲= RDA 50 ($r^2 = 0.21$, $p = 0.024$) and x = RDA 100 ($r^2 = 0.23$, $p = 0.018$). [7]

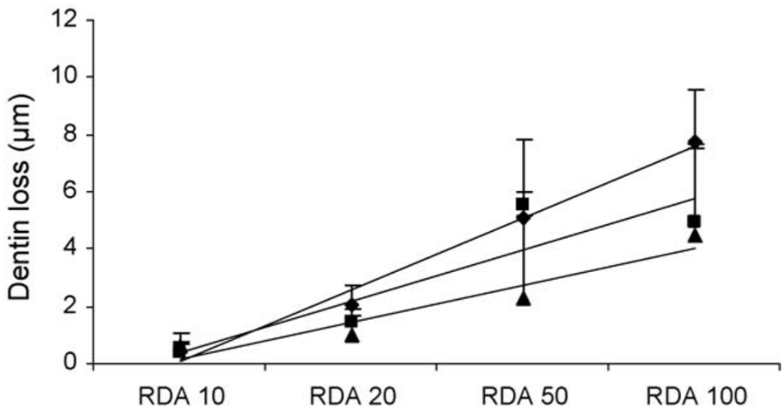

Figure 5: Dentin loss (average ± S.D.) and regression lines for dentin loss with respect to RDA for three dissimilar diameter: ♦ = 0.15mm ($r^2 = 0.85$, $p < 0.0001$), ■ = 0.2 mm ($r^2 = 0.42$, $p < 0.0001$) and ▲= ($r^2 = 0.36$, $p = 0.0003$) [7]

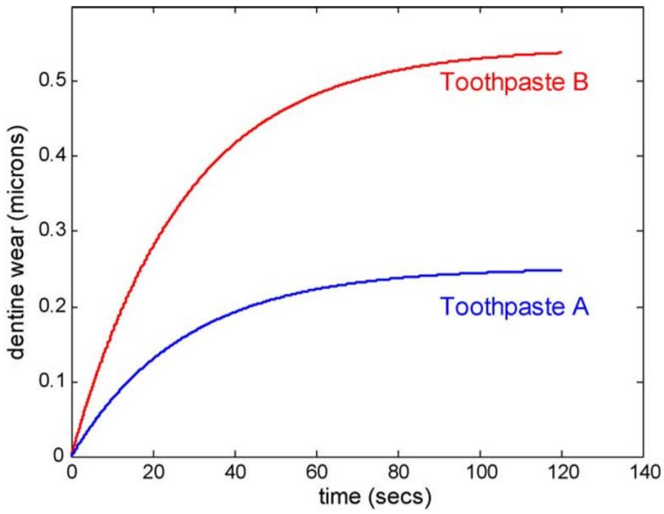

Figure 6: Calculated dentin wear during experiments [8]

Table 1: Enamel and dentin wear [8]

Concentration (w/w, %)	Wear (µm)(S.D.) after 3000 brushing cycles (1200s)			
	Enamel		Dentin	
	Toothpaste A	Toothpaste B	Toothpaste A	Toothpaste B
0	0.06 (0.05)	0.06 (0.05)	0.28 (0.16)[a]	0.28 (0.16)[a]
14.4	0.05 (0.09)	0.03 (0.02)	1.05 (1.05)[ab]	2.94 (1.08)[a]
20	0.03 (0.02)	0.07 (0.01)	2.75 (0.26)[ab]	5.26 (0.87)[ab]
33.33	0.08 (0.07)	0.07 (0.07)	4.23 (1.88)[bc]	10.31 (1.87)[bc]
50	0.08 (0.07)	0.06 (0.03)	6.89 (1.93)[cd]	14.04 (0.79)[c]
65	0.11 (0.12)	0.07 (0.03)	10.19 (2.87)[de]	21.81 (1.38)[d]
80	0.11 (0.05)	0.08 (0.06)	12.73 (2.33)[e]	27.63 (8.36)[d]

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