Comparison between digital and conventional occlusal indicators

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Background and objective: Occlusal adjustments are an integral part of any dental restorations; any occlusal discrepancy will affect the masticatory system generally and the occlusal scheme specifically. This unsolved problem may cause restoration and/or tooth fracture, also may result in TMJ problems.
The objective of this study is to find out the best material and method for occlusal adjustment.
Methods: An upper metal cast with a lower resin cast was made and mounted to an apparatus that moves like the mandibular movement during mastication. Four different occlusal indicators (articulating paper 100 and 40 microns, OccluSense (digital occlusal analysis device) with 60 micron and Articulating silk 80 micron) were used to evaluate their occlusal adjustments.
Results: Test of variance revealed that a highly significant difference between the articulating paper 40 micron with the other indicators except for 100 micron articulating paper, while there was a significant difference between the OccluSense and Articulating silk.
Conclusion: The OccluSense digital device significantly was the most accurate occlusal adjusting indicator, followed by articulating silk, while the articulating paper 40 micron was the least accurate one.
key-word: OccluSense, Digital occlusal analysis, Articulating paper, Articulating silk

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Introduction

Dental occlusion is defined as "the static relationship between the incising or masticating surfaces of the maxillary or mandibular teeth".[1]

What makes the occlusion important is that it is a part of the masticatory system, so any change in occlusion can lead to a change in the temporomandibular joint and masticatory muscle but this effect is not essentially done inversely, and there will be a distortion of the teeth then in response it may affect the periodontium. The usefulness of 'occlusion' in dentistry is dependent on the interactions within these linked biological and mechanical systems. When it is realized that nearly every type of dental treatment can cause occlusal disturbance, the necessity to define what makes appropriate occlusal management becomes obvious and apparent.[2]

During clinical examinations, the existence of occlusal discrepancies may not be visualized; consequently, additional occlusal analysis is needed. Occlusal markers are essential in identifying occlusal problems.[3]

A number of occlusal markers are already present, and accurate occlusal indicator choosing offers essential data about occlusion improvement. Occlusal indicators can be separated into two categories: qualitative (traditional) and quantitative (digital).[4]

Because of their easiness of usage and low price, qualitative-type occlusal markers are most often utilized in clinical dental practice. Only the location of the occlusal contact points is attainable using qualitative approaches; their timing and relative intensity

cannot be established. However, other researchers contend that the apparent marking's size and color might be used to gauge the intensity of the contacts.[5-8] Articulating paper; "is ink-coated paper strips used to locate and mark occlusal contacts.1 The most frequent occlusal indicator, which simply records the contact size and location and cannot measure the occlusal forces produced, the number of contacts made, or their sequence.[9] The primary drawbacks of articulating papers are their thickness, readily damaged by saliva, and have a base material that is somewhat rigid, more pseudo contact marks are created,[10] also its matrix is damaged as ink is lost when articulating paper is repeatedly occluded into, therefore the articulating paper is non -repetitive occlusal indicator material.[11]

In a study to determine a method for occlusal adjustment, they concluded that: subjective assessment is a poor clinical method for assessing the relative occlusal force strength of tooth contacts.[12] After that in 2018 a study was conducted to evaluate whether dentists can accurately estimate occlusal loads by 2 visually analyzing articulating paper marks, the results also revealed that subjective methods are incapable to visualize high occlusal force.[13] another study done in 2020 showed the same result.[14] Another occlusal indicator is Bausch articulating silk, which is available with 80µm thickness that made from high-quality natural silk; which is made of fibrils, which are tube-shaped protein structures with a high color reservoir capacity due to their content .15 Since silk strips are frequently filled with dye, they can be used on the same patient multiple times.[16] Unfortunately silk strips lose their marking capacity after the stain components have dried.[15]

Similar to healthcare, dental care is increasingly depending on biometric and digitized workflow technology to direct clinicians during diagnosis procedures. Through being capable of "seeing" information that analogue technologies and conventional approaches cannot supply, this is an effort to support patients with more efficient management.[17]

A novel computer-assisted device that can precisely reveal details on the location, intensity, and frequency of occlusal contacts has been introduced to the public as digital occlusal assessment. This technology has significant promise as a clinically diagnosing screening tool for occlusion because of how quickly and precisely it can determine the dispersion of tooth contacts. Much of the occlusal state's world is unseen, and many of the most effective tooth contacts in occlusion are so minor can be observed using computed tomography technology in the manner of a digitized occlusal analysis apparatus.[18]

An innovation in 2019 was the OccluSense system. This uses a thin 60µm thickness, flexible, self-ink red color-covered computerized pressure sensor to identify the occlusal contacts and assess the occlusal pressure. The measured data are collected and delivered to software that allows individuals to visualize the occlusal contacts in color and occlusal pressures in percentages. Additionally, occlusal issues with static and dynamic occlusion can be managed using the device's analytical information's.[17, 19]

In a study, compared the efficiency of the T -scan device and the OccluSense device. The OccluSense sensor is covered with ink to label the teeth, allowing force contact in the data to be readily identified to the ink on the teeth opposite to T-scan which its sensor is not covered with ink also it is thicker than OccluSense. It was concluded that both devices ought to measure force in ways that are very close and similar to each other.[17]

In a comparative study of three techniques used for occlusal adjustment, the results showed that the articulating paper and intraoral 3D scanner showed no occlusal deficiencies, just the digital device revealed occlusal interferences and occlusal discrepancy.[20]

Methods:

1. Machine:

A semi-adjustable (Hanau articulator) was used (Figure 1) and modified to construct a device that mimics the mandibular movement in human beings during the mastication process as shown in (Figure 2).

The criteria of the machine:

The normal (perpendicular) load on the two jaws was 10 kg.

The bilateral movement between the two jaws was about 3 mm in each direction in the horizontal plane.

The speed of the curvilinear motion was selected as 2.27 cycles per minute.
Two aluminum blocks (Cast holding blocks) were manufactured to hold the casts in place. The upper member which is the movable part holds the upper metal cast and the lower member holds the lower resin cast.
The loading block which is a spring-loaded aluminum block used to apply the desired load on the lower resin cast during masticatory movement through two pre-calibrated springs to allow grinding of the lower resin teeth during masticatory movement.
The block also holds the cam housing which is designed to rotate the upper member of the articulator in the horizontal plain in an elliptical form as shown in (Figure 2).

For the sake of defining the effect of operating the device factors of speed with load applied had been taken in consideration knowing that the movement is almost similar to human. To find equivalence to the human will be as follow:

Human parameters			Device parameters		
Force [Kg.]	Lateral movement mm	Movement frequency [cycles/minute]	Force [Kg.]	Lateral movement mm	Frequency [corresponding cycle]
50	6	50	10	6	250

Figure 1: Semi-adjustable Hanau articulator

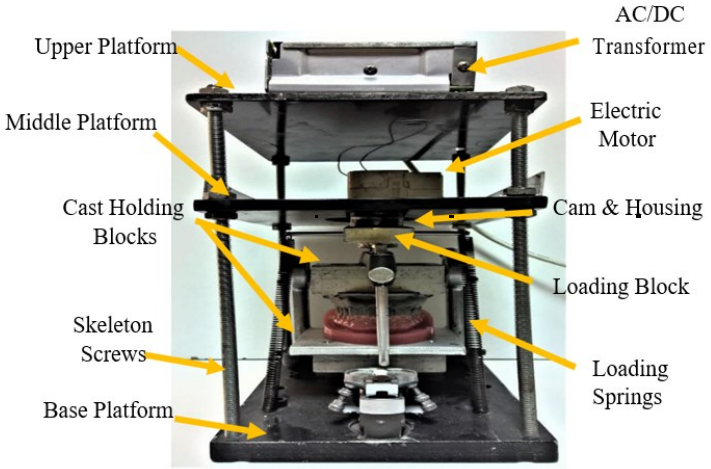

Figure 2: Design of the machine

The normal cycles per minute is up to 50, the load is 50 kg, and sideways movement is 6 mm, so in order to mimic the mentioned parameters in the human being a 50 cycle in a normal human being will be equal to 250 cycles on the machine.

For equivalence to a human being, it is required to (50)/ (2.27) = 22.02 times the human being as the time required under identical conditions, while for total equivalence the ratio will be 110.13 times.

To find out the machine operation corresponding to human mouth movement following procedure shows these findings:

As each cycle by machine takes 0.44 minutes equals to 26.4 seconds meaning the speed will be 2.27 cycles per minute.

So, in order to reach 250 cycles on the machine, it will require 110 minutes which is the same as 50 cycles for a human being in 1 minute. The operating time for the machine will be 1 hour and 50 minutes for 250 cycles. For 2500 cycles the machine should be operating 18 hours and 20 minutes.

2. Upper cast:

An upper cast has been scanned with a 3D scanner (SHINING 3D-DS-EX), for 10 minutes - then it was sent to (Exocad) software in order to remove any defect that might occur during scanning, then converted to an SLT file and it was sent to (Riton Dual-150 metal 3D printer) to make a metal upper cast by laser adding metal powder particle, later the cast was placed in a (Riton oven) for 6 hours to minimize stresses due to the laser sintering process and to achieve a solid form of the cast then the cast left to cool down, finally the irregular particles were removed by a NAIS cutting disk. In order to achieve a rough occlusal surface, the upper metal cast was sandblasted with 250-micron particle size by (Renfert- Basic eco)5 machine, to enhance the grinding of the lower cast without affecting the occlusal topography of the metal upper cast model. (Figure 3 a)

3. Lower cast

A lower cast has been scanned with a 3D scanner (SHINING 3D-DS-EX) and the same process was followed to make a resin lower cast, except the printer was different ; since the lower cast is made from resin, printing was done by a (Microlay SA system versvs 385) printer which will form the resin cast by digital light processing technology and constructing a resin model by polymerizing resin (solidifying) with light, form three dimensional resin model weight 62.1 gram.(Figure 3 b)

Materials used for occlusal registration

OccluSense (digital occlusal analysis device 60µm thickness/BK5025) by Bausch (Figure 4).

Arti-Check micro-thin Articulating paper (Plastic dispenser horseshoe /BK17), two-sided blue color by Bausch company (40µm).

Articulating silk with progressive two-sided blue color transfer (BK877) (3m/80µm) by Bausch company.

Articulating paper with progressive two-sided blue color transfer (horseshoe /BK53) by Bausch (50 sheets /100µm).

Figure 3: a. Upper metal cast **b. Lower resin cast**

5. Operating the device
The first occlusal adjustment indicating material used was OccluSense (Digital occlusal indicator) the sensor with the handle was placed between upper and lower casts to record the static occlusion, once the indicating colors were copied on the occlusal surface of the lower teeth then it was removed from the device and scanned with (Trios 3 Pod,3 shape) wireless scanner, in order to get a 3D picture of the area marked by the occlusal indicator on the occlusal surface of the teeth, After the scanning ,the marking spots on the cast were removed by alcohol and dried with tissue, all the other occlusal indicator has been used in the same manner. This procedure was repeated every 2500 cycles.

6. Measuring the marking areas
3 Shape Ortho System software has been used to measure the contact areas. Before starting the measurements, the software was calibrated in order to achieve the correct measurements. After that, the outer margin of every colored area on the occlusal surface of the teeth was measured in millimeters. (Figure 5).

Figure 4: OccluSense (digital occlusal analysis device)

Figure 5: Measuring the colored area by OccluSense device

A Shapiro–Wilk normality test was conducted to test intergroup normality as samples taken didn't approach 50 cases, as shown in (Table 1) the data distributed normally for all intergroup because the P>0.05, when its non-significance it means the data distributed normally. Obtained data by the four materials indicated higher significance for OccluSense the digital occlusal analysis device (Figure 6)
With the support of (Figure 6) it observed that all supporting better distributed with OccluSense cases than other materials, while the articulating paper 40µm showed worse characteristics of uncertainty cases, revealing that less thickness material present worse performance than thicker ones may be due to material composition.
Performing ANOVA test for variance shows clear variance with a very high significant difference between the four types under test, this test compares the mean between variables, the mean of OccluSense is 3.29 scored less magnitude as an indicator for high accuracy and sensitivity during test opposite to the articulating paper 40µm scored highest magnitude 7.96 as an indicator for least accuracy and sensitivity during use. According to the standard error because all the numbers are low it means that there is homogeneity, there is a significant difference between the 4 categories with a P value 0.000. As shown in (Table 2).

Table 1: Tests of Normality

	Type of material	Shapiro-Wilk		
		Statistic	df	Sig.
area Marking	Articulating paper 40µm	.916	8	.400*
	OccluSense 60µm	.959	8	.800*
	Articulating silk 80µm	.926	8	.481*
	Articulating paper 100µm	.961	8	.817*

*. This is a lower bound of the true significance.

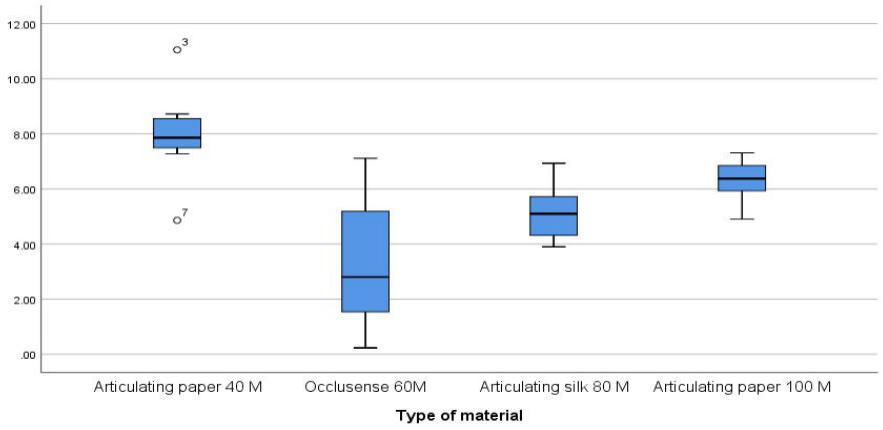

Figure 6: Distribution of data

Table 2: Test of Variance

Type of material	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum	F-value (p-value)
Articulating paper 40µm	8	7.9650	1.71091	.60490	4.86	11.05	12.184 (0.000**)
OccluSense 60µm	8	3.2975	2.36883	.83751	.23	7.11	
Articulating silk 80µm	8	5.1388	1.02003	.36064	3.90	6.93	
Articulating paper 100µm	8	6.3138	.75470	.26683	4.90	7.31	
Total	32	5.6787	2.29851	.40632	.23	11.05	

* Significant at level (p<0.001)

From (Figure 7) the mean average for all teeth with a continuous run of tests indicates reasonable results with OccluSense better than other materials, the Articulating paper 40μm shows lower performance results with a higher magnitude that puts the type at a lower rank of reliability. So, the OccluSense is the best material for precise and accurate marking areas and a more dependable method for occlusal adjustment.

Post-hoc analysis results presented in (Table 3) give an indication of significant difference degree of each material results corresponding to the remaining materials, The OccluSense is a highly significant difference from both articulating papers 40μm and 100μm while there is no highly significant difference compared to the silk material. The 40μm articulating paper is no highly significant different from the 100μm articulating paper, what was interesting is that there is a significant change between silk material 80μm with the OccluSense 60 μm, while there is no significant difference with articulating paper 100μm.

Table 3: One way ANOVA to discover the difference between mean and value of the groups.

Type of material	Type of material	Mean Difference	Std. Error	Sig.
Articulating paper 40μm	OccluSense 60μm	4.66750*	.79642	.000
	Articulating silk 80μm	2.82625*	.79642	.001
	Articulating paper 100μm	1.65125*	.79642	.047
OccluSense 60μm	Articulating paper 40μm	-4.66750-*	.79642	.000
	Articulating silk 80μm	-1.84125-*	.79642	.028
	Articulating paper 100μm	-3.01625-*	.79642	.001
Articulating silk 80μm	Articulating paper 40μm	-2.82625-*	.79642	.001
	OccluSense 60μm	1.84125*	.79642	.028
	Articulating paper 100μm	-1.17500-	.79642	.151
Articulating paper 100μm	Articulating paper 40μm	-1.65125-*	.79642	.047
	OccluSense 60μm	3.01625*	.79642	.001
	Articulating silk 80μm	1.17500	.79642	.151

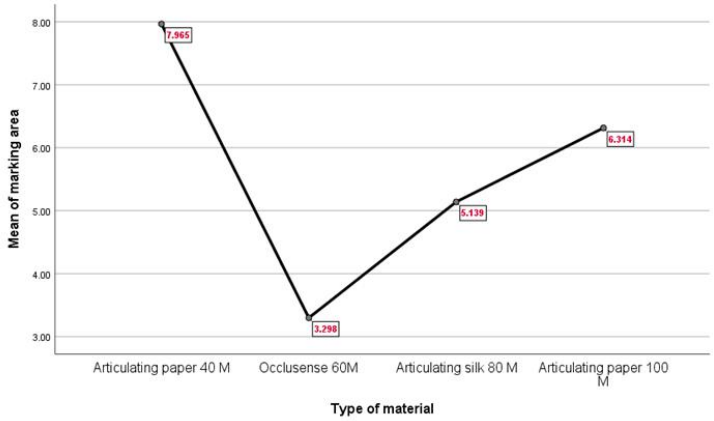

Figure 7: Mean of average marking areas for the four materials

Discussion

The current study showed that the digital occlusal analysis device OccluSense is the most accurate material for determining occlusal contact and the best method for occlusal adjustment while the least accurate was the articulating papers, this may be due to that the articulating paper painting all the contact areas, this finding was also concluded by Qadeer et al when they correlated the applied force with the marked size area by using the articulating paper and digital device for occlusal analysis. It was revealed that occlusal surface morphology, rather than the amount of applied occlusal load, becomes the most important factor in deciding mark size, also found that the qualitative materials are not very accurate for occlusal adjustments procedures.[8]

A similar result was found by other researchers, when using articulating paper and exerted load starting from 25N till 450N, there was no evidence of a linear correlation among applied load and articulating paper indicator mark area.[5]

Millstein and Maya declared that the manufacture of occlusal indicator materials is controlled by the uniformity of thickness, surface deposition of inks, transferring media, size of indicator, plastic deformation and hygienic manufacturing procedures, the composition of indicators containing waxes,[10]

oils, pigments and solvents. Their research showed significant differences in thickness, color and plastic deformation of articulating paper and films, they proved that areas increases as the material thickness increases except in one case because of ink and material composition.[21]

In a comparative study between applied loads to the quantity and size of paper marks produced using thick and thin articulating papers, it was found that variations in paper thickness have an impact on the size and quantity of marks produced, the thicker articulating paper the more marking area. Also found that , the qualities of the bulge, the kind of dye, and the thicknesses of the backing affect the form of marking.[6]

All these findings are completely supporting current study that 60µm digital occlusal analysis, silk 80µm, articulating paper 100µm follows the trend except 40µm. With the digital device is more trustworthy for determining mark areas.

Forrester et al found that silk are a more reliable material in determining occlusal contact for occlusal adjustment unlike articulating paper and digital occlusal analysis device which affect on the neuromuscular function during occlusion. However, T-Scan thickness close to silk, but it was, though, significantly more plastic compared

to the other indications and stiff in compression, limiting its capacity to adapt to the blocked surfaces.22 According to our study the OccluSense is more accurate than the t-scan and has less thickness as seen in results that had better performance than the silk material recommended by Forrester study.

The most accurate occlusal indicator that determines the exact and precise location of the marked area without requiring subjective interpretation is the digital occlusal device.[5, 8, 12, 14]

In contrast, a study done by Dias et al suggested that the subjective method is more accurate than the digital one. They claimed that recording contacts on a stiff and thick digital sensor may not be regarded as the best technique for determining true intercuspation. This adverse finding to most other research may be due to the varying thicknesses of the recording materials complicated a real comparison and distorted the findings of Dias study. Also mentioned that a thickness of more than 60 μm might enlarge the markings and have a significant impact on contact impression, interarch position, dental intercuspation, and even movement reproductions.[23]

In another research found that the T-Scan system can accurately record the amount, sequencing, dispersion in the arches, intensity, and duration of the length of the occlusal contact, but it was unable to properly determine the position of the contacts on the tooth occlusal surface or their area size.[11] Based on these observations, it is advised that the sensor be associated with carbon paper during the occlusal contact recordings.[24] In our study the OccluSense device overcome this short come of the t scan that it contains ink coated sensor. Again, the same recommendation was made by other studies.[25-27]

Conclusion

The OccluSense digital occlusal analyzer device was the most accurate , precise and minimize subjective errors followed by silk, if the load is not a matter, the silk is more practical in general dental practice, while the articulating papers is not recommended for precise occlusal adjustment.

Conflict of interest

The author reported no conflict of interests.

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