**Introduction:** Over the years, occlusal analysis has been a matter of guess work. Occlusal indicators are widely used in dental treatment to measure tooth contacts that occur during occlusion. They are important tools in locating interference and refining occlusal contacts during prosthodontic rehabilitation.[1] Aids such as articulating paper, waxes, pressure indicating paste are used when the dentist has to assess and balance the occlusal forces. The accurate measurement of tooth contacts can provide valuable information for diagnostic, treatment or prognostic purposes. The accuracy of these indicators is essential for the establishment of occlusal harmony.[2]

Occlusal indicators can broadly be divided into two categories based on their measurement capacity. Qualitative indicators, such as articulating paper and articulating silk, are limited in measurement to only the location and number of tooth contacts[1]. These are the most commonly used indicators because of their low cost and ease of application. Quantitative indicators, on the other hand, include electro-optic and resistive techniques such as the T-Scan pressure measurement system. These indicators come with the added capability of measuring the time and force characteristics of tooth contacts but are more expensive.[1]

It has been advocated in textbooks on Occlusion [4,5,6,7,8] that the articulating paper mark area is a representative of the load contained within the mark. While using the articulating paper we tend to assume that a vivid occlusal contact is the location where a large occlusal force has been applied.[9] Articulating paper mark appearance describe that large and dark marks indicate heavy load, and that smaller and light marks indicate lesser loads. Additionally, the presence of many similar sized marks spread around the contacting arches is purported to indicate equal occlusal contact intensity, evenness, and simultaneity.[10] However, limited literature exists to clinically correlate and confirm these findings. By employing articulating paper as a force measurement device, we as clinicians, will miss seeing properly the occlusal force, occlusal contact intensity, evenness, and simultaneity.[9] Hence, this proposed experiment design was done to determine if a relationship exists between the occlusal load applied and the size of the markings produced from tooth contact when a clinically used dental articulating paper and T-scan is interposed alternatively.
**Materials and Method:** Bausch 40μm micro-thin articulating papers and T-Scan III sensor an ultra-thin (.004”, 0.1 mm), were used. The articulating paper was tear resistant and coated with liquid colors on both sides. The special color coating with liquid colors consists of many color-filled microcapsules. Even the slightest masticatory pressure can cause the capsules to burst and thus release the distinctly visible color. The T-scan system is composed of a sensor, handle and cable, system unit, and software that detects patient’s occlusal forces. The handle’s attached USB cable is then connected directly to the computer via the USB port.

**Mounting of metal dies and contact procedure:** Occlusal loads on articulating paper mark was evaluated on a solid metal die with no soft tissue components. Vertical loading was accomplished by designing a cast anchoring apparatus that attached the metal dies to the metal jig. The metal dies were secured to the metal jig by means of machined rods with alignment holes that ensured precise alignment of the maxillary and mandibular casts prior to testing. The recording materials—articulating paper and T-Scan III were placed sequentially on the occlusal surface of the mandibular teeth of the model.

**Methodology:** Preliminary loading of casts was performed once to properly mate the casts and secondly to ensure that the overshoot of load cell was an acceptable values. Then, the Bausch articulating paper thickness of 0.04mm, red surface occluding the maxillary cast and blue surface occluding the mandibular cast was held in place between the casts. The loading began before the dies were intercuspated until complete intercuspation at 25N loads. The readings on the displaying unit were recorded before returning to zero position, to release the load. This procedure was repeated twice more, each 3-tap trial comprised one test. Next, the paper markings left on the maxillary and mandibular casts was photographed with a 10 megapixel digital camera. The load was gradually increased from 25N to 450N, and the entire process was repeated.
Recording procedure using T-Scan III- Prior to recording, the handle with a sensor and arch support was placed between the maxillary and mandibular metal die. The sensor was placed in such a way that it aligned centrally with the midline of the maxillary incisors. The recording was initiated by depressing and releasing the recording button that is located on the top surface of the recording handle. After the handle button was pressed the arch model was automatically created on the screen. When the sensor was placed between the two opposing dies at maximum intercuspation, the resultant reduction in electric resistance was translated into image on the screen. The software is designed to analyze and display tooth contact data as registered by the sensor. The T-scan III was occluded between the metal die and the force was loaded and recorded. The load was gradually increased from 25N to 450N and the entire process was repeated. This procedure was repeated twice more, each 3-tap trial comprised one test.

**Image analysis and processing:** Photographs of the paper markings left on the maxillary and mandibular casts resulting from each 3-tap trial was analyzed. A 10-mega pixel digital camera placed at a distance of 6 inches from the metal dies was used. The experimental design produced 100 photos for analysis. In all photographs, 6 prominent markings (indicating 6 contacts) were identified on the casts. Any other inconsistent occlusal markings were disregarded. The 6 distinct contact markings were analyzed using MOTIC software to magnify the markings. The markings were analyzed sequentially: from contact numbers 1-6. A total of 180 (6 teeth x 10 force levels x 3 repetitions =180) marks were statistically analyzed. Photographs of T-Scan markings which were displayed as arch model on the screen were also analyzed using MOTIC software.

**Calculation of the size of the largest paper mark per photograph:** A freehand sketcher (Adobe Photoshop CS4, San Jose, CA, USA) was used to magnify and calculate the paper mark surface area in photographic pixels, of the largest and most prominent articulation paper mark found in a marked quadrant. The MOTIC software was used to magnify the markings so that the freehand sketcher could be used to trace the boundary of the paper mark. The largest mark was outlined using
the MOTIC software outline sketcher command, which accessed the number of pixel count within the enclosed boundary (the freehand sketcher automatically calculates the number of pixels enclosed within the outlined area). The tooth and the contact location of the largest paper mark in a quadrant were recorded in a spreadsheet for future data analysis.

**Statistical analysis:** Descriptive statistical analysis has been carried out in the present study. Comparisons were carried out with one-way analysis of variance (ANOVA), student t-test and Karl Pearson’s correlation coefficient method.

**Results:** Data was plotted for each of six marks of articulating paper and the marks which were evaluated by T-Scan. A best fit curve, one way ANOVA and Karl Pearson’s correlation coefficient method was performed. Data was also grouped plotted by each load level to calculate descriptive statistics. Since all teeth were subjected to exactly the same loads, the Student’s t-test was employed to determine if the mark areas were the same or significantly different at each load. During all tests, no gross observable paper failure was found; however, some local indentations or crinkling was observed as paper conformed to the shape of tooth edges. And each T-Scan sensor was used for 10 test loads.

From results of this study we can say that, the articulating paper mark area in incisors region from was maximum at 300N with 282.50 sqµm whereas with T-Scan, the maximum area was 30.63 sqµm at 100N. (Table 1, 2 & Graph 3) The mark area in size of articulating paper was approximately 9 times greater than T-Scan. In the canine region, (Table 1, 2 & Graph 4) the articulating paper mark area was maximum at 200N with 130.33 sqµm whereas, with T-Scan the maximum area was 52.87 sqµm at 450N. The mark area of articulating paper was approximately 2 times greater than T-Scan. In the premolar region,(Table 1, 2 & Graph 5) the articulating paper mark area was maximum at 250N with 549.67 sqµm whereas, with T-Scan, the maximum area was 56.37 sqµm at 450N. The mark area of articulating paper was approximately 9 times greater than T-Scan. In the 1st molar region (Table 1, 2 & Graph 6) the articulating paper mark was maximum at 250N with 271 sqµm
whereas, with T-Scan the maximum area was 49.97 sqµm at 450N. The mark area of articulating paper was approximately 5 times greater than T-Scan mark. In the 2\textsuperscript{nd} molar region ( Table 1, 2 & Graph 7) the articulating paper mark area was maximum at 350N with 265.33 sqµm whereas, with T-Scan the maximum area was 19.30 sqµm at 450N. The mark area of articulating paper was approximately 10 times greater than T-Scan.

\textbf{Discussion:} Articulating papers are the most frequently used qualitative indicators to locate the occlusal contacts intraorally. Their basic constituents are a coloring agent and a bonding agent between the two layers of the film.\cite{10} On occlusal contact, the coloring agent is expelled from the film and the bonding agent binds it on to the tooth surface.\cite{13} On heavy contacts i.e., (=greatest masticatory pressure), more color is squeezed out resulting in dark marks. When light contacts are made i.e., (=slight masticatory pressure) less color is expelled, therefore light marks results. The selected marks to adjust are generally chosen based on their appearance characteristics. The characteristic marking is observed as a central area that is devoid of the colorant and surrounded by a peripheral rim of the dye. This region is called “target” or “iris” owing to their appearance, and it denotes the exact contact point. The density of these markings does not denote the force of the contact; instead, heavier contact tends to spread the mark peripheral to the actual location of the occlusal contact. Only the central portion in heavy contact areas indicates the interference requiring correction.\cite{13} This hypothesis was evaluated to see if a relationship exists between the occlusal load applied and the size of the markings produced from tooth contact when a clinically used dental articulating paper and T-scan is interposed alternatively.

Results of this study suggest that there is no correlation between the mark area and applied occlusal load. With the articulating paper there was false positive result; which is in accordance with the study conducted by Kerstein et al\cite{11,14} that previously attempted to correlate occlusal force to paper mark size. Hence, we can conclude that the characteristics of paper mark appearance do not describe the amount of occlusal force present on a given tooth. The study also proved that the incremental load increase did not result in an equal mark area size increase on any individual.
contact. This study also showed that the maximum area recorded was at maximum force with T-Scan which is in accordance with the study conducted by Kerstein et al[10], Kim et al[9], Moini et al[15], and Garcia et al[16]. This computerized occlusal analysis showed similar sized and widely distributed marks did not indicate a measurably simultaneous occlusal scheme. It was also shown that, despite their similar size, those same marks exhibited a wide range of forces.

Kevin et al[17] reported that computerized occlusal analysis system provide quantifiable force and time variance in a real-time window from the initial tooth contact into maximum intercuspation and therefore provides valuable information.

Tanya et al [18], reported that the T-SCAN system provides a very accurate way of determining and evaluating the time sequence and force magnitude of occlusal contacts by converting qualitative data into quantitative parameters and displaying them digitally. The system is a useful clinical method that eliminates a biased subjective evaluation of the occlusal and articulating relations on the part of an operator., which is accordance with the results of our study.[18]

An assumption made regarding articulating paper labeling is that the size and color intensity describes forceful contact. A broad contact that is dark colored is perceived to mean a forceful contact. A possible explanation for this relationship between the size of contact and its force content is that the applied pressure of the occlusal force is measured relative to its surface area such that:

\[
\text{Pressure} = \frac{\text{applied force}}{\text{Surface area}}
\]

Broad contacts dissipate force over a large area resulting in low pressure concentration, whereas; a small contact will dissipate occlusal force over a small area. The smaller the surface area that receives a given force, the more pressure results. Computer analysis may reveal that our profession has been misreading the size of articulating paper labeling by reading it inversely. Large or broad contacts are representative of low pressure, while small contacts represent high pressure. The only data that appears to be obtainable with articulating paper labeling are occlusal contact location and surface area. Color intensity, size of labeling and micro scratch labeling reveal the presence of an
occlusal contact without revealing any description of the force content or time sequence data. From the results of this study we can conclude that the combination of these two different mediums can guide the occlusal adjustment procedure to result in a measurable bilateral simultaneous occlusal contact sequence. And also, the size of an articulating paper mark may not be a reliable predictor of the actual load content within the occlusal contact and, T-Scan gave more predictable results of actual load content within the occlusal contact.

Limitations of the study: Only one type of commonly used articulating paper was used in this study so extrapolations of the behavior of other paper/ribbon types cannot be universally made. The results do not necessarily reflect other types, and/or thicknesses of differing commercially available articulating papers. Articulating paper is very delicate and they tend to smudge even with finger pressure and they tend to give false positive markings. In this study, the complexities of the anatomical and physiological aspects of the human teeth which rest in the hydrodynamic environment of the periodontal ligament were purposefully not duplicated. A final limitation was when subjectively defining and sketching the boundary of the mark area with MOTIC software. It was easier to identify the boundaries of the blue markings versus the red markings.

Conclusion: In this bench analysis, a linear relationship between applied load and articulating paper mark area could not be found. This was due to the high degree of mark area variability observed at each test load between differing teeth and contacts. These findings question the long-standing dental premises, that the size of an articulating paper mark indicates it’s load content. Contact marking using T Scan for an applied occlusal load concluded that the mark area increased with the increase in the load. The results of this study suggest that the size of an articulating paper mark may not be a reliable predictor of the actual load content within the occlusal contact and, T-Scan gave more predictable results of actual load content within the occlusal contact. Hence it is imperative that dentists realize that articulating paper mark size is subject to interpretation and can be unreliable method to use for occlusal equilibration.
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