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Original Article

Comparison of articulating paper markings and T Scan III recordings to evaluate occlusal force in normal and rehabilitated maxillofacial trauma patients

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ABSTRACT

Background: Prosthodontic Rehabilitation of Treated Maxillofacial Trauma Cases by Evaluating Occlusal Force Distribution Using Computerized Occlusal Analysis.

Method: 30 patients were selected for the study. 15 normal and 15 treated trauma patients were subjected to T Scan analysis and evaluated for the occlusal force distribution.

Results: The results take into consideration the two parameters. Firstly the largest articulating paper mark (photographed) and secondly the T scan of the same patient. Comparison was made between the largest articulating paper mark and highest force tooth in the quadrant using T Scan. The matches and no matches were then tabulated for statistical analysis assessing the frequency of the matches to the no matches.

Conclusion: The ultimate advantage of a T Scan III analysis is that it can detect the amount of force as well as location of the highest intensity contacts of a single tooth which is very specific.

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Introduction

Maxillofacial trauma often leads to fracture of the facial bones and teeth.^{1,2} Facial fractures are usually treated by reduction and immobilization or fixation of the fractured segments,

followed by occlusal adjustments and restoration of missing teeth and soft tissues where necessary.³ The ultimate goal is optimal achievement of functional occlusal forces and maximum intercuspation.⁴ The patient's teeth should be restored in such a manner that they are able to take up full

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functional load during mastication of food.⁵ The occlusal tactile sensibility for natural teeth can be as low as 8–10 μm .^{6,7} Patients may be able to feel occlusal discrepancies of that dimension when the teeth are restored. Accurate methods of locating the altered occlusal contact points in maximum intercuspation clinically are essential during rehabilitation of maxillofacial trauma patients.⁸ These corrective adjustments are made by selectively grinding the marks to obtain occlusal stability,⁹ multiple contacts throughout the arches that exhibit simultaneity¹⁰ and reduce stress on the occlusal contacts and the periodontium.¹¹ Shimstock foil in combination with articulating paper markings have been advocated in the determination of occlusal tooth contacts that require adjustments.¹² Because the shimstock foil does not mark the selected teeth, the articulating paper markings are the primary guide for the operator when selecting which contacts require adjustment. In textbooks of occlusion it has been advocated that marked area is a representative of the load contained within the mark.^{13–15} The T-Scan III computerized occlusal analysis system (Tekscan Inc., South Boston, MA USA) overcomes the known limitations of articulating paper.¹⁶ It quantifies and displays relative occlusal force information, so the clinician can minimize repeated errors of incorrect occlusal contact selection that often occur from relying solely on the combination of dental articulating paper and patient feel. T-Scan III can help ensure that high quality and complete occlusal end results are predictably obtained from clinical occlusal treatment.¹⁷ The T-Scan III determines the contact time sequencing and the percentage of relative occlusal force between numerous occlusal contacts and then displays them for all dynamic analysis.¹⁸ This enables the clinician to better identify many interfering contacts that are not readily identified by articulation paper markings. Due to T-Scan system improvements made over the past 25 years, we are able to treat different occlusal problems successfully and provide patients with predictable high quality occlusal treatment end results which were not possible previously.

This study was undertaken to evaluate the occlusal force distribution and functional load in dentulous patients using computerized occlusal force evaluation system (T-Scan III) as compared to conventional method of articulating paper. The study proves T Scan III as an effective tool in measuring and comparing the occlusal force distribution in maxillofacial trauma patients before and after surgical, prosthetic rehabilitation.

Aims and objectives

1. To evaluate the occlusal force distribution and functional load in dentulous patients using computerized occlusal force evaluation system (T Scan III) as compared to conventional method of articulating paper.
2. To determine the relationship between size of largest paper mark and the percentage of force applied to the same tooth.
3. To rehabilitate the maxillofacial trauma cases to active occlusal force and make them fit for effective mastication.
4. To compare the measurement of occlusal forces using computerized and conventional methods.

Materials and method

This study was undertaken to rehabilitate the maxillofacial trauma cases to active occlusal force and make them fit for effective mastication. This study also compares the measurements of occlusal forces obtained by computerized and conventional methods. The following materials and methods were used-

1. T Scan III Computerized occlusal analysis system (Tekscan Inc., South Boston, MA USA) [Fig. 1]
2. Articulating paper [Products Dentaires SA Vevey Switzerland] [Fig. 2]
3. Camera [Canon Power Shot {SX220HS} 12.1 Megapixel]

Patients above 21 yrs of age who had complete set of permanent maxillary and mandibular teeth and treated maxillofacial trauma patients with complete set of permanent maxillary and mandibular teeth were selected. Patients with TMJ disorders, skeletal deep bite, skeletal and dental open bite, syndrome affecting the craniomaxillofacial apparatus, skeletal Class III malocclusion, cleft lip and palate and missing/grossly unrestored carious teeth were excluded.

A total of 30 cases who met the above inclusion and exclusion criteria were selected. The cases were divided into two groups as follows.

- a. Group 1: Normal dentulous group with complete set of 32 maxillary and mandibular permanent teeth
- b. Group 2: Maxillofacial trauma cases with complete set of 32 maxillary and mandibular teeth before surgery and after prosthetic rehabilitation.

Intraoral and Extraoral photographs of all the patients were taken prior to carrying out the analysis. All the patients were subjected to articulating paper occlusion recording. The articulating paper was placed intraorally and the subject was asked to clench their teeth firmly on the articulation paper. Standardized photographs were taken to compare the markings with those T Scan III multi-bite recordings at a later stage. All photographs were taken with a digital SLR camera (Canon) in manual mode. An intraoral mirror was placed in the mouth and photos of the articulating paper markings were captured accurately. The procedure was repeated until a clear photograph was obtained. A freehand sketcher (Adobe Photoshop

Fig. 1 – T-Scan III recording handle connects directly to a computer via a USB interface.

Fig. 2 – Articulating paper and Miller's forceps.

CS4, San Jose, CA, USA) was used to magnify and calculate the paper mark surface area in photographic pixels. The largest and most prominent articulation paper mark found in the maxillary and mandibular arches were noted. The boundaries of the largest paper mark were magnified using the software later on used to compare with the T-Scan markings. The tooth and the contact location of the largest paper mark were recorded on a Microsoft excel sheet.

T-scan III bite recording procedure

T scan III is a device used to analyse relative occlusal force that is recorded intraorally by a pressure mapping sensor. It analyzes the order of the occlusal contacts while simultaneously measuring the force percentage changes of those same contacts, from the moment the teeth first begin making occlusal contact, all the way through maximum intercuspation. Therefore, it can assess the initial occlusal contact, the order that all the occlusal contacts occur in, and the amount of relative occlusal force loading each contact.

The width of the maxillary central incisor of each subject was measured by a digital calliper. The sensitivity level of the T Scan III was adjusted according to the manufacturer's recommendation before any occlusal force data was acquired from each subject. The subjects were asked to occlude into and through the recording sensor and hold their teeth firmly intercusped together for 1–2 s [Figs. 3–5]. The procedure was repeated thrice and the average of three recordings was taken. The tooth force percentage distribution recorded with T Scan III was then compared to the articulating paper mark photographs of the same subjects. Data analysis was accomplished by placing the relative occlusal force distribution data side-by-side with the counterpart photograph of the articulating paper marks. When the largest paper mark (measured in surface area of pixels) demonstrated the highest relative force on the same tooth in that quadrant, it was considered to be a “match”. When the tooth with the largest paper mark did not demonstrate the largest force on that same tooth, it was considered to be a “no match”. In Fig. 4, the largest paper mark in a patient subjected to T Scan III analysis was on maxillary right second molar with the force percentage totalling 10% which did not coincide with the largest articulating paper mark of the same subject. The largest mark and highest force percentage did not match. The procedure was repeated in maxillofacial trauma patients. Articulating paper markings and T Scan recordings were made for patients affected by

Fig. 3 – T Scan III recording of a normal patient.

trauma before surgery. Following surgery, prosthetic rehabilitation was accomplished. The patients were subjected to the articulating paper markings and T Scan III analysis before surgery and after prosthetic rehabilitation [Fig. 6]. The readings were tabulated as match and no match based on the comparison between the largest articulating paper mark and the highest force contact shown by T Scan. The results were statistically analysed.

Results

The study was conducted with the aim of evaluating the occlusal force distribution and functional load in dentulous patients using computerized occlusal force evaluation system (T-Scan III) as compared to conventional method of articulating paper. Normal patients with full complement of dentition (32 teeth) were subjected to articulating paper markings and T-Scan III occlusal analysis. The readings were tabulated.

Maxillofacial trauma cases with full complement of dentition were selected. The cases were subjected to articulating paper markings and T Scan III analysis before surgery and readings were tabulated. Following surgery and prosthetic rehabilitation the treated trauma patients were again subjected to articulating paper markings and the T Scan analysis.

The results take into consideration the two parameters. Firstly the largest articulating paper mark (photographed) and secondly the T scan of the same patient. Comparison was made between the largest articulating paper mark and highest force tooth in the quadrant using T Scan [Tables 1–3].

The matches and no matches were then tabulated for statistical analysis assessing the frequency of the matches to the no matches.

The results showed that the largest articulating paper mark matched with the highest force tooth in the quadrant analysed by T scan in almost 80% of cases in normal, maxillofacial trauma and treated maxillofacial trauma individuals. Only in 20% of cases there was no match with the largest

Fig. 4 – Comparison of articulating paper markings and T Scan III recordings in a normal individual with complete set of dentition.

Fig. 5 – Comparison of the largest articulating paper mark and highest relative force on the same tooth on T Scan III analysis.

Fig. 6 – Comparison of articulating paper markings and T Scan III recordings in treated maxillofacial trauma patients.

articulating paper mark and the highest force tooth in the quadrant. Regression analysis showed a *P* value of 0.0057 ($P < 0.05$). The results were statistically significant indicating a good correlation between articulating paper markings and T Scan analysis in both normal and maxillofacial trauma individuals.

Discussion

This study is on similar lines to the other studies that have previously correlated the largest articulating paper mark size and the percentage of force applied to the same tooth.^{19,20} In cases of bruxism the teeth have large flat surfaces and on opposition large marks appear both with articulating paper and T Scan III recordings. Similarly when a sharp pointy surface opposes a flat surface, a small mark is likely to result. Tooth morphology basically determines the actual paper mark surface area and not the applied occlusal force. This determines large mark can have a much higher force associated with it.²¹

In our study comparison between normal patients and maxillofacial trauma cases subjected to articulating paper markings and T-Scan showed that in 87% of cases the articulating paper markings matched with the highest relative force on the same tooth and in only 13% of cases there was no match between the two. With the regression analysis the *p* value was found to be <0.05 which infers that the results were statistically significant.

Table 1 – Depicts frequency distribution and percentage calculation between matches and no matches in normal individuals. In 80% of cases there was match and 20% of cases there was no match between the articulating paper markings and the percentage of force applied to the same tooth on T Scan analysis.

	Frequency	Percent	Valid percent	Cumulative percent
Subject A	1	6.7	6.7	6.7
Subject B	1	6.7	6.7	13.3
Subject C	1	6.7	6.7	20.0
Subject D	1	6.7	6.7	26.7
Subject E	1	6.7	6.7	33.3
Subject F	1	6.7	6.7	40.0
Subject G	1	6.7	6.7	46.7
Subject H	1	6.7	6.7	53.3
Subject I	1	6.7	6.7	60.0
Subject J	1	6.7	6.7	66.7
Subject K	1	6.7	6.7	73.3
Subject L	1	6.7	6.7	80.0
Subject M	1	6.7	6.7	86.7
Subject N	1	6.7	6.7	93.3
Subject O	1	6.7	6.7	100.0
Total	15	100.0	100.0	
Match/No match				
	Frequency	Percent	Valid percent	Cumulative percent
Valid Match	2	13.3	13.3	13.3
Match	10	66.7	66.7	80.0
No Match	3	20.0	20.0	100.0
Total	15	100.0	100.0	

Table 2 – Depicts frequency distribution and percentage calculation between matches and no matches in maxillofacial trauma individuals. In 87% of cases there was match and in 13% of cases there was no match between the articulating paper markings and the percentage of force applied to the same tooth on T Scan analysis.

	Frequency	Percent	Valid percent	Cumulative percent
Subject Aa	1	6.7	6.7	6.7
Subject Bb	1	6.7	6.7	13.3
Subject Cc	1	6.7	6.7	20.0
Subject Dd	1	6.7	6.7	26.7
Subject Ee	1	6.7	6.7	33.3
Subject Ff	1	6.7	6.7	40.0
Subject Gg	1	6.7	6.7	46.7
Subject Hh	1	6.7	6.7	53.3
Subject Ii	1	6.7	6.7	60.0
Subject Jj	1	6.7	6.7	66.7
Subject Kk	1	6.7	6.7	73.3
Subject Ll	1	6.7	6.7	80.0
Subject Mm	1	6.7	6.7	86.7
Subject Nn	1	6.7	6.7	93.3
Subject Oo	1	6.7	6.7	100.0
Total	15	100.0	100.0	
Match/No match				
	Frequency	Percent	Valid percent	Cumulative percent
Match	13	86.7	86.7	86.7
No Match	2	13.3	13.3	100.0
Total	15	100.0	100.0	

In the third step the same 15 maxillofacial trauma individuals subjected to the study underwent surgery followed by prosthetic rehabilitation. Articulating paper markings and T Scan III analysis was done after complete treatment and the readings were compared. It was noticed that again in 80% of individuals there was a match between the articulating paper markings and the highest relative force on the same tooth and only in 20% of cases there was no match between the markings. A regression analysis showed *p* value <0.05 which was statistically significant. Hence the correlation between the articulating paper marks and the T Scan III analysis was statistically significant.

In accordance with the findings of this study it clearly indicates that the largest mark indicated the maximum force on the same tooth with T Scan III in more than 80% of cases in normal, maxillofacial trauma and treated maxillofacial trauma individuals. The clinician would be choosing the right tooth at least 80% of times in performing the occlusal corrections and only in less than 20% of individuals the wrong tooth might be subjected to corrections. T Scan III analysis could be used as a reliable indicator in the occlusal adjustment and analysis.

Conclusion

Within the limitations of the study the following conclusions and recommendations could be drawn.

Table 3 – Depicts frequency distribution and percentage calculation between matches and no matches in treated maxillofacial trauma individuals. In 80% of cases there was match and in 12% of cases there was no match between the articulating paper markings and the percentage of force applied to the same tooth on T Scan analysis.

	Frequency	Percent	Valid percent	Cumulative percent
Subject A1	1	6.7	6.7	6.7
Subject B1	1	6.7	6.7	13.3
Subject C1	1	6.7	6.7	20.0
Subject D1	1	6.7	6.7	26.7
Subject E1	1	6.7	6.7	33.3
Subject F1	1	6.7	6.7	40.0
Subject G1	1	6.7	6.7	46.7
Subject H1	1	6.7	6.7	53.3
Subject I1	1	6.7	6.7	60.0
Subject J1	1	6.7	6.7	66.7
Subject K1	1	6.7	6.7	73.3
Subject L1	1	6.7	6.7	80.0
Subject M1	1	6.7	6.7	86.7
Subject N1	1	6.7	6.7	93.3
Subject O1	1	6.7	6.7	100.0
Total	15	100.0	100.0	

Match/No match				
	Frequency	Percent	Valid percent	Cumulative percent
Match	12	80.0	80.0	80.0
No Match	3	20.0	20.0	100.0
Total	15	100.0	100.0	

1. The size of the largest articulating paper mark cannot be taken the only criteria while performing occlusal adjustments. A computerised occlusal analysis is very much essential when performing the occlusal adjustments.
2. Computerized occlusal analysis provides accurate information when performing selective occlusal grinding of the cusps because the scanning not only analyses the tooth with premature contacts but also specifically indicates the slopes of the cusps that have to be subjected for grinding.
3. Computerized occlusal analysis is not very technique sensitive and the procedure can be performed easily to obtain accurate results as compared to the articulating paper because the thickness of the sensors is standardised whereas the articulating paper thickness varies from one company to other.
4. Articulating paper markings can be contaminated by the saliva and hence can cause misinterpretation of readings whereas in T Scan III the sensors are synthetic and resistant to salivary wetting of the sensors thus maintaining the accuracy of the recordings.
5. T Scan III analyses the first tooth contact on the computer thus providing accurate information of the type of occlusion and jaw movements for the patient.
6. In this study there were no differences in T Scan III readings and the articulating paper markings in normal and treated maxillofacial trauma individuals which strongly suggest that there is a strong correlation between the articulating paper marks and the T Scan III recordings. This will be very helpful in the field of implant dentistry where

in implant occlusion can easily be established with the support of the computerized occlusal analysis system.

7. The ultimate advantage of a computerized occlusal analysis is that it can detect the amount of force as well as location of the highest intensity contacts of a single tooth which is very specific.
8. T Scan III is a reliable tool to detect early contacts and can be effectively used to check occlusal balances.
9. It can be used in full mouth rehabilitation and other occlusal rehabilitation cases very effectively.

Recommendations

1. T Scan III is the only tool to estimate the force differences between the implanted tooth and the natural tooth in occlusion. Hence it is strongly recommended in the field of implant dentistry in restoring implant occlusion.
2. T Scan III is strongly recommended in treated maxillofacial trauma patients having occlusal interferences post surgery.
3. It is recommended that T Scan III can be introduced in Armed Forces and used for all clinical cases which require occlusal rehabilitation.

Conflicts of interest

All authors have none to declare.

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