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RESEARCH ARTICLE

EFFECTIVENESS OF KINEMATIC FACEBOW IN ENHANCING OCCLUSAL EQUILIBRATION IN FIXED RESTORATIVE TREATMENT- A SYSTEMATIC REVIEW

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ABSTRACT

Background: Location of hinge axis and its precise transfer to the articulator where the occlusal rehabilitation is planned is a vital therapeutic protocol in fixed prosthodontics. However, there is an uncertainty regarding the effectiveness of the arbitrary or true hinge axis transfer influencing the therapeutic outcome of occlusal harmony provided by restorations, whichneeds to be investigated further in detail.

Aim: To evaluate occlusal discrepancies arising after mounting with arbitrary and kinematic facebows in fixed restorations.

Materials and methodology: An electronic search was initiated on the PubMed, Medline, Google Scholar data bases for articles discussing the above mentioned aim, listed in the databases till 31st December 2015. Suitable MeSH terms and key word search was initiated with Boolean operators and articles were selected. Data extraction was done from the articles satisfying the inclusion and exclusion criteria and subjected to statistical analysis.

Results: The search methodology identified 13 studies out of which five studies fulfilled inclusion criteria and were included in this review. Comprehensive analysis after data extraction revealed significant heterogeneity among the included studies over the outcome variables and so a meta-analysis could not be performed. All the included studies favour the use of kinematic face bow transfer to minimize occlusal errors with a significant statistical difference ($p<.05$) over arbitrary facebow transfer.

Conclusion: Kinematic face bow transfer is more effective than arbitrary face bow transfer in minimizing occlusal errors in fixed restorations.

INTRODUCTION

Mounting the maxillary and mandibular casts in the articulator is of great diagnostic importance in dentistry. The maxillary cast should have the same relation to the axis orbital plane as in the patient to ensure improved success in occlusal rehabilitation. This relation can be transferred from the patient to the articulator by means of a face bow (Zuckerman, 1982). The localization of the hinge axis can be determined through various kinematic and arbitrary methods. In arbitrary methods a certain margin of error has to be considered after articulation. It is well known that the most precise mounting of the casts is made possible by a kinematic localization of the hinge axis (HA) and an adjustable face bow. However, the arbitrary method is used more often because of its simpler and quicker handling. This use often results in an incorrect mounting of casts in the articulator (McCollum, 1960). Some authors of investigating the accuracy of the arbitrary methods agree that deviations within a radius of 5 to 6 mm around the precise point of an axis would be sufficiently accurate clinically (Thorp *et al.,* 1978), (Palik *et al.,* 1985). The results of these investigations, however, differ significantly from each other in regard to the exact and arbitrary axes. Schallhorn found that 98% of all axes had an area within 5 to 6 mm (Schallhorn, 1957). Teteruck and Lundeen reported 33% of the arbitrary axes to be within a circle of 6 mm in radius around the kinematically localized point of the axes. The use of a modified face bow increases this percentage to 54%(Teteruck and Lundeen, 1966) depending on the position of the arbitrary point. (Walker, 1980) reported values of 20% to 34%, respectively. Moreover, a difference of more than 5 mm between the right and left sides in 33% of 220 patients was observed and it was concluded that an arbitrary localization of the axis would be too inaccurate. Although it is essential to the prosthodontics, the effect of the arbitrary mounting maxillary jaw on occlusion has seldom been investigated. Zuckerman et alelaborated these effects in a theoretic study where error is 5 mm, which is within the mentioned range said to be clinically sufficiently precise, a divergence between 0.3 mm and 0.8 mm was found at the incisive edge. This divergence depended on the height of the centric relation record. The use of arbitrary face bows causes problems in patients with complete dentures with asymmetries. In these cases the prosthesis, based on a reference plane that is tilted in space with respect to the occlusal plane, leads to esthetically unsatisfactory results (Zuckerman, 1982). Fox et al has treated this problem only theoretically and has concluded that for diagnostic purposes and for the fabrication of complete dentures, the arbitrary determination of the axis is precise enough, because the largest possible error in occlusion amounts to 0.25 mm.

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This investigation, however, is based on the results of Schallhornn with 97% to 98% of the axes situated in the previously mentioned radius of 5 mm. In regard to the technique of crowns and fixed partial dentures, it is essential that this axis be localized accurately so the occlusal error does not exceed 0.05 to 0.075 mm (Fox, 1967). Articulators are commonly used in the fabrication of dental restorations. Their purpose is to simulate jaw movements with the teeth in occlusal contact (Hobo *et al.,* 1976). Generally dental casts are transferred to the articulator in maximum intercuspation. In some cases, however, it may be necessary to alter the vertical relation in the articulator(Lauritzen and Bodner, 1961). A clinical need for altering the vertical relation may for example arise when using centric relation records, but sometimes also in complete denture or splint therapy. When the vertical relation is changed in the articulator, casts will rotate around an axis that differs from the true hinge axis (HA) depending on whether the cast was mounted in relation to arbitrary HA points or according to mean settings(Adrien and Schouver, 1997). As a consequence, teeth will occlude at contact sites that deviate within the occlusal plane from contact points in the patient's mouth (Lauritzen and Wolford, 1961). These deviations are frequently termed "horizontal occlusal errors."

Regrettably the task of determining a patient's true HA is considerably more complex and therefore rarely applied in comparison to mounting techniques based on arbitrary HA points or mean settings (Brotman, 1960). Several investigations addressed the implications of the latter relatively straightforward approaches in terms of occlusal errors(Gordon *et al.,* 1984). Commonly, occlusal errors were calculated assuming fixed values for the deviation of arbitrary HA or mean value HA points, respectively, from true HA points (Morneburg and Pröschel, 1998). In reality, however, arbitrary or mean HA points will not deviate by fixed amounts, but will be randomly distributed around the true HA points (Weinberg, 1963). Practitioners using arbitrary HA points or mean settings as a standard method for mounting of casts frequently encounter errors when altering the vertical dimension in the articulator. The hinge axis is an imaginary line that passes horizontally through the rotation centers of both condyles to the right and left when the condyles are in their most distal, unstrained, retruded positions in their respective fossae. It is a position where the condyles can demonstrate pure rotary motion around the horizontal axis of rotation during opening and closing movements of the mandible, thus the name hinge axis, or terminal hinge axis. The hinge axis is a fixed anatomic and geometric reference axis that can be relocated repeatedly by mechanical methods. This point is stable in a healthy, physiologically functioning adult joint and can be used as a reference point with accuracy for mounting casts or measuring jaw movement.(Bernhardt *et al.,* 2003)

Centric relation is the starting position for all mandibular movements. The position of condyle in centric relation to the maxilla is required to orient the upper cast to the condylar elements, i.e. the condylar axis of the articulator. Face-bow essentially records the positional relation of the maxilla to the condyles in centric relation and later transfers this relation to the articulator so that the maxillary cast is mounted in the same spatial relationship as seen in the mouth. Arbitrary hinge axis is commonly used for complete denture construction and many authors have concluded similar results with and without face bow transfer in fixed restorations, but the clinical effectiveness of arbitrary facebow over kinematic facebow which record the true hinge axis influencing occlusal harmony is not clearly established in the literature and needs to be investigated further.

Aim

To evaluate the amount of occlusal discrepancies in fixed restorations, arising after mounting with arbitrary and kinematic face bow.

MATERIALS AND METHODS

An electronic search was initiated on the PubMed, Medline, Google Scholar data bases for articles discussing the above mentioned aim and objectives listed in the databases till 31st December 2015. Suitable MeSH terms and key word search was initiated with Boolean operators and articles were selected. Data extraction was done from the articles satisfying the inclusion and exclusion criteria and subjected to statistical analysis.

Pico analysis

P-Population or problem
All partially edentulous and dentition requiring fixed restorative treatment.

I-Intervention
Hinge axis location using Kinematic facebow transfer.

C-Control
Hinge axis location using Arbitrary facebow transfer.

O-Outcome
•Primary outcome
Occlusal interferences

•Secondary outcomes
Centric Contacts

Patient Perception of occlusion following treatment.
Quality of Life

Search Strategy

An electronic search was initiated on the PubMed, Medline, Google Scholar data bases for articles discussing the above mentioned aim listed in the databases till 31st December 2015. Suitable MeSH terms and key word search was initiated with Boolean operators and articles were selected. Data extraction was done from the articles satisfying the inclusion and exclusion criteria and subjected to statistical analysis.

Selection of studies

The review process consisted of two phases. In the first phase, titles and abstract of the articles were initially screened for relevance and full text of relevant manuscripts were obtained and accessed. The hand search of the selected studies as well as search of references in the selected studies was also done.

Table 1a. Data extraction for variables of interest in selected articles

S. No	Author	Journal/ Year of Publication	Study Design	Nature of the subjects	Locationof hinge axis		Type of articulator	Statistical Data
					Arbitrary	Kinematic		
1.	Thomas R. Morneburg *et al*	Clinical oral investigation, 2011, Vol 15, Pg:427-434	Experimental study	57 dental students 32 men, 25 women	12mm in front of posterior border of the tragus along the tragus canthus line	MTI 602 Ultrasound System	Virtual Articulator	Descriptive Statistics at varying vertical dimension of occlusion.
2.	Olaf Bernhardt *et al*	Journal of Prosthetic Dentistry, 2000, Vol 89 Pg:175-179	Experimental study	30 subjects 11 women 19 men	Girrbach Dental System ear piece arbitrary facebow	Cardix compact and gamma cardix kinematic facebow	Girrbach Dental System	Intra class correlation and Kappa Statistics
3.	Lundeen *et al*	Journal of Prosthetic Dentistry, 1984, Vol 51, Pg:407- 410	Experimental study	10 subjects	Whipmix ear piece facebow	Hinge axis locator facebow	Whipmix semiadjustable articulator	Descriptive Statistics and Student's t test
4.	Thomas R Morneburg *et al*	Journal of Prosthetic Dentistry, 2002, Vol 15 Pg:358-364	Experimental study	57 subjects 32 men 25 women	12mm in front of posterior border of the tragus along the tragus canthus line	Located using mechanical axis locator	Virtual Articulator	Descriptive Statistics at varying vertical dimension of occlusion.
5.	Eva Piehslinger *et al*	Journal of Prosthetic Dentistry, 1995 Vol 74, Pg: 279-283	Experimental study	31 dental students	Anatomic transfer bow	Adjustable axiograph (hinge axis was measured with computed axiograph)	SAM Articulator	Students t test, Kolmogorov test

Table 1b. Data extraction for Variables of Interest In Selected Articles

S. No	Author	Horizontal condylar guidance	Lateral condylar guidance	Third point of reference	Reference plane for mounting	Interocclusal record	Type of interocclusal recording	Materials for interocclusal recording
1.	Thomas R. Morneburg *et al*	Not mentioned	Not mentioned	Right infraorbital point	1)Bonwill Triangle 2)Infraorbital point and Arbitrary hinge axis point 3)Infraorbital point at true hinge axis point.	Virtual	Virtual	Virtual
2.	Olaf Bernhardt *et al*	Not mentioned	Not mentioned	Mentioned	Not mentioned	Not mentioned	Graphic Tracing	Not mentioned
3.	Lundeen *et al*	Not mentioned	Not mentioned	Mentioned	Not mentioned	Not mentioned	Graphic tracing	Not mentioned
4.	Thomas R Morneburg *et al*	Not mentioned	Not mentioned	Orbital point	Not mentioned	Not mentioned	Not mentioned	Not mentioned
5.	Eva Piehslinger *et al*	Not mentioned	Not mentioned	Orbital point	Not mentioned	Interocclusal recording done 1-5 mm	Not mentioned	Not mentioned

Table 1c. Data extraction for variables of interest and outcome measures

S. No	Author	Adjustments to the articulator	Evaluation of centric contacts	Evaluation of eccentric contacts	Remounting	Protrusive contacts	Any other methods of measuring occlusal discrepancies	Outcome Measure	Arc of closure/ Balkwil angle
1.	Thomas R Morneburg *et al*	Horizontal condylar guidance 30º Lateral condylar guidance 15º	Mentioned	Mentioned	Not mentioned	Not mentioned	Virtual using Apple Power Macintosh G5 computer using Kaleidagraph 4.0 software	Occlusal discrepancy at 0mm, 2mm, and 4mm VDO	17º,18º, 20º, 22º, 25º- Balkwil Angle
2.	Olaf *et al*	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Sagittal condylar inclination and transverse condylar inclination reflected by graphic tracings	Not mentioned degree of overla between excursive and incursiv tracing and tracing curvatur recorded.
3.	Lundeen *et al*	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Variation in mandibular condylar position and Bennett's shift in mm	Not mentioned
4.	Thomas R Morneburg *et al*	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Occlusal errors at 0mm, 2mm, and 4mm VDO	Not mentioned
5.	Eva Piehslinger *et al*	Not mentioned	Not mentioned	Mentioned	Not mentioned	Not mentioned	Not mentioned	Evaluation of occlusal errors using digital tracing methods.	Not mentioned

Table 2. Characteristics for Excluded Articles

S.No	Name of the author/year	Study design	Characteristics of Excluded Studies
1.	(Bowley et al., 1992)	Experimental study	Influence of errors after articulator mounting was studied in kinematic face bows only.
2.	(Wieckiewicz et al., 2014)	Experimental study	This study evaluated the discrepancies induced by kinematic face bows only.
3.	(Zakaria et al 2011)	Invivo study	Arbitrary hinge axis located by using manual methods only not using arbitrary face bow
4.	(Wood and Korne, 1992)	Experimental study	Condylar displacement by hinge axis transfer done for orthodontic purposes
5.	(Catić and Naeije, 1999)	Experimental study	Study done on disorders of TMJ
6.	(Nazir et al., 2012)	Experimental study	Sagittal inclination of mounted maxillary casts was evaluated using arbitrary hinge axis records only.
7.	(Adrien and Schouver, 1997)	Experimental study	True hinge axis recording with a kinematic facebow not done.
8.	(Farias-Neto et al., 2013)	Systematic review	The study compared dental prostheses and occlusal splints constructed with and without a facebow.

The articles that were obtained after first step of review process using the following inclusion and exclusion criteria were screened in the second phase and relevant and suitable articles were isolated for further processing and data extraction.

Inclusion Criteria

- Randomised control trials evaluating the effectiveness of arbitrary and kinematic facebow transfer in fixed restorative treatment.
- Articles discussing full mouth rehabilitation of mutilated dentition.
- Articles discussing full mouth rehabilitation with regressive alterations involving the teeth.
- Articles discussing full mouth rehabilitation with severe attrition.
- Articles discussing full mouth rehabilitation with restoration of vertical dimension.
- Articles discussing full mouth rehabilitation with enamel and dentinal defects.

Exclusion criteria

- Case reports.
- Case series.
- Finite elemental analysis.
- Articles discussing full mouth rehabilitation involving fixed removable restorations.
- Articles discussing full mouth rehabilitation of maxillofacial defects.
- Patient undergoing orthodontics treatment, orthognathic surgery.
- Patients undergoing treatment for myofacial pain dysfunction syndrome.
- Patients undergoing removable splint therapy.
- Patients undergoing dentofacial orthopaedic treatment.

Search Results

The database search yielded 13 articles out of which none of them were discarded after reading the title. Full texts were obtained for all the 13 articles. 5 articles were selected based on inclusion and exclusion criteria and 8 were excluded. The finally selected 5 articles were subjected to data extraction.

Data Extraction: The data from the finally included studies were tabulated and the following information was extracted:

- Nature of the subjects.
- Type of face bow.
- Third point of reference.
- Location of hinge axis- Arbitrary and Kinematic
- Horizontal condylar guidance.
- Lateral condylar guidance.
- Reference plane for mounting.
- Inter-occlusal record.
- Type of inter-occlusal recording.
- Materials for inter-occlusal recording
- Type of articulator used.
- Adjustments to the articulator.
- Evaluation of centric contacts.
- Evaluation of excentric contacts.
- Remounting.
- Protrusive contacts.
- Any other methods of measuring occlusal discrepancies.
- Outcome measure.
- Arc of closure/ Balkwins angle.

Statistical method

RESULTS

Table 1a Shows the variables of interest in the selected articles. The following information were extracted and tabulated; name of the author, study design, nature of the subjects, location of hinge axis- Arbitrary and Kinematic, type of face bow, Type of articulator used and statistical analysis done. Table 1bShows extracted data on horizontal condylar guidance,Lateral condylar guidance, Reference plane for mounting, Interocclusal record, Type of interocclusal recording, Materials for interocclusal recording, Table 1cShows extracted data on Adjustments to the articulator, Evaluation of centric contacts, Evaluation of eccentric contacts, Remounting, Protrusive contacts, Any other methods of measuring occlusal discrepancies, outcome measures, Arc of closure/ Balkwills angle. Table 2 Describes the characteristics for excluded articles, in this name of the author, study design and characteristics for excluded articles were specified.

DISCUSSION

When fabricating dental restorations, casts are usually transferred to the articulator based on arbitrary hinge axis or mean values instead of true hinge axis points. Using arbitrary hinge axis points or mean values can lead to occlusal errors if the vertical relation is changed in the articulator. Whenever a change of vertical relation is necessary and can be confined to 2 mm, a face-bow transfer based on arbitrary hinge axis points is recommended because this method is not too time consuming. When vertical adjustments of more than 4 mm are unavoidable, it might be useful to determine the true hinge axis for the purpose of transferring and mounting the cast. (Morneburg and Pröschel, 2011) Ultimately, this decision will also be influenced by the material of restorative choice, as occlusal errors will have different effects depending on whether they act on occlusal splints or on ceramic masticatory surfaces. However, opinions differ about the most appropriate method with regard to transferring dental casts from the patient to the articulator. Some investigators have demanded that this should be accomplished by true HA points (Adrien and Schouver, 1997), (Brotman, 1960), (Craddock and Symmons, 1952), (Lauritzen and Bodner, 1961), (Piehslinger *et al.,* 1995).Other authors have found arbitrary mounting to be sufficient (Morneburg and Pröschel, 2002), (Schulte *et al.,* 1984). Yet another group of authors have deemed the use of a face bow unnecessary but have relied on mean settings for mounting (Craddock and Symmons, 1952), (Carlsson, 2009). These different views raise the question as to which one is the most reasonable approach. There are various ways of addressingthis question. Randomized clinical studies would be ideal to settle the issue, but appropriate investigations have not beenpublished, and those that were already published were reported to have methodological flaws. Another way to approach this problem is to calculate what errors could be expected and to use the results in deciding which method is the most appropriate.

Some investigators approached the problem of calculating occlusal errors by assuming fixed values for the extent to which arbitrary and mean HA points would deviate from true HA points (Lauritzen and Bodner, 1961), (Brotman, 1960), (Gordon *et al.,* 1984), (Lundeen and Mendoza, 1984). However, these approaches ignore the fact that HA deviations and occlusal contact points are subject to random distribution in any given population (Morneburg and Pröschel, 1998). A possibility to incorporate this variability into a mathematical model is to determine individual parameters of a group of subjects and to calculate occlusal errors that would emerge if dental restorations of these subjects would be performed according to a certain treatment procedure (Morneburg and Pröschel, 2002). The resulting frequency distributions of occlusal errors can then be used to calculate probabilities with which occlusal errors of a certain size could be expected in a clinically representative population (Morneburg and Pröschel, 2002). This approach is closer to reality than calculations based on fixed parameter deviations of which it is not known, how often these really appear (Weinberg, 1963), (Schallhorn, 1957), (Simpson *et al.,* 1984), (Teteruck and Lundeen, 1966), (Walker, 1980). Some approximations, however, were still necessary. This model will not be able to account for effects arising from differing positions of arbitrary HA points on either side. If a centric relation record can be obtained without a change of vertical dimension, no horizontal occlusal errors at all are to be expected upon closing of the cast in the articulator. Provided that a change of vertical dimension can be limited to 2mm, horizontal errors caused by the use of an arbitrary axis will stay below 300µm in 87% of cases and will hardly exceed 500µm, if, for whatever reasons, the change of vertical dimension should significantly exceed 2mm, the determination of a hinge axis may be indicated (Morneburg and Pröschel, 2002). In the case of a clinically practicable centric relation record of 3 mm, 100% of the volunteers showed an absolute spatial deviation between the reference points of casts mounted according to the hinge axis and the arbitrarily mounted casts of 0.075 mm or greater. At record heights greater than 4.15 mm, 95% of the subjects or more were estimated to have occlusal errors greater than 0.1 mm (Piehslinger *et al.,* 1995). The results of the current systematic review included a detailed review of six included articles and the nature of the subjects, location of hinge axis- Arbitrary and Kinematic, type of articulator used statistical analysis done, horizontal condylar guidance, Lateral condylar guidance, Reference plane for mounting, Interocclusal record, Type of interocclusal recording, Materials for interocclusal recording, the Adjustments to the articulator, evaluation of centric contacts, evaluation of eccentric contacts, remounting, Protrusive contacts, any other methods of measuring occlusal discrepancies, outcome measures data were all extracted.

There was a significant amount of heterogeneity observed amongst all the included studies and hence a meta-analysis was not possible. Out of five selected studies Morneburg *et al.,* have used virtual simulators to evaluate the changes in the occlusal discrepancies with arbitrary and kinematic facebow at varying amounts of vertical dimension and various Balkwill's angles devoting steepness of arc of closure. In both articles it was concluded that as vertical dimension increased, the amount of occlusal errors increased significantly more in arbitrary hinge axis mounting than the kinematic mounting. The amount of error occurring is more in posteriors than in anterior and hence kinematic face bow help to minimize the occlusal error occurring with increase in vertical dimension. (Piehslinger *et al.,* 1995) also used digital methods to study occlusal discrepancy with increase in vertical dimension, the amount of occlusal errors during closure is significantly more for mountings done under arbitrary hinge axis location than the kinematic hinge axis location. A systematic review has been done with respect to effectiveness of usage of facebows in complete dentures and concluded for complete denture constructions facebows may not be superior to arbitrary mounting. However, this cannot be extrapolated in dentulous situation involving increase in vertical dimensions. Cross over trials with increased vertical dimension may not be possible with permanent restorations but could be initiated with removable occlusal splint. A randomized control trial studying the effectiveness of arbitrary and kinematic facebow is scare in the literature and further studies could be initiated to study this phenomenon.

Conclusion

Within the limitations of this study, it could be concluded that kinematic facebow transfer could minimize the amount of occlusal errors in situations involving increased in vertical dimension than the arbitrary mounted procedures, however

quantum of evidence to fully endorse this opinion is insufficient and further studies with proper randomization and observation protocols is necessary to validate this observation.

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