Comparison of Bite Force with Locking Plates versus Non-Locking Plates in the Treatment of Mandibular Fractures: A Meta-Analysis

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Int Arch Otorhinolaryngol 2018;22:181–189.

Abstract

Introduction Mandibular fractures represent a high percentage of all facial fractures, and the bite force is a fundamental parameter to measure the actual mandibular function and, subsequently, the masticatory efficiency and quality of life.

Objectives The purpose of the present systematic review was to verify if there is any difference in the bite forces of patients with mandibular fractures fixed by locking or non-locking plates, testing the null hypothesis of no difference in this parameter.

Data Synthesis A systematic review of the literature was conducted using four databases (PubMed, Virtual Health Library, Web of Science and Science Direct) without restrictions as to publication date or language. We found 3,039 abstracts, and selected 4 articles for this review.

Conclusion The overall results show better performance in bite force for the locking plates when compared with the non-locking plates in the incisor region (mean deviation [MD]: 1.18; 95% confidence interval [95%CI]: 0.13–2.23), right molar region (MD: 4.71; 95%CI: 0.63–8.79) and left molar region (MD: 10.34; 95%CI: 4.55–16.13). Although the results of this study indicated a better bite force result with the locking plates, there is still no sufficient evidence to support this information safely.

Keywords
- bite force
- mandibular fracture
- fracture fixation
- bone plates
- internal fixators

Introduction

Mandibular fractures represent a high percentage of all facial fractures.[1–3] The most common causes of these injuries are interpersonal violence, falls, lesions practicing sports, and accidents at work and traffic accidents.[4] The consequences of mandibular fractures can include malocclusion, temporomandibular joint syndrome, and poor mastication,[5] leading to a decrease in quality of life.[6]

The mandibular fracture fixation by metallic plates was first described by Michelet in 1973,[7] and was subsequently improved by Champy in 1975,[8] who described the ideal places in the mandible to apply plates that could resist to torsional forces during osteosynthesis. The standard plate system works when the heads of the screws compress the plate to the bone to maintain stability, preventing changes in the alignment of the fragments and maintaining occlusal stability.[9] On the other hand, the locking plate system

received
April 1, 2017
accepted
May 9, 2017
published online
July 14, 2017

DOI https://doi.org/10.1055/s-0037-1604056.
ISSN 1809-9777.

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attaches the plates to the bone by locking the screws to both the bone and the plate, which maintains the stability of the system.[10] Therefore, treatments with locking plates lead to fewer changes in occlusal relationships, fewer screw-loosening events, less problems with bone vascularization, greater stability between fragments, and easier placement of the plates when compared with treatments with non-locking systems.[11,12]

Some characteristics of the locking plate systems are recognized as disadvantages, such as the fact that they are more expensive than the standard systems, and need a specific apparatus in order to be applied in the bone. Thus, for each method and instrument launched by new studies, it is necessary to evaluate the actual advantages and disadvantages, so they may be properly applied in clinical situations. According to a recent meta-analysis,[13] there are no significant differences in the postoperative complication rates with the use of locking plate systems when compared with the use of standard plate systems in the management of mandibular fractures, but this study did not assess the bite force measurements. Bite force is a fundamental parameter to measure the actual mandibular function and, subsequently, the masticatory efficiency and quality of life.

The purpose of the present systematic review was to verify if there is any difference in the bite force of patients with mandibular fractures fixed by locking or non-locking plates, testing the null hypothesis of no difference in this parameter.

Review of the Literature

The present study was conducted according to the *Cochrane Handbook for Systematic Reviews of Interventions* (apud Chrcanovic, 2014),[13] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement using the Review manager (RevMan) software, version 5.3 (The Cochrane Collaboration, Copenhagen). It was registered in the International Prospective Register of Systematic Reviews (PROSPERO; CRD42016051937).

We conducted an electronic search to identify relevant literature published since November 11, 2016, in the PubMed, the Virtual Health Library (VHL), the Web of Science and the Science Direct databases. The search was performed using four different combinations of terms in all databases, following these stages: stage 1–(*mandibular fracture*) AND *osteosynthesis* AND (*bite force*); stage 2–(*mandibular fracture*) AND *osteosynthesis* AND (*occlusal force*); stage 3–(*mandibular fracture*) AND *osteosynthesis* AND (*masticatory force*); and stage 4–(*mandibular fracture*) AND (*locking plate* OR *non-locking plate* OR *non-locking plate* OR *standard plate* OR *conventional plate*).

Furthermore, we also searched the gray literature (Google Scholar), published theses (http://bancodeteses.capes.gov.br/banco-teses), and the reference lists of all studies identified as relevant reviews for possible additional studies. We also searched for relevant ongoing clinical trials in the Clinical Trials Registry (http://www.clinicaltrials.gov).

The included studies must have reported the criteria for bite force measurement of the patients and the follow-up measurements. The exclusion criteria were: textbooks, case reports, technical reports, review papers, opinion articles, cover letters, in vitro studies, animal studies, and papers without available abstracts. After independently reading paper titles and abstracts, the reviewers checked the results of the selected papers. Disagreements were resolved by consensus. The same process was performed when reading the full text for the final inclusion of the papers in the systematic review.

After the database search, 3,039 studies were identified. After removing duplicates, 1,697 studies remained. After screening titles and abstracts, we retrieved 25 full-text studies. The reference lists of the selected papers and a hand search revealed one additional relevant paper. A total of 4 studies involving 130 patients[4,14–16] evaluated bite force and were included in the qualitative synthesis (►**Fig. 1**). One study was mentioned in two separate papers[14,16] that reported the same statistical data. These two articles were thus considered a single paper for the meta-analysis. One study presented the results through graphs, and it was not possible to extract the adequate statistical data for it.[15] The author was contacted by e-mail, but we could not obtain an answer. Therefore, only two studies[4,14] were included in the meta-analyses.

The relevant characteristics of the included studies are presented in ►**Table 1**. All studies evaluated and compared the bite force of patients treated with locking and non-locking plates for the osteosynthesis of the mandibular fractures. The follow-up periods ranged from 1 to 12 weeks. The number of fractures ranged from 31 to 34. Out of the four studies, three used the very own patients as controls by measuring the bite force preoperatively. All plates systems were 2.0 mm (►**Table 1**). The results were checked by reviewers after data collection to ensure accuracy.

The quality of the included studies was independently assessed by the same reviewers using a specific protocol developed by Higgins & Green (2011, *apud* Chrcanovic, 2014) [13] for the assessment of the risk of bias. The classification of the potential risk of bias for each study was based on the following criteria: sequence generation; allocation sequence concealment; blinding of participants, personnel, and outcome assessors; incomplete outcome data; and selective outcome reporting. Each study was submitted to analysis, and the criteria were rated as exhibiting low, high, or unclear (no information or uncertain) risk of bias. The disagreements between reviewers were resolved by consensus for the final classification. Our assessment is presented in ►**Fig. 2**.

The meta-analysis was performed using the R software (R Foundation for Statistical Computing, Vienna, Austria), version 3.3.1. The packages "meta" and "metafor" were used to perform the statistician calculation and the forest plots. The heterogeneity of the results of the studies was assessed using the I-squared (I^2) test. Values above 25% and 50% were considered indicatives of moderate and high heterogeneity respectively. As heterogeneity was present ($I^2 > 0$) in all tests, the random effect model was used to perform the meta-analysis.[17,18]

The effect estimates were expressed as the weighted mean difference between the groups, and were obtained

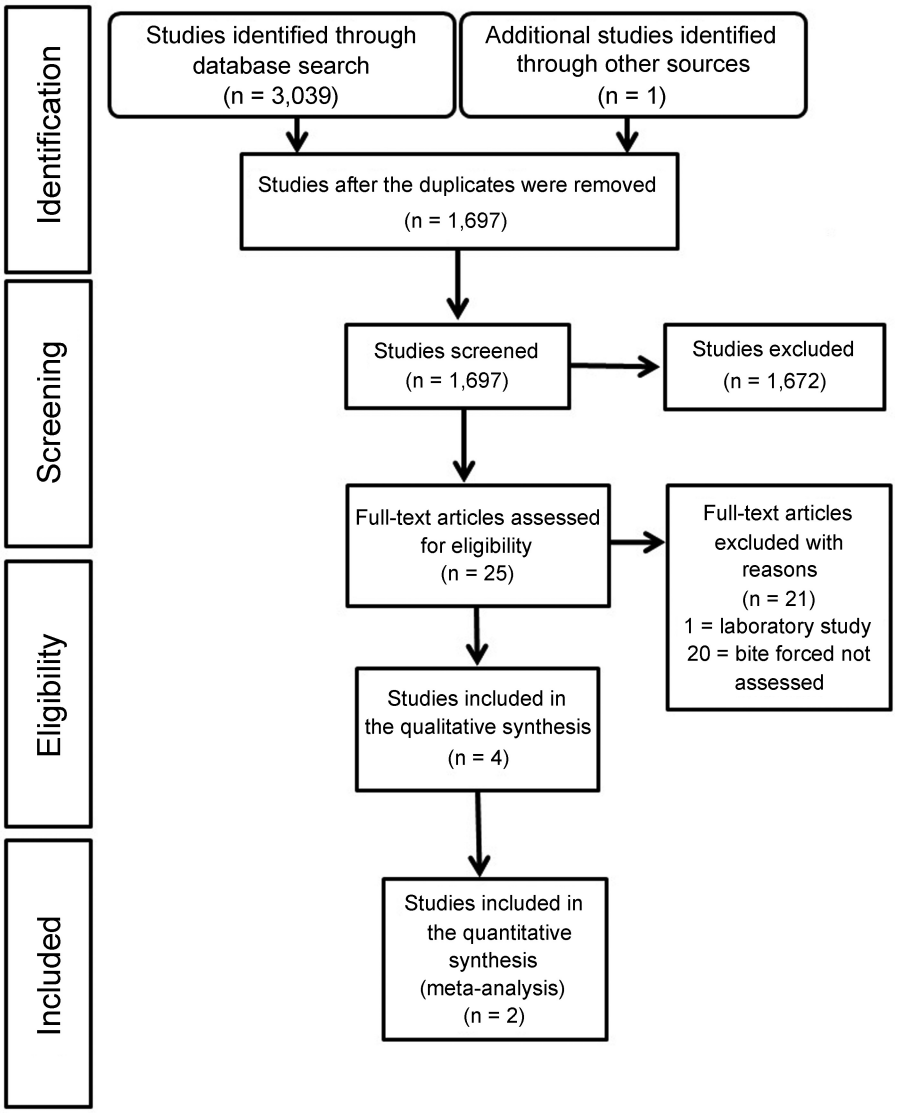

Fig. 1 Selection of studies for the systematic review.

by comparing the baseline mean values at the end of the study for each group.

All studies evaluated the bite forces by the same method, using the indigenous Bite Force Recorder, which consists of four strain gauges mounted on steel bars, forming a Wheatstone bridge. Load changes in the steel bar produced a measurable voltage change across the four strain gauges. All measurements were made with the patient seated with the head upright, in an unsupported natural head position, and looking forward. The patients were instructed to bite on the pads of bite force gauge to the maximal level. The results were analyzed in the follow-ups at 1, 3, 6, and 12 weeks, observing the mean of the bite force measurements in the incisor, left molar, and right molar regions (►**Table 2**).[4,14–16]

The results of the meta-analysis showed that when the bite force in the incisor region was evaluated, the patients treated with locking plates showed no difference in bite force when compared with the patients treated with non-locking plates in the first (mean deviation [MD] :0.84; 95% confidence interval [95%CI]: -0.62–2.30), third (MD: 0.91; 95%CI: -0.29–2.10), and sixth (MD: 1.05; 95%CI: -1.11–3.20) weeks. However, when evaluating the pooled bite force including 3 months of follow-up, the locking plates obtained better results than the non-locking plates for the osteosynthesis of mandibular fractures (MD: 1.18; 95%CI: 0.13–2.23; $I^2 = 57.2\%$) (►**Fig. 3**).

The patients treated with locking plates showed no difference in bite force in the right molar region in the first (MD: 1.45; 95%CI: -1.24–4.14), third (MD: 1.18; 95%CI: -2.82–5.18) and sixth (MD: 7.47; 95%CI: -6.85–21.78) weeks when compared with the patients treated with non-locking plates. However, the effect of the locking plates considering 3 months of follow-up was better than the effect of the non-locking plates (MD: 4.71; 95%CI: 0.63–8.79; $I^2 = 76.8\%$) (►**Fig. 4**). Regarding the left molar region, locking plates and non-locking plates did not differ significantly in the first (MD: 5.46; 95%CI: -2.85–13.78), third (MD: 8.16; 95%CI: -5.25; 21.58), and sixth (MD: 12.47; 95%CI: -9.85; 34.79)

Table 1 Characteristics of studies included in the systematic review

Study	Country	Mean Age (years)	N (M/F)	Site of mandibular fracture*	Number of fractures	Follow-up	Interval** (mean)	Control for bite force	Type of plates used	Bite force measurements method
Agarwal et al[4]	India	(16–30)	20 (19/1)	Parasymphysis	34	1, 3, 6 weeks and 3 months	8.7	Same patients pre-operatively	Synthes (West Chester, Pennsylvania, US) 2-mm locking titanium miniplates and Synthes 2-mm non-locking titanium miniplates	Indigenous Bite Force Recorder
Kumar et al[15]	India	27.2	20 (18/2)	Body of mandible	ND	7, 14, 21, 28 and 90 days	7.4	Same patients pre-operatively + healthy patients (control group)	Single 4-hole, stainless steel locking miniplate and two 4-hole, stainless steel conventional miniplates (2.0 mm system, SK Surgicals, Pune, Maharashtra)	Indigenous Bite Force Recorder
Giri et al[14]	India	(11–20)	20 (17/3)	Parasymphysis	31	1, 3 and 6 weeks	7.5	Same patients pre-operatively	2-mm locking titanium miniplates and 2-mm standard titanium miniplates	Indigenous Bite Force Recorder
Rastogi et al[16]	India	(11–40) min-max	20 (17/3)	Parasymphysis	31	1, 3 and 6 weeks	5	Same patients pre-operatively	2-mm locking miniplates and 2-mm standard miniplates	Indigenous Bite Force Recorder

Abbreviations: F, female; M, male; N, number of included patients; ND, not declared.
Notes: *The area of the mandible most affected by fractures; **Interval between the moment of the injury and the treatment in days.

Fig. 2 Risk of bias assessment.

weeks of follow-up. The analysis after 3 months of follow-up showed that the locking plates obtained better results for bite force than the non-locking plates for the osteosynthesis of mandibular fractures (MD: 10.34; 95%CI: 4.55–16.13; $I^2 = 89.2\%$) (►**Fig. 5**).

Discussion

When comparing the use of locking and non-locking plate systems for the osteosynthesis of mandibular fractures, several clinical parameters have already been analyzed and published in two systematic reviews.[13,19] However, none of these studies compared the bite forces of the patients after surgeries that used these plate systems. It has been proved that the bite force is a primordial factor for masticatory performance,[20–22] having a significant influence on the patients' quality of life.[23] As the current trend in the treatment of facial fractures through osteosynthesis is the early reestablishment of the function of the stomatognathic system, understanding the advantages and disadvantages of these two fixation plate systems in this variable is necessary. The results of the present review suggest that there was no difference in bite force evaluated between the two fracture fixation systems until the sixth week, although a gradual increase in bite force was verified until the third postoperative month in both groups. Nevertheless, better bite force was observed in the groups of locking plates after three months

Table 2 Data extracted from the included studies (mean and standard deviation of bite forces)

Follow-up 1st week						
Author, year	Incisor region: Mean ± SD		Left molar region: Mean ± SD		Right molar region: Mean ± SD	
	Locking	Non-locking	Locking	Non-locking	Locking	Non-locking
Agarwal et al[4]	2.47 ± 1.74	0.90 ± 0.91	14.6 ± 6.30	4.73 ± 3.74	8.39 ± 5.72	5.55 ± 3.68
Giri et al[14]	5.54 ± 1.67	5.46 ± 1.22	16.92 ± 2.87	15.54 ± 4.26	16.60 ± 3.45	16.10 ± 4.46
Kumar et al[15]	ND	ND	ND	ND	ND	ND
Rastogi et al[16]	5.54 ± 1.67	5.46 ± 1.22	16.92 ± 2.87	15.54 ± 4.26	16.60 ± 3.45	16.10 ± 4.46
Follow-up 3rd week						
Author, year	Incisor region: Mean ± SD		Left molar region: Mean ± SD		Right molar region: Mean ± SD	
	Locking	Non-locking	Locking	Non-locking	Locking	Non-locking
Agarwal et al[4]	4.22 ± 2.45	2.61 ± 1.75	27.79 ± 11.85	12.23 ± 5.94	20.52 ± 9.58	15.26 ± 9.69
Giri et al[14]	7.26 ± 1.96	6.85 ± 1.59	19.83 ± 2.19	18.00 ± 4.97	19.5 ± 2.17	19.34 ± 4.99
Kumar et al[15]	ND	ND	ND	ND	ND	ND
Rastogi et al[16]	7.26 ± 1.96	6.85 ± 1.59	19.83 ± 2.19	18.00 ± 4.97	19.5 ± 2.17	19.34 ± 4.99
Follow-up 6th week						
Author, year	Incisor region: Mean ± SD		Left molar region: Mean ± SD		Right molar region: Mean ± SD	
	Locking	Non-locking	Locking	Non-locking	Locking	Non-locking
Agarwal et al[4]	7.93 ± 4.94	5.17 ± 2.41	43.27 ± 13.80	18.99 ± 6.08	37.92 ± 10.44	22.73 ± 7.40
Giri et al[14]	8.83 ± 1.97	8.49 ± 1.39	22.69 ± 2.09	21.20 ± 5.70	23.64 ± 3.02	23.08 ± 5.99
Kumar et al[15]	ND	ND	ND	ND	ND	ND
Rastogi et al[16]	8.83 ± 1.97	8.49 ± 1.39	22.69 ± 2.09	21.20 ± 5.70	23.64 ± 3.02	23.08 ± 5.99
Follow-up 3rd month						
Author, year	Incisor region: Mean ± SD		Left molar region: Mean ± SD		Right molar region: Mean ± SD	
	Locking	Non-locking	Locking	Non-locking	Locking	Non-locking
Agarwal et al[4]	16.76 ± 9.34	6.95 ± 2.02	63.07 ± 21.30	28.69 ± 7.42	58.43 ± 20.25	31.58 ± 9.58
Giri et al[14]	ND	ND	ND	ND	ND	ND
Kumar et al[15]	ND	ND	ND	ND	ND	ND
Rastogi et al[16]	ND	ND	ND	ND	ND	ND

Abbreviations: ND, not declared; SD, standard deviation.

of follow-up. These results enable us to imply that the locking plate system promotes the reestablishment of masticatory functions earlier than the non-locking plate system. This may be due to the locking plate system's ability to join the fragments of the fracture without leaving gaps.[12] In the non-locking plates system, the existence of these gaps enables the formation of bony callus between the fragments of the fracture, delaying the repair process and thus reducing the effectiveness of this system.[24]

Four articles met the inclusion criteria for this study.[4,14–16] Two of these articles presented identical results;[14,16] therefore, the most recent article was excluded from the meta-analysis.[16] Another study included in this review expressed the results in graphs, so it was not included in the meta-analysis due to the impossibility of extracting raw data such as mean and standard deviation.[15] Despite the possibility of performing a meta-analysis with only two studies,[25] this is a limitation of this study. The lack of studies is justified by the fact the other studies that investigated bite force comparing locking and non-locking plate systems were laboratory studies using finite element analysis,[26] ex vivo human[27] or animal[28] parts, or a combination of methods,[29] and they failed to meet the inclusion criteria adopted in this review.

In order to evaluate the bite force, one could use a dynamometer,[30] a bite fork,[31] or the indigenous Bite Force Recorder, which was used in all the studies included in this review.[4,14–16]

In addition to the diversity of methods for measuring bite force, there is also no established standard anatomical sites used for this purpose.[30,31] In this systematic review, all studies performed the measurement of bite force in the incisor, left molar and right molar regions, in agreement with the studies by Gupta and coleagues (2012) and Kshirsagar and colleagues (2011).[32,33]

To avoid possible biases and facilitate the comparison among future studies, a single measurement of bite force

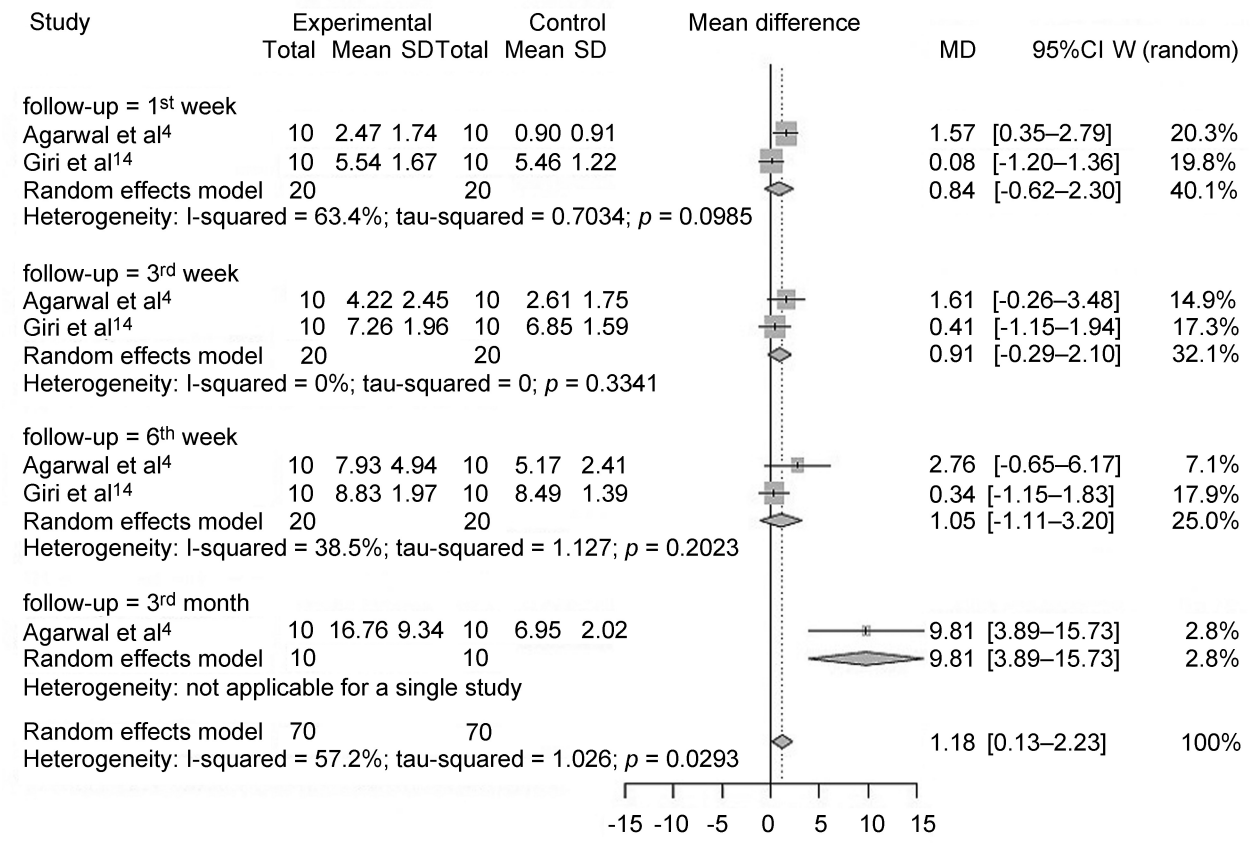

Fig. 3 Forest plot for the bite forces in the incisor region. Abbreviations: 95%CI, 95% confidence interval; MD, mean deviation; SD, standard deviation.

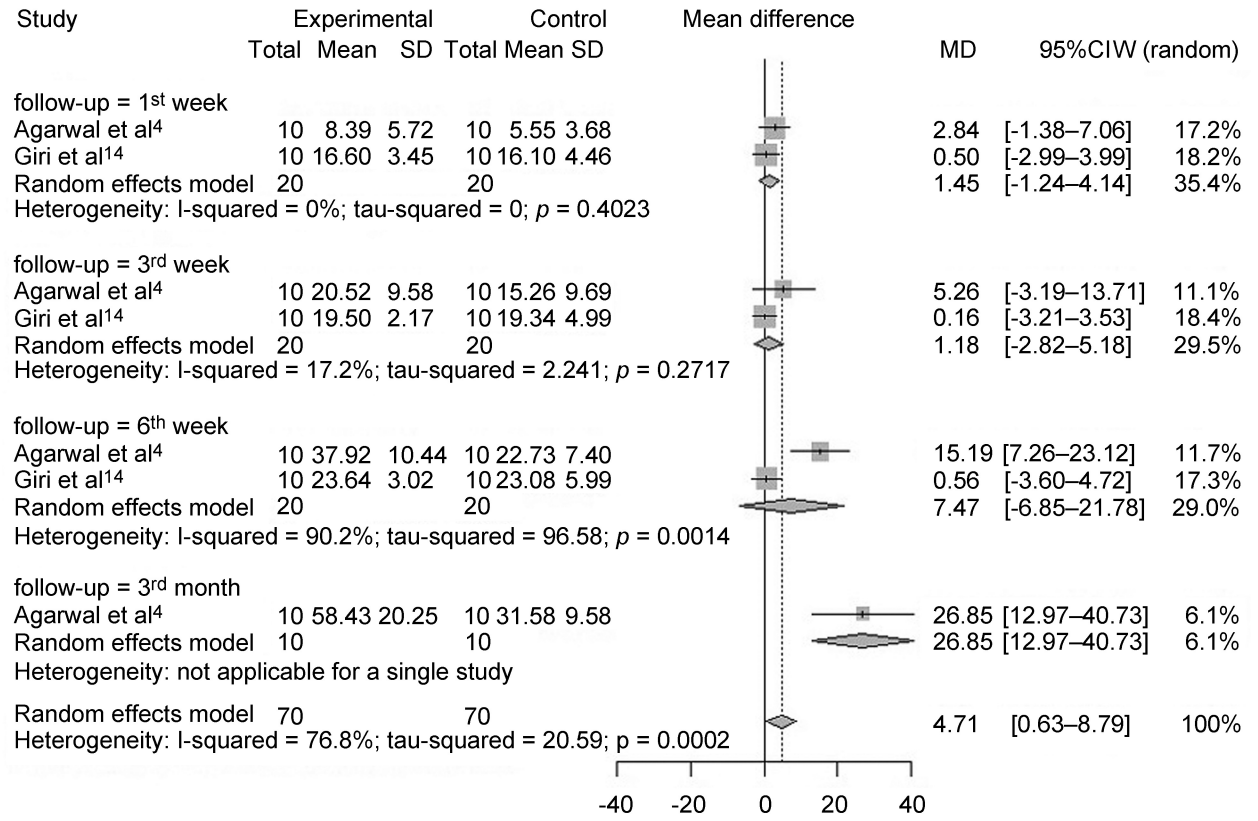

Fig. 4 Forest plot for the bite forces in the right molar region. Abbreviations: 95%CI, 95% confidence interval; MD, mean deviation; SD, standard deviation.

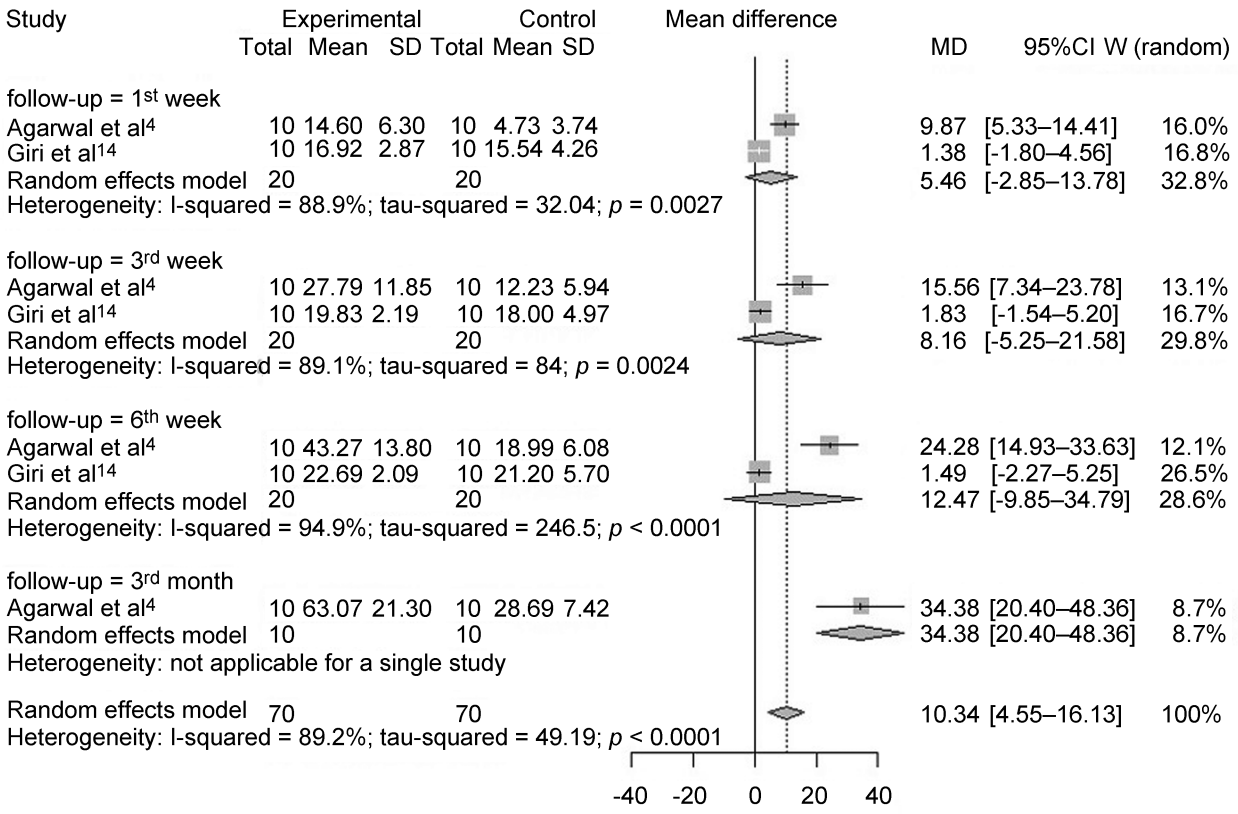

Fig. 5 Forest plot for the bite forces in the left molar region. Abbreviations: 95%CI, 95% confidence interval; MD, mean deviation; SD, standard deviation.

would enable a better evaluation of the performance of the plate systems, since there is no significant difference in the bite force between the fractured side and the non-fractured side[30] because, in the immediate postoperative period, there is a reduction in this force caused by protective neuromuscular mechanisms. This single measurement could further help control the bias of measuring the bite forces of one edentulous side and another toothed side. In addition, it is suggested that the maximum bite force would be obtained after at least three attempts, since the first attempt at measuring should be considered a stage of adaptation to the technique by the patient.[34] Some clinical parameters such as infection, malocclusion, hardware failure, wound dehiscence, paresthesia and pain may decrease the bite force of patients treated after mandibular fractures.[13,19,30] Although it is difficult to establish what would be a short follow-up period following osteosynthesis surgeries, these factors may have contributed to the fact that in the follow-ups of only a few weeks after surgery there were no significant differences in the means of the bite forces in the regions evaluated when comparing the fixation plates systems. This suggests that the success of the treatment is more related to bone quality, fracture site and surgical technique than to the type of plate system.[13,19] This is a limitation that must be recognized in this review. Although the studies state that most of the treated fractures have occurred in the symphysis and mandibular parasymphysis regions, standardization cannot be achieved due to the peculiarities of each type of fracture. Other limiting factors that may influence the results of this review are the size of the plates and the size of the screws used in each type of fracture.[35] Since there was some standardization during data collection for the bite force variable in the studies included in this meta-analysis, the high heterogeneity present in this review can be attributed to the variability of osteosynthesis techniques due to the peculiarity of each type of mandibular fracture treated.

The literature points to a higher financial cost of the locking system in relation to the non-locking system.[36] However, it is possible that this cost difference is compensated by the increase in bite force in the third month of follow-up, and by the decrease in postoperative complications associated with the locking system.[11,12] Cost-effectiveness studies are needed to compare the costs of each fracture fixation system with its respective impact on clinical outcomes, and to identify the best alternative for the treatment. The current review presents a summary of the effect of the measures regarding the bite force of patients treated with locking and non-locking plates, which may contribute to the validity of future economic analyzes.

Final Comments

There are some limitations to this study that cause these results to be evaluated with discretion. First, a limited number of articles were included in this review. Then, these articles presented unclear results on most bias risk criteria (according to the *Cochrane Handbook for Systematic Reviews of Interventions*) and an unadjusted presentation of the

results. For a better consistency of the presented evidences, it is suggested that more clinical trials should be performed to evaluate the bite force, measuring the whole mouth in a single time, or even using electromyographic analysis to avoid possible biases. In addition, greater standardization of fracture site, and size of plates and screws used would increase the homogeneity of the results. Using the patient as his or her own control is also a way to standardize the analysis of the results in a more reliable way, which was not done by one of the four included studies.[15] Once statistical significance was found only at the 3-month follow-up, a longer follow-up period should be considered in the next experiments, considering a reduced interval between the measurements in order to accurately estimate the moment of return to functional normality.

Although the results of this study indicated a better bite force result with the locking plates, there is still no sufficient evidence to support this information safely.

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