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A consecutive, prospective analysis of the Rotoglide 1st metatarsophalangeal joint replacement

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Highlights

Following 1st metatarsophalangeal joint replacement, the is a normalisation of the distribution of the foot pedobarographic pressure and an improved patient outcome.

1. Introduction

Whilst Davies-Colley in 1887 first described stiffness and pain of the first metatarsophalangeal joint from wear of the joint [1], Cotterill in 1888 has been credited with first using the term hallux rigidus. The degenerative process involves reduction of joint space, formation of marginal osteophytes which capture the joint reducing the range of motion and stiffness. The increased load bearing of the foot causes callus formation and interphalangeal hyperextension of the great toe [2]. Coughlin et al [3] described the grading of the severity of hallux rigidus.

Patients present with pain, symptoms of locking or impingement of the dorsal osteophytes within the shoe. They tend to load the lateral border of the foot in preference to the medial column. Once conservative measures have failed, surgical intervention should provide pain relief, restore range of motion, offer good cosmesis, maintain the medial column and toe length, restoring normal function and gait. Limited procedures such as cheilectomy, joint realignment and more aggressive treatments such as joint surface excision and fusion have been employed depending on the severity of the degenerative process. Joint replacements have evolved from the previous silicone implants, resurfacing implants on the metatarsal head only and the more

phalanx metal on polyethelene implants. These preserve range of motion allowing normal gait via the windlass mechanism as well as assisting in balance and normal stance during gait. Some dorsiflexion may be desirable for those wishing to wear heels. The balance and improvement of gait should be reflected in a redistribution of pressures in the foot following joint replacement.

We assessed the Rotoglide 1st MTPJ replacement prosthesis, an uncemented, non-constrained three component metal on polyethelene implant. The metal metatarsal and phalangeal stems are hydroxyapatite coated encouraging osteointegration. The rotating meniscal ultra-high molecular weight polyethelene (UHMWPE), improves the range of movement possible. We propose that following this joint replacement, the pedobarographic pressure distribution should be improved and medialised, the range of motion of the joint should be maintained and that the clinical outcome as measured by a validated outcome measure The Manchester-Oxford questionnaire (MOXFQ) should reflect this improvement.

2. Methods

We carried out a consecutive prospective service evaluation of all patients undergoing the Rotoglide 1st MTPJ replacement. All data and radiographs have been anonymized for this study. Kinematic data was collected in our gait laboratory preoperatively and postoperatively at 6 and 12 months. The MOXFQ score [4] a validated patient reported outcome measure comprising a set of 16 questions assessing quality of life in the preceding 4 weeks was also recorded at these times.

Within the gait laboratory a 10 camera BTS Smart DX system capturing at 100 Hz was employed. For kinematic data, the modified Davis foot model was employed [5], to include a hallux segment. This model also reduces the hindfoot transverse plane error of the Oxford foot model [6] by its differing definition of the hindfoot coordinate system from the medial and lateral hindfoot markers. A minimum of 4 passes where made aiming for at least 4 gait cycles for each foot to reduce error and inconsistencies.

For pedobarographic pressure measurements, a 1 meter RS Scan footscan pedobarograph was employed, capturing data at 200 Hz A minimum of 4 passes were made to capture at least 6 clear footprints on each side (right and left). Peak pressures under the 1st and 5th metatarsal heads during the stance phase of gait were identified from the pedobarograph system, and a ratio between these two was calculated to give an indication of medial-lateral weight bearing before and after surgery. Data under the 1st metatarsal head were also compared with the unaffected contralateral side to determine if values were shifted towards this more normal asymptomatic foot following surgery.

Kinematic modeling allowed us to calculate the maximal dorsiflexion of the 1st MTPJ during walking to determine if use of the joint replacement had any effect on dynamic range of motion of the hallux during gait. Data was compared with the unaffected contralateral side.

Pre and post-operative MOXFQ score was collated to determine changes to patient reported quality of life. We also assessed the radiographs for any signs of loosening or lysis. All complications were noted and reported. The Mann Whitney test was employed for non-

3. Results

33 Rotoglide 1st MTPJ replacements were performed in 30 patients between August 2014 and August 2016. The mean age of patients was 59.2 years (range 40-80 years). 29 patients were female. Mean time to follow up was 16 months (range 6-24 months). It is to be noted that 3 patients had bilateral 1st MTPJ replacements. Accordingly, we only report on their first joint replacements as we are then able to take measures of the unoperated contralateral foot, hence reporting on only 30 out of the 33 joint replacements performed (n = 30) (Fig. 1, Fig. 2 Table 1).

Fig. 1. Post op weight bearing AP radiograph.

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Fig. 2. Post op weight bearing Lat radiograph.

Table 1. MOXFQ and 1st & 5th MT peak pressure operated foot.

N = 30	Pre-op (+/-SD)	Post-op (+/-SD)	P value
MOXFQ	55.3 (9.68)	34.3 (15.66)	<0.00001
1st MT peak pressure (mean in kPa)	146 (75.71)	226 (174.08)	0.04036
5th MT peak pressure (mean in kPa)	226 (198.19)	201 (188.69)	0.36812
1st:5th MT peak pressure ratio	0.74 (0.47)	2.24 (2.75)	0.012

There was a statistically significant improvement in the MOXFQ scores at the six month stage compared to the pre operative MOXFQ ($p < 0.00001$). In addition we found a statistically increased pressure under the 1st MTPJ following replacement of this joint indicating that the patients were able to bear more weight through the medial column ($p = 0.04036$). Although the 5th metatarsal peak pressure showed a reduction following 1st MTPJ replacement, this was not statistically significant ($P = 0.36812$). There was a statistically significant increase in the 1st to 5th metatarsal head peak pressure ratio from 0.74 to 2.24 ($P = 0.012$) post operatively indicating a redistribution of foot pressures towards the medial column post operatively (Table 2).

Table 2. 1st MT peak pressure operated vs unoperated foot.

1st MT peak pressure (mean +/- SD in kPa)	Test group	Control	P value
Pre op (n = 30)	146 (75.71)	201 (94.88)	0.008
Post op (n = 30)	226 (174.08)	201 (94.88)	0.033

improvements in the operated foot. We found that the peak pressure following surgery to replace the 1st MTPJ increased from its preoperative pressure towards the patient's normal foot 1st MT pressure and this was statistically significant (Table 3).

Table 3. 1st MTPJ weight bearing range of movement during gait.

1st MTPJ dorsiflexion (Mean +/- SD in degrees)	Pre op	Post op	P value
Test (n = 30)	21.3 (11.78)	18 (10.65)	0.27
Contralateral (n = 30)	28.4 (11.0)	22 (12.14)	0.36

Using the kinematic data obtained from the modified Davis model in the gait laboratory, we were able to measure the functional dorsiflexion range of motion during gait instead of the passive range of motion. We felt this was a more accurate reflection of the useful functional range of motion. We compared the operated foot against the un-operated foot and also the pre operative state to the post operative state. Our results revealed a preservation of the functional weight bearing range of motion of the 1st MTPJ following surgery. There was no statistically significant change or increase of this dynamic range of motion following surgery.

The contralateral un-operated limb values were found to have changed over time before and after surgery to the affected foot. The pre-op data on the un-operated limb may have been higher than post-op data either because the un-operated limb was required to take on more weight due to an antalgic gait of the limb with hallux rigidus or equally because maybe this data was not reproducible after surgery. Since we were not able to perform adequate statistical analysis on these values, we suggest that this was un-reproducible data (Table 4).

Table 4. Complications.

Complication	Number
Revision	1 (phalangeal implant size)
Osteolysis	2
Fracture	0
Loosening	1
Infection	0
Nerve damage	0

One patient required a revision at 12 months due to loosening of the phalangeal component. There were no wound infections or patients with nerve injury. Osteolysis was seen in 2 phalangeal components, one revised the other with a 1 mm margin being closely followed up.

the peak pressures we report in this paper. Peak pressure is defined as the highest magnitude measured by the sensor in a particular area of interest such as the 1st or 5th metatarsal heads. The force time integral and contact area are used for calculating the pressure time integral (PTI) as described by Melia et al [7]. This is the cumulative effect of pressure on a plantar area over time (area under the pressure-time curve), and could be a more representative value of the total load exposure of a plantar area during stance Stevens et al [8].

4. Discussion

Brodsky [9] in a prospective gait analysis study of patients following 1st MTPJ arthrodesis (fusion) concluded that it provided an objective improvement in propulsive power, weight bearing function of the foot and stability during gait. Stevens [10] demonstrated that following 1st MTPJ fusion, the lesser metatarsals endured higher pressures whilst the hallux was less loaded resulting in the persistence of symptoms in some dissatisfied patients following 1st MTPJ fusion. Complications of fusion may result in excessive dorsiflexion, varus or valgus of the hallux.

Most papers looking at 1st MTPJ replacement only involve small numbers of patients and are mainly concerned with the survival of the joint in several case series. Our group reported on the mid term results of the TOEFIT Plus joint replacement (Smith and Nephew) a few years ago with poor results and we recommended that it should be discontinued [11,12]. Recently Kofoed (the designer) has presented his series of Rotoglide joint replacements reporting good medium term survival rates [13]. Tunstall et al reported on their early outcomes of a total of 33 Rotoglide joint replacements from seven UK centers supporting the use of this joint [14].

The 2 studies which attempt to study the kinetics of the foot following 1st MTPJ replacement, use the latest generation of stainless steel on polyethelene joint replacements. Kofoed [15] found that following the rotoglide 1st MTPJR for hallux rigidus in twelve patients, there was reduced ground reaction force under the lateral column of the foot and reduced bone mineral density of this side of the foot. This suggests that there has possibly been some weight transference to the medial side of the foot following surgery. Nuesch et al [16] presented twelve 1st MTPJ replacements (Integra Life), revealing statistically significant pedobarographic pressure changes after surgery.

Stevens et al [8] compared fusions in 10 feet to 21 healthy feet finding statistically significant changes in pressure time integral under the 1st and 5th metatarsals. Knessl [17] found that following the TOEFIT joint replacement, he could only demonstrate a push off pressure in 75% of his patients. It should be noted that in this study he had a mixture of total and hemi arthroplasty patients. This suggests that in his patients following surgery, the great toe is elevated hence not allowing contact with the ground.

Our prospective study has demonstrated by pedobarographic pressures that following 1st MTPJ replacement, the medial column of the foot is loaded more than preoperatively, hence redistributing the foot pressures more towards the normal pressure distribution of the normal unaffected foot. In addition the kinematic data obtained from our gait laboratory reveals a functional preservation of the dynamic range of motion of the 1st MTPJ following surgery.

there was statistically significant difference after surgery.

5. Conclusion

In terms of the first MTPJ replacement, as far as we are aware, this is the first prospective study that has demonstrated the above improved combined effects. We would commend the continued use of 1st MTPJ replacements over fusion for the treatment of end stage hallux rigidus, especially as part of a continued well controlled prospective clinical trial. We hope to present our longer term results with pressure time integrals in the near future.

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Conflict of Interest

We the authors of this paper declare that we do not stand to gain financially and that there are no parties that have influenced the objectivity of this study. To prevent ambiguity, we the authors explicitly declare that there are no potential conflicts of interest in the preparation of this study nor in its potential publication.

Author Agreement/Declaration

We the authors of this paper confirm that this work is our original work which has not received prior publication and isn't under consideration for publication elsewhere.

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